Addressing phosphorus related problems in farm practice

Final report to the European Commission

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Executive Summary

1. The focus of this document is on the role and use of phosphorus in the agricultural sector of the European Member States, on phosphorus legislation and on legal and practical measures that can be taken to reduce the losses of P from agricultural activities to the aquatic environment. The contribution of agriculture to the phosphorus loads in surface waters is estimated by the EEA between 20 and more than 50% and includes both point sources (waste water from farms and seepage from manure stores) and diffuse contamination (agricultural land). Due to reductions in the discharge from household and industry sources, the relative contribution from agriculture has risen in recent years, and has reached more than 50 % in particular in areas with intensive agriculture.

2. Phosphorus (P) is an essential element for plant growth and is also added to animal feed. In the soil, phosphorus exists in different forms: associated with soil particles; in mineral form mostly as Fe-Al oxides or Ca-carbonates; incorporated in organic matter; and, to a much lesser extent in soluble form dissolved in the soil solution. Phosphorus sorption capacity is the process in which soluble phosphorus is substituted for less soluble forms by reacting with inorganic or organic compounds of the soil so that it becomes immobilised.

Phosphorus can move into surface waters and cause water quality problems such as eutrophication. In surface waters, phosphorus is often found to be the growth-limiting nutrient. If excessive amounts of phosphorus and nitrogen enter the water, algae and aquatic plants can grow in large quantities. Cycles of algal blooms and periods of low dissolved oxygen concentrations can lead to fish kills and may ultimately result in a reduction of biodiversity.

Mineral and organic fertilisers contain varying amounts of micropollutants such as heavy metals (in particular cadmium, zinc and copper). Various regulations at Community and Member State levels are aiming at a limitation of the amount of such elements brought onto the land through fertilisers. These measures are not expected to have an effect on, or to constitute a limiting factor to the phosphorus input on agricultural land.

3. Phosphorus is indispensable for crop production and economically viable yields; toxicity to crops due to excess has never been reported. Phosphorus is supplied to agricultural land by broadcasting mineral fertilisers (natural rock phosphate, super-phosphates and NPK mixtures) and organic fertilisers (mostly animal manure and slurry and, to a lesser extent, compost and sludge). Since phosphorus is not very mobile in the soil solution, most soils contain too little quantities that are readily available for plants. Fertilising strategies therefore aim at building up and maintaining a certain soil reserve. However, once this optimum range has been reached, application rates exceeding crop requirements (plus an allowance for

unavoidable losses) seem unwise from both environmental and economic viewpoints.

Trends in Northern Europe show a growing substitution of mineral fertilisers by manure due to an explosive development of intensive livestock farming that started in the 60's and stagnated somewhat since the 90's. In Mediterranean countries, soils are extremely phosphorus deficient so that consumption of mineral P-fertiliser is still on the increase, since the 80's a partial substitution with animal manure is taking place. In Eastern Europe, a sharp decline in livestock numbers and in the use of mineral P-fertilisers occurred in the early 90's; both are rising again since 2000. Current statistics demonstrate that manure is the main source of phosphorus in all but a few European Member States.

P-use and P-management approaches vary widely in function of the farming system. In the 'old' member states, the CAP has lead to specialised farming types and intensification of livestock breeding and arable farming. In the new member states, the use of inputs has sharply dropped during the transition period and is now picking up again.

Low intensity farming systems account for tens of millions of hectares of land throughout the Union, but take up a small proportion of the input use. Nutrient balances in such systems are close to zero or even negative Organic farming accounts for a few percentages only of the agricultural land, and has low P-surpluses at least when managed extensively.

Conventional specialist farming is by far the most widely spread system in the EU. Nutrient balances (including P) vary widely in function of the type of farm. Livestock farms (in particular dairy farms) and horticultural farms show high yearly surpluses on their P-balances. The lowest balance surpluses are recorded on cereal farms and on extensively managed cattle farms.

Fertiliser recommendation systems based on soil analysis are available in all member states, but are not equally called upon in all countries or regions. In particular in new member states, the activity of soil laboratories has fallen to a low level. The fertiliser advice systems currently used are mainly based on the determination of extractable soil P. Methods for P-extraction and the consecutive systems for P-advice vary widely between member states, and sometimes several systems co-exist within the same country. This can be explained by the fact that no single extraction method can be considered to be the best in all circumstances, and that the actual fertiliser advice bases have mostly been developed from empirical field work, carried out under the local agro-ecological conditions. The correlation between the extraction systems is not always strong, and varies mainly in function of soil type. At present, an advanced harmonisation of the analysis and advisory methods at European level is not considered to be essential. However, a confrontation of methods and units is desirable in order to make a better assessment and comparison of the current advice systems, in particular in view of any future definition of tolerable P-fertilisation ceilings.

Systematic analysis of farm yard manure or sludge is practiced in a limited number of member states, but would be a useful tool for fine-tuning of fertiliser recommendations.

4. The phosphorus pressure on the agricultural land has been assessed at the regional scale by means of the surface balance method, which calculates surpluses on the basis of inflow and outflow pathways. The inputs considered were mineral P-fertilisers and livestock manure production; the outputs were crop production, including pasture, all for the year 2003. Data on crop areas and livestock numbers were taken from FAOSTAT. Coefficients for uptake and nutrient content were taken from literature and from the OECD data base on P-balances. For lack of detailed figures on mineral P-use at the local level, national figures were split up proportionally to the area of arable land. The results calculated per NUTS II/III region for 2003 vary from -20 kg P/ha (deficit) to just over 50 kg P/ha (surplus) but most regions fall within the range of -5 to +20. High balances surpluses are often, but not necessarily, linked with high livestock densities. These figures do not take transfer of manure into account, nor the use of inputs other than manure and fertiliser. Further analysis of the results shows that, with respect to balance results, animal manure and fertiliser are interchangeable phosphorus sources.

Although manure transfers are a known practice between regions and Member States with surpluses and deficits, reliable figures are not readily available but for a few cases. The significant impact of manure transfers on the P-balance for the Netherlands and Flanders demonstrates that internal redistribution and/or export of animal manure helps to alleviate pressure in regions with high livestock densities.

5. Phosphorus can be transported into surface waters associated with soil particles and organic matter during erosion processes, particularly on agricultural land where phosphorus fertiliser and manure have been applied. Soluble phosphorus can move off-site with run-off water during heavy rainfall, particularly from livestock confinement areas and grazing lands, or can reach the groundwater by leaching. Factors determining processes of leaching, run-off, erosion and sorption capacity were combined to arrive at vulnerability classes and sensitivity maps.

Pedotransfer-rules using the Soil Geographic Database of Europe (SGDBE) were used to define areas at potential risk, i.e. with a low sorption capacity, high erosion rates and increased risk of accelerated drainage. Because of the unclear effect of the factor drainage and the lack of reliable data for the EU 25, efforts were focused on sorption capacity and erosion risk. Five vulnerability classes for phosphorus retention capacity were determined, whereby soils with sandy texture, poor drainage and wet water regime or high water table, with low pH and with low content of sesquioxides and/or soluble salts are most susceptible. The sorption vulnerability class was corrected through iteration for erosion, runoff and drainage processes based on soil physical properties such as soil texture, erodibility and slope. Phosphorus can easily be leached from highly organic soils (e.g. peat) and from sandy soils with low retention capacity. Small amounts are lost from most soils, but when the soils become phosphate saturated, leaching will be enhanced. P accumulation in soils might increase concentrations of dissolved and colloidal P in drainage. Calcareous soils on flat land were found to be the least sensitive to P-surplus.

The resulting phosphorus sensitivity map was subjected to frequency analyses at European, Member State and NUTS II/III level. At the Member State level the

Netherlands, Slovenia, Latvia and Estonia show the highest share in sensitive classes. At the regional level, southern Greece and Scotland have the highest percentage in sensitive classes.

6. The results of the surface balance model were confronted with the proportion of vulnerable soils in order to indicate areas at risk of encountering potential phosphorus excess. Manure transfers were not included, and the mineral phosphorus input was assumed linearly proportional to arable land area. The soil sensitivity was determined for the entire NUTS II/III region or Member State, not taking into account that sensitive soils (i.e. easily erodible or with a low sorption capacity) are often considered marginal to agriculture. Areas (NUTS II/III regions or Member States) with high phosphorus surpluses (pressure) and at the same time a high proportion of soils prone to erosion and/or low P-sorption capacity are most vulnerable. The Netherlands and Slovenia display the highest rate of vulnerable soils and the highest balance surplus. In the Netherlands sensitive soils are prone to leaching, in Slovenia, erosion and run-off are the main agents of P-loss.

Monitoring the actual P-status of soils is taking place in several member states, sometimes at a detailed level. Maps are usually drawn from existing data on soil analysis, available from the advisory institutions. In countries were such monitoring is not taking place as yet, sufficient data are likely to be available to do so, though not always at a detailed scale or with recent figures. Insight into the actual P-status of the soils and to the susceptibility to P-loss is essential for the interpretation of the balance calculations. On soils with low P-status, relatively high P-surpluses are not necessarily a negative phenomenon, as such soil require the build-up of P-reserves towards an optimum level.

Only in the Netherlands and in Flanders, zones vulnerable to or affected by P-saturation are established. In the Netherlands, this has no practical implication as yet to the farmers situated within such zone. In Flanders, application of P in vulnerable zones is restricted to a maximum of 40 kg P_2O_5 per hectare.

7. Several Member States are signatories to multi-national environmental agreements and initiatives, the majority of which aim at the protection of marine resources and include nutrient management in the marine environment. In the European Community environmental legislation and policy, several directives related to water, waste, air and biodiversity address the off-site impact of phosphorous use in agriculture. In the legislative text of the Water Framework Directive, an indicative list of pollutants includes organophosphorous compounds and substances that contribute to eutrophication (in particular nitrates and phosphates). The Groundwater Directive, which is repealed with effect from 13 years after the date of entry into force of the Water Framework Directive, explicitly states that Member States shall take the necessary steps to limit the introduction into groundwater of *inter alia*, inorganic compounds of phosphorus and elemental phosphorus so as to avoid pollution the groundwater. The measures and Code(s) of Good Agricultural Practice established within the Action Programmes of the Nitrates Directive aim to control diffuse and direct water pollution caused or

induced by nitrates from agricultural sources and indirectly influence the use of phosphorus in farm practice.

The legal instruments of the Common Agricultural Policy (CAP) have formed the crucial driving force behind agricultural development and through land management changes have influenced nature and environment. The measures set out to address the integration of environmental concerns into the CAP encompass environmental requirements (cross-compliance) and incentives (e.g. set-aside) integrated into the market and income policy, as well as targeted environmental measures that form part of the Rural Development Programmes (e.g. agri-environmental measures). Some of the agri-environmental measures are directed at mitigating soil erosion; others tackle the problem of excess nutrients through reduced fertiliser use. From 2005 onwards, all direct payments are conditional upon 19 statutory requirements in the field of environment, food safety, animal and plant health, and animal welfare.

Codes of usual Good Farming Practice represent minimum standards for farmers to get, in the framework of the Rural Development Regulation, compensatory allowances/payments in the Least Favoured Areas and support for voluntary agri-environmental measures on the basis of income foregone, additional costs and the need to provide an incentive. Codes are set up by the Member States as verifiable standards in their rural development plans. The Rural Development Regulation for the period 2007-2013 contains compulsory cross-compliance and its implementation offers further scope to improve phosphorus management at the farm level. Beneficiaries of direct payments will be obliged to keep land in good agricultural and environmental conditions (GAEC).

8. In most Member States, three different groups of standards or requirements are applied with respect to nutrient related problems in farm practices. They are applied in different but sometimes overlapping situations in the Member States and comprise the Good Agricultural Practices of the Nitrates Directive, the Codes of usual Good Farming Practices, and Good Agricultural and Environmental Condition practices of the cross-compliance requirements. Different regulations and directives refer to definitions, implementation and control of Good agricultural Practices, Codes of usual Good Farming Practices and Good Agricultural and Environmental Condition Practices.

The mandatory standards of farm practices consist of existing legal obligations, mainly in the field of fertiliser use, laid down in EU, national and regional law, and only few countries defined standards going beyond legislation. In addition, national and regional legislations include other control mechanisms related to phosphorous use in agriculture, mainly in the area of fertilisation practices and soil conservation. As national legislation would be too large a subject to be covered entirely and in detail in the framework of the current study, the member states were interrogated on their policy regarding P in agriculture through a questionnaire.

Water quality norms with respect to phosphorus in surface waters exist in almost all the Member States, but not for all uses of water. For groundwater, standards for phosphorus concentrations are sometimes lacking. Within the frame of the Water

Framework Directive, water quality standards (e.g. for phosphate to combat eutrophication) will be reviewed in different Member States to achieve a good status of waters in 2015.

A sectoral discharge standard for waste water from manure treatment plants (2 mg P/l) is mentioned only by Belgium (Flanders). The Netherlands aim at reducing diffuse emission of P from agriculture using a gradual evolution to a situation of equilibrium P-fertilisation, but no specific discharge standards are mentioned.

Legislation regarding application of fertilisers exists in several countries, most often as a means to comply with the Good Agricultural Practices as outlined in the Nitrates Directive, with the Codes of usual Good Farming Practices or with the Cross-Reference Requirements (GAEC Practices). Codes of good practices devote chapters to reduce, directly or indirectly, the risk of P-pollution, but are often on a voluntary basis. The application of sewage sludge in agriculture is regulated through the national implementation of the Sewage Sludge Directive; restrictions apply primarily to the heavy metal content and in some countries on P-content too (e.g. Sweden and Latvia). Denmark applies a tax on phosphorus in mineral fertilisers. Some Member States report that regulations on P-use are in preparation (e.g. Poland, Malta and Ireland). Only Flanders (Belgium) and the Netherlands based their nutrient management legislation on phosphorus and have legal restrictions on the use of phosphorus fertilisers.

Legal restriction on P-production at farm level exists in Flanders (Belgium), The Netherlands and Sweden via limitations to the livestock density. In the Netherlands and in Flanders, the size of livestock units is expressed in terms of P-production, and farmers have a P-quota. In Sweden, livestock density is limited to the equivalent of 22 kg of P per hectare. In Denmark there are no limitations to P-production, but a new tax on P in feedstuff should discourage its production. In the Walloon region of Belgium, livestock size (for the purpose of licensing) is expressed in terms of N-production, and therefore only indirectly in terms of P. Most of the new member states do not pay specific attention to P-production at farm level, since livestock densities have decreased significantly compared with the situation before 1990.

9. Measures to reduce phosphorus production at farm level include the use of low phosphorus animal feed, manure processing and export, taxation of phosphorus use in animal feeds and reduction of livestock numbers. Phosphorus intake must be balanced with dietary requirements; otherwise the manure N/P ratio will decrease, inducing phosphorus enrichment particularly on soils where manure applications are based on nitrogen content.

Best management practices for phosphorus use on agricultural fields fall into two main categories: phosphorus-use practices and erosion control. The potential for phosphorus movement into surface waters can be reduced by rational fertiliser applications rates linking soil and manure analysis to crop requirements. Applications of fertiliser and especially manure should be incorporated into the soil with light tillage or injected below the soil surface. Since most phosphorus under field conditions is strongly attached to soil particles, farm management practices that reduce soil erosion and run-off play an indirect, major role in reducing the potential for phosphorus movement. The effectiveness and feasibility of all measures and management practices is discussed.

Methods to reduce the P content of manure at the source are commonly practised in Flanders, the Netherlands, Sweden, Denmark and Austria; and include low P-content animal feed, phase feeding and the use of phytase in pig, poultry and egg production.

The OECD are presently co-ordinating a P-balance exercise at national level for all OECD member countries. For policy reasons, several member states (e.g. Malta, Spain, Austria, Flanders, and The Netherlands) calculate P-balances at national or regional level in order to identify any areas with high surplus or to monitor development. Farm level nutrient balances are a compulsory practice in Flanders and the Netherlands, whereby farmers have to declare their annual input and output of P. Fines for non-compliance range from 1 €/kg P in Flanders to 9 €/kg P in the Netherlands. In the future, the Dutch levy will be set at 11€ per kg and legal prosecution will become possible. The Walloon region of Belgium has developed calculation methods to establish nutrient balances at various levels, but with the emphasis on nitrogen.

In order to reduce the use of mineral P in animal feed (and therefore the P-content of manure), and after having studied a number of scenarios, Denmark has recently established a tax or 4 DKK per kg of P added. To compensate the farming sector for the additional burden, the land tax was lowered. The Danish government hopes to achieve a reduction of 25 % on the balance surplus.

Manure treatment (without reduction of nutrients) and manure processing (with reduction of nutrients) is practised in Member States with high levels of manure production (Flanders-Belgium, The Netherlands, Brittany, Lombardy, Denmark) but remains expensive. Current methods mainly aim at a reduction of the water content or at its complete elimination, e.g. by incineration, and may be applied on-farm or off-farm. Apart from incineration, most treatment methods have little or no effect on the amount of phosphorus, but the resulting manure products are easier to transport and more attractive to potential users. Separation techniques allow to modify the nutrient ratios (in particular N/P), broadening the manoeuvering space for the use of manure products as a substitute to mineral fertilisers. Few figures have been released on the economic feasibility of the various methods that have been developed up to now. However, drying and composting of poultry manure seems to be the only technique with proven feasibility and profitability. Pending better prices for the electricity produced by the combustion of poultry manure, the profitability of this method is not proven either.

Export, import and local transfer of manure and manure products are regulated by international and local regulations and through bilateral agreements. Red tape and uncertainty about the future possibilities for guaranteed export are the main constraints for the further development, and although not all MS are equally concerned, there is a need for a European approach to this problem.

10. Three European regions with known or expected problems of phosphorus surplus were studied in detail: Flanders (Belgium), the Brittany region of France and the Po-valley region of Italy.

In Flanders, phosphorus balances have been highly positive for years, and considerable P-reserves have been built up in the Flemish farmland. Not surprisingly the phosphorus issue has been the focal point of the manure legislation from the very beginning. Vulnerable zones have been identified and delineated where excess P or an advanced state of P-saturation has been observed. Flanders is the only known area in the EU were specific restrictions on P are imposed in such zones, and one of the few regions were specific maximum rates are legally imposed on the input of P.

The measures taken by the Flemish authorities focus on effective and cost-efficient methods of input reduction (reduction of livestock and decreased P production in manure, improved uptake of P by the crops and manure processing/manure export. The latter is hampered mainly by the absence of a clear legal framework allowing increased export to neighbouring regions. Although Flanders has made good progress in decreasing the balance surplus, the region still has one of the highest surpluses of P per hectare, and the region still does not comply with the Nitrate Directive.

11. In Brittany, the government policy has been aiming so far mainly at the strict implementation of the Nitrate Directive, thereby paying little attention to phosphorus. Redistribution of the manure production, using N as the yardstick and compulsory manure treatment are the two major tools to reduce the size of the manure surplus. Only recently the Breton authorities are paying more attention to phosphorus, mainly influenced by environmental groups and water agencies, and under pressure of the Water Framework Directive. In 2004, a precedent was set by a court in Brittany when it ruled that a pig farm should not receive an extension permit for fear of possible P-pollution problem.

12. The Po-valley region of Italy shows comparable pressures in terms of phosphorus surpluses on agricultural land, but soils are not yet saturated with phosphorus and there is no specific legislation in place aiming at the control of P-use. However concern on the potential P-problem is clearly growing.

13. The last chapter contains a series of recommendations on measures to be taken by authorities at European, national or local level, as well as by farmers level to tackle the P-problem and to reduce the P-surplus at regional level or at farm level.

Concerning the perception of the P-issue by the member states

Phosphorus in agriculture is to be put on the agenda of all member states as a specific item, and more attention is needed for the assessment of the current P-status of the soil, pressure at local level, effects of redistribution of manure and the expected impact from future agricultural developments

Concerning P-management practices

Due to the nature of the element and its role in crop production, phosphorus fertilisation requires a specific approach, different from nitrogen. Current strategies of building reserves of soil-P and compensation for uptake and unavoidable loss still apply, but more attention should be given to soils with high P-status. In these cases, very little or no P should be applied in order to bring down excessive levels to normal ranges. For farmers using manure as the main source of nutrients, this will require a change in approach. Manure separation, whereby the N/P ratio is changed, may provide a useful tool.

Since negative effect is to be expected from P-overdose, current advisory systems have considerable built-in safety margins for this element. Advisory institutes should therefore be encouraged to review their advice tables.

The nutrient content of manure is highly variable. Systematic use of manure analysis provides a much better picture of the actual nutrient content than the usual standard figures, and allows for more precise implementation of recommendations. Therefore this practice should be encouraged.

The usual formulae of commercial fertilisers are not necessarily adapted to the local situation. In particular in areas with high soil-P, popular formulae may provide too much phosphorus. Custom made mixtures, formulated in function of actual crop requirements provide a good alternative.

Fertiliser application methods should be adapted to improve the efficiency of P-use, and to reduce the risk of loss by runoff and erosion. In practice, all measures reducing the risk of erosion have a positive effect on the prevention of P-losses. Other relevant techniques are row application of mineral fertiliser and sod injection of slurry in grassland. Homogeneous spreading of fertilisers reduces the risk of hot spots.

Concerning legal limits on P-doses

At present clearly defined general legal ceilings on P-application do exist in a few member states only. Limits on N-application imposed by the Nitrate directive have a predictable but varying effect on P-use, depending mainly on the type of manure. If and where it is deemed necessary to impose such limits, care should be taken to consider the actual P-status of the soil, its binding capacity, the agro ecological conditions, erosion risk and specific cropping system requirements. Therefore setting standard rates for P similar to the limit for nitrogen is not relevant.

In areas with known P-saturation, it would be preferable to link the maximum allowable P-rates to soil analysis and specific P-advice, rather than to set standard limits.

Concerning the use of balances and P-sensitivity maps as policy tools

Results of balance calculations should always be set against the actual P-status of the soil. On low P status soils with normal or high binding capacity, high surpluses are needed to bring the soil to the higher fertility level in order to improve its productivity. Providing erosion and runoff is sufficiently controlled, this should not lead to increased risk of P-loss.

In the current study, balances were calculated for the NUTS II/III level. It speaks for itself that more detailed calculations are necessary when tackling the P-problem at a lower scale. When assessing the sensitivity of the soils to P-loss, it may be more relevant to limit the assessment to the agricultural land only, as sensitive zones often correspond with marginal land, hardly or not used for high input agriculture.

Balances on P are useful only insofar they can be related to actual P-status figures. Therefore member states should be encourage to develop monitoring systems. In most cases, if such systems do not already exist, this can be done at minimal cost, since basic data are available. In areas prone to P-saturation, efforts should be undertaken to identify zones of saturation or likely to be saturated. Such areas are expected to occur widely in all northern member states.

Concerning P-balances per farming type

The current regional imbalances in nutrients use and nutrient production are partly due to the development of specialised farming as a consequence of the EU CAP. A complete return to the pre-CAP situation of mixed farming is hardly an option. As an alternative, exchange circuits between farming systems could be encouraged. With respect to soil fertility management, this would mean a further substitution of mineral fertilisers on arable farms by manure and manure products provided by the surplus sectors. In order for such exchange system to succeed, the arable farm sector must have at its disposal a product of consistent and regular quality, available at the right time and place, and must be convinced of the feasibility of such substitution by information and demonstration actions.

On legislation

Agriculture must play its part in ensuring that water is as clean and healthy as practicable, which translates in this case to reducing concentrations of phosphorus. The issue of phosphorus pollution of water should be addressed in the development of river basin management plans to apply from 2009 under the Water Framework Directive (WFD) in conjuction with action programmes under the Nitrates Directive. Should positive results not ensue then it may be necessary to establish a more coherent approach to the issue.

Long-term surpluses in risk areas can be tackled by reductions in inputs, through extensification, land use change and mutual adjustment of farming systems. Possible responses by agriculture include changes in management practice such as better soil conservation; better precision in applications of fertiliser; extensification of agricultural systems such as livestock reductions, lower yields with lower inputs, conversion to low-intensive farming particularly on sensitive soils; changes in land use within farming areas to include natural/seminatural habitats, woods, hedges and woodlands. Many of these farm practices should be and are incorporated in the Codes of usual Good Farming Practice, defined by the Member States.

Reductions in stocking numbers and fertiliser use but allowing intensification in risk-free zones should be and are to a large extent enforced by responses of the Common Agricultural Policy, through continued reforms, cross-compliance conditions on direct payments, and continued agri-environment support. Particularly the compulsory cross-compliance conditions on direct payments offer scope to couple CAP 1st and 2nd pillars in order to implement better phosphorus management at the farm level.

Phosphorus pollution in surface waters ultimately requires a catchment approach. The establishment of a nutrient balance at field or farm level is a first step in budgeting phosphorus pollution. However, the extent to which phosphorus will impact upon a water body is determined by several catchment-related factors such as its size, the location of pollutant sources and the degree of hydrological connectivity.

In order to be effective European environmental legislation must be fully and correctly implemented by the Member States, particularly in the case of diffuse contamination of waters where transboundary environmental health is at stake. A standardised reporting procedure on phosphorus is required in order to monitor and assess progress of implementation in the national legislation of the Member States.

On measures to control/reduce P balance surpluses

Reducing the amount of P excreted by animals by acting on the feed composition is a proven, effective, safe and viable technique that should be further developed and encouraged by the member states.

Manure treatment and processing techniques have been developed and applied with variable success in several member states. Drying and composting of poultry manure has given the best results so far. Methods for the treatment of slurry, be it separation or digestion techniques, are less successful today and do not have the same economic viability, but new developments are under way. Obtaining operating licences, emission standards and profitability remain major constraints. Another problem to be solved is to produce manure products that can be transported easily to P-deficient areas and that are attractive to the potential user.

The most important limiting factor however is the absence of a well-defined and unambiguous legal framework that would allow easy transfer of manure products beyond the regional or national boundaries. This problem should preferably be tackled at the European level.

Economic measures to reduce the input of P have recently been studied in Denmark. Following the outcome of the evaluation of a number of alternatives, the Danish government imposed a tax of 4 DKK on the use of added P in feedstuffs (compensated by a reduction of the land tax). By doing so it hopes to reduce the P-surplus by 25 %.

Similar taxes imposed in Flanders on the production and use of P and N in manure and fertilisers have a limited effect on the use of P. Significantly higher levels on P produced beyond the authorised quota (1 €/kg of P_2O_5 in Flanders or 9 € in the Netherlands) do have a marked effect on excess P-production.

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INTRODUCTION

Subject and scope of the study

The aim op this study is to investigate farm practice in relation to P use, EU, MS and regional responses to environmental problems arising from it and to provide recommendations to overcome these problems. This was done primarily by reviewing and analysing the current situation via an extensive review of farm practice, approaches to legislation, and implementation together with a detailed examination of options to establish an improved approach to farm P management.

The study was complemented by using case studies of three of the EU regions with known problems, Flanders, Brittany and the Po-valley.

The study has been divided into four parts:

- Phosphorus balance at farm level in the EU agriculture
- Legal situation regulating P (and approaches limiting P problems) at EU and Member state level
- Cases studies
- Conclusions and recommendations

Part 1: Phosphorus balance at farm level in the EU agriculture

Part 1 provides a short introduction on the share of agriculture in the overall phosphorus losses to the environment at MS and regional level. The following chapter summarises briefly the effects of P and other aspects accumulation in water, soil, and biodiversity, including the situation with regard to heavy metals associated with P inorganic fertilizer. The chapter is basically drawn from existing scientific papers.

Subsequently and in greater detail the following chapter focus on P use and on evaluation of P surplus in farming practice, on the basis of the estimates of inputs and outputs which need to be established for the major farm sectors. Phosphorus balances were calculated at national level and at NUTS II/III levels. Maps were established of the sensitivity of the European soils to P-surplus as well with respect to erosion as to saturation and leaching.

By confronting pressure and resilience, areas at risk of P-saturation could be identified. Due caution should be observed when interpreting the results as certain important factors such as the local use of fertilisers and manure transfers could not be taken into account. Approaches to define and to map phosphorus saturation, and methods to monitor the P-status of the soils, followed in the Netherlands and in Flanders are commented.

The chapter is structured as follows

- Brief introduction including the extent of the problem in relation to other P sources, i.e. urban wastewater, detergents etc. in order to assess the contribution of agriculture compared to the other sources in the P pollution across the different areas of Europe
- Description of the farm practices in the use of P should be described. These include the method, amount and timing of the application of P (organic and inorganic) for the different farm sectors, as well as data on historic and current use of phosphorus.
- A description of MS systems of soil P classification and P-analysis methods together with an analysis of their comparability.
- Calculation of P balance at MS and, insofar as possible, regional level. This analysis provides information about MS and NUTS II/III level and therefore enables to identify regions and farming systems with highest surpluses.
- Assessment of the vulnerability of the European soils to P-excess, resulting in maps of soils which are P fixing and likely not to be associated with P problems, and those at high risk of phosphorus loss
- Identification of areas currently at risk of P-losses

Part 2: The legal situation regulating P and approaches limiting P problems at EU and Member States level

The first chapter of this part focuses on the use of existing EU level legislation concerning the utilisation of P in agriculture aimed at prevention and reduction of adverse environmental effects. The analysis addresses the application of regulations aimed at limiting (organic and inorganic) fertiliser application. It also tries to provide an insight as to how this legislation is applied at farm level dealing with obligations on farmers, how they are controlled and any penalties for non compliance. In particular, the study addresses the issue of including P nutrient management within the scope of cross-compliance in so far as direct payments under the CAP are concerned.

Apart from the European legislation, attention was also paid to various non-EU international initiatives with respect to the pollution of ground and surface water from agricultural sources, such as the OSPAR convention and the Danube partnership.

A second chapter details the national implementation of international legislation and specific legislation related to the phosphorus issue at national level.

The third chapter of part 2 is devoted to technical and economic measures. At present, various measures are being taken, or are under development, to control the phosphorus surplus or to reduce negative impact of excessive phosphorus use, including source oriented approaches such as the use of low P animal feed, manure processing and export, rational fertiliser use, taxation and livestock reduction. These measures are commented on their effectiveness and feasibility.

Part 3: Case studies

Case studies were worked out for three EU regions with known problems of P surpluses: the Flanders region of Belgium, the Brittany region of France and the Po-valley area of Italy.

Depending on the individual situation and on the available information, an analysis was made of the origin and current situation of the phosphorus problem, including the build-up of P-reserves in the soils, and the measures taken by the respective governments to address the P-issue.

Part 4: Conclusions and recommendations

This chapter examines available farm options for the reduction of problems associated with P. Among them are :

- Changes in farm management practices and increased exchanges between the various farming sectors
- Requirements regarding P treatment and the scope for such facilities for the major livestock producing systems
- Restrictions to be imposed on P use in areas of P saturation.
- The identification and evaluation of economic instruments to encourage more sustainable use of P.

Data sources

Data for the present study were basically gathered from existing literature, or was provided by EU sources, various institutions and individual experts. Whenever possible, statistical data were obtained from Eurostat. Complementary data, in particular on the new member states, were found at the FAO.

Complementary data on the legal approaches practiced by the Member states was obtained through a questionnaire sent via the EU delegations in Brussels. Replies were received from the Czech Republic, Latvia, Sweden, Hungary, Slovakia, Poland, Austria, Belgium (Flanders), Denmark, Spain, the Netherlands, Malta, Belgium (Walloon region) and Ireland.

PART I: PHOSPORUS BALANCE AT FARM LEVEL IN THE EU AGRICULTURE

1. P-losses to the environment by sector

Some 25 years ago, reports of undesirable changes in the freshwater environment in several countries led to a growing concern for the aquatic environment in general. These changes were considered to be related to the increasing concentration of nutrients in the water. Nitrogen, phosphorus, carbon and in some cases silicon are the nutrients of concern in relation to eutrophication. However, because phosphorus is the limiting nutrient in freshwater environment, it attracts the most attention when the problem of eutrophication is considered in relation to fresh water.

Source apportionment is the estimation of the contribution from different sources to pollution. The method is based on the assumption that the nutrient transport at a selected river measurement represents the sum of the components of the nutrient discharges from different sources. Figure 1 shows the relative contribution to phosphorus loading from various sources in different regions of Europe.

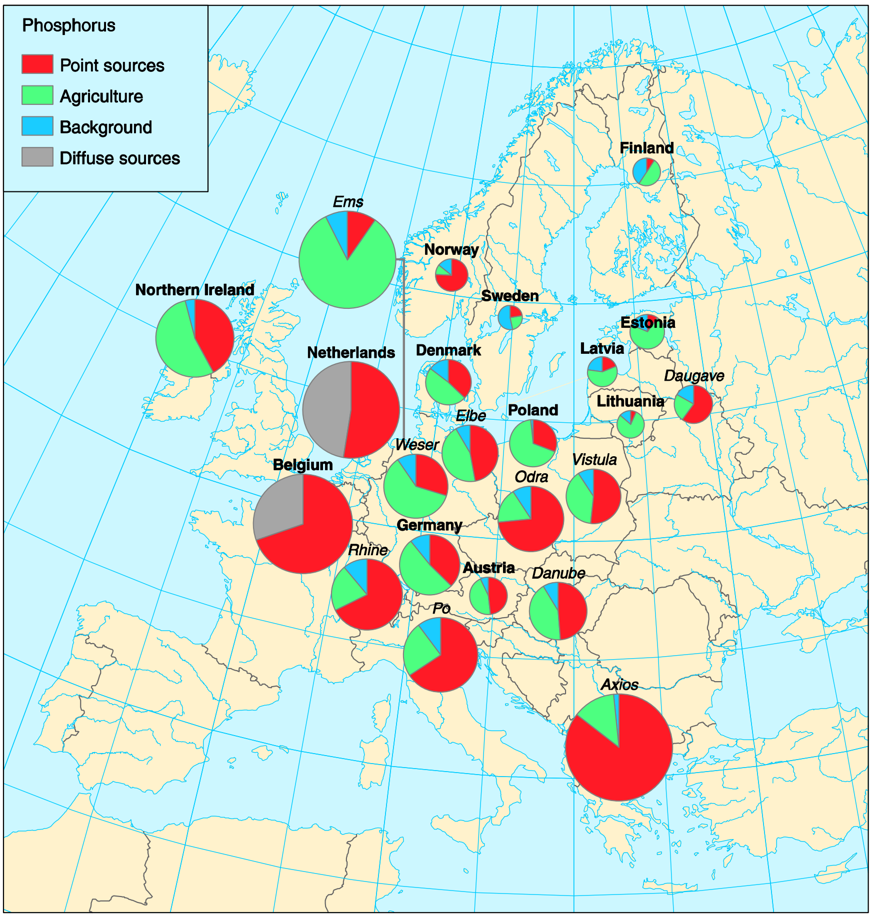
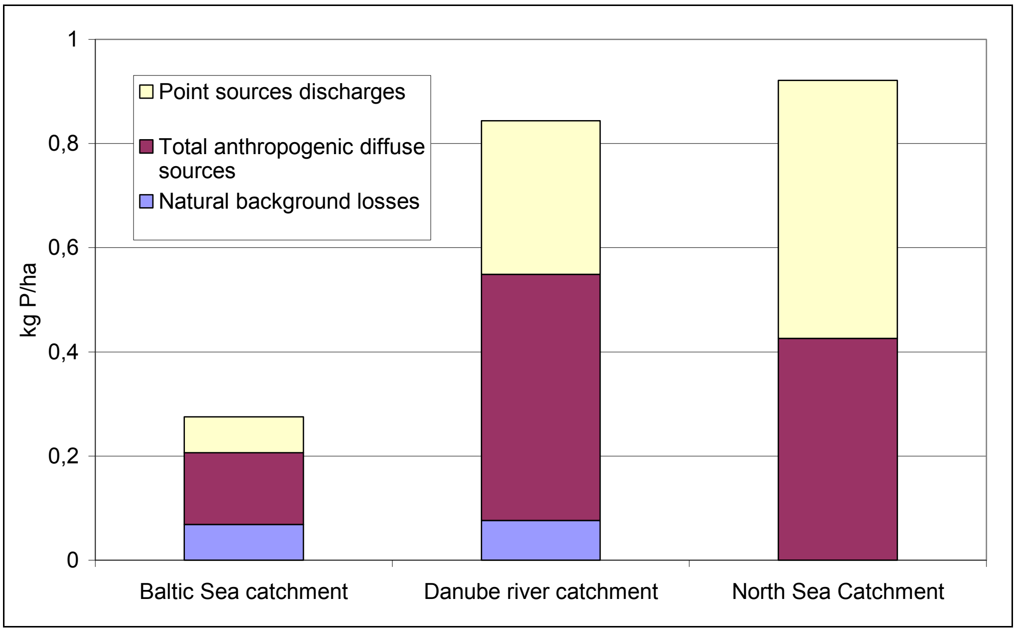


Figure 1: Source apportionments of phosphorus loading in selected regions and catchments. The area of each pie indicates the total area-specific loading (Source: Bøgestrand et al., 2005)

The absolute phosphorus load (proportional with the pie area in Figure 1 is high in North-West Europe, smaller in Eastern Europe and the smallest in the Baltic states and the Nordic countries. In general, the total area-specific loading of phosphorus is highest in countries with high population density and high share of agricultural land. In regions with low population density and with low percentage of agricultural land such as the Baltic Sea catchment the phosphorus load is only one third of the area-specific load in densely populated regions in central and North-western Europe (Figure 2).



(No information on background losses for the North Sea; Source: Bøgestrand et al., 2005)

Figure 2: Source apportionment of annual phosphorus loading for the Baltic Sea catchment, the Danube river and the North Sea catchment .

The relative significance of the different sources of phosphorus loading is diverse. Generally there is a distinction between:

- Point sources such as discharges from urban wastewater; industry and fish farms;
- Diffuse sources including background losses (natural land, e.g. forest), losses from agriculture, losses from scattered dwellings and atmospheric deposition on water bodies, e.g. marine areas or lakes.

Some areas are dominated by high shares of point source discharges (e.g. Belgium, Netherlands, Po-region) and others are dominated by the agricultural contribution (e.g. Estonia, Northern Ireland, Poland). The Axios river basin in Greece has, for example, a very high load from industrial discharges (Figure 1), while Norway has high point source discharges because of its many marine fish farms. The Ems and Weser river basins in Germany have, on the contrary, very high agricultural shares, which is due to the agricultural exploitation of bog soils in downstream parts of these rivers. The bog soils have poor phosphorus binding capacities and the surplus of P is lost to the aquatic environment relatively fast, whereas in many other soils there is still a high capacity for immobilising phosphorus more or less permanently. However, the Ems and Weser cases suggest the potential magnitude of the pollution by continued application of surplus phosphorus to the soils. For Europe as a whole, it seems that both point sources and agricultural sources are significant, but the relative significance of each source can differ quite a lot from one catchment to another.

The contribution from diffuse sources, including agriculture, was considered to be insignificant in the past. Nowadays the amount of phosphorus from point sources has declined mainly due to purification of wastewater and therefore the relative contribution of the total phosphorus load coming from agriculture has increased. Over the past 15 years, phosphorus discharges from urban wastewater treatment plants in many countries in North-west Europe have fallen by 50-80 %. The main reason for this reduction is the upgrading of wastewater treatment plants to include phosphorus removal (tertiary treatment). The shift to phosphate-free detergents has also contributed. Households and industry are no longer the biggest contributors of phosphorus to the environment. The reported phosphorus losses from different sources into surface waters for countries of the Baltic Sea and the North Sea catchments demonstrated that agricultural activities played a major role (Figure 3). Particularly, in those parts of Europe with intensive agriculture, the contribution from agriculture approaches 50 % or more of the total phosphorus load.

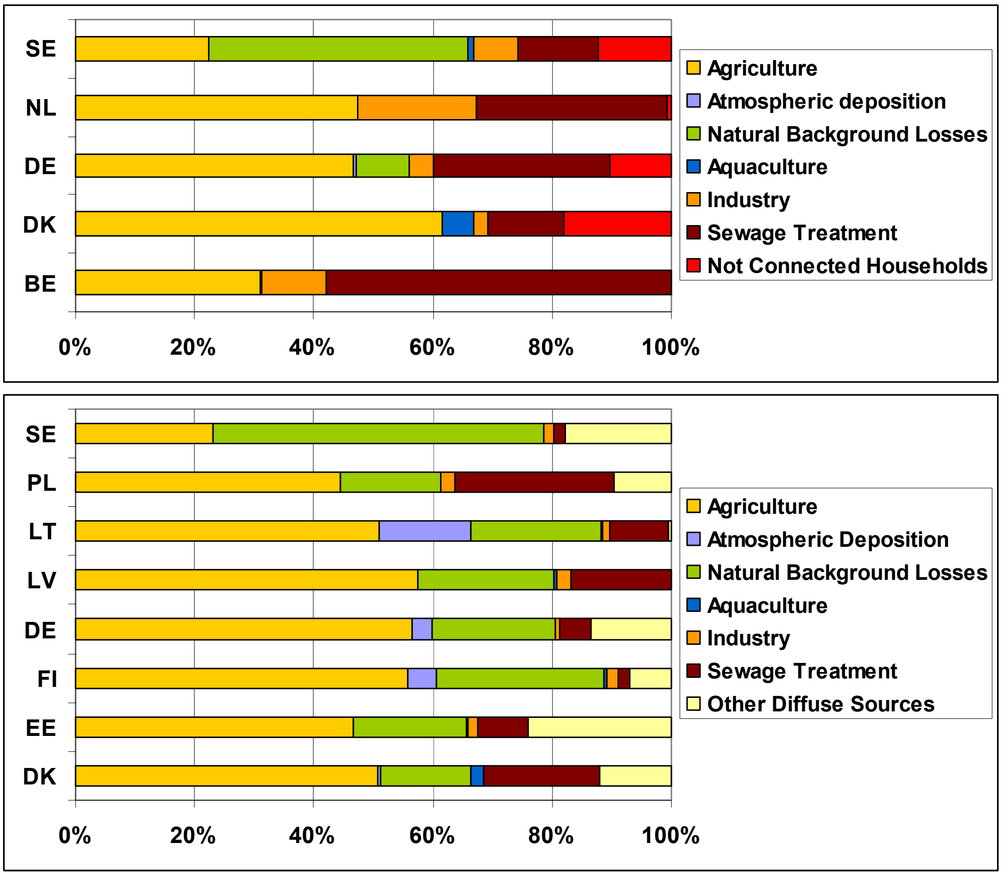


Figure 3: Sources of phosphorus load (in % contribution) in 2000 for different countries around the North Sea (upper graph; OSPAR, 2003) and around the Baltic Sea (lower graph; HELCOM, 2004).

Between 1985 and 2000 there were significant reductions in phosphorus discharges to the North Sea from urban wastewater treatment works (UWWT), industry and other sources (Figure 3). The reduction from agriculture has been less marked and this was also the largest source of discharges in 2000. The data for the Baltic Sea give a similar picture with significant reductions in discharges of phosphorus from agriculture, UWWT, industry and aquaculture. In 1995, the major source of phosphorus to the Baltic Sea was UWWT and agriculture, respectively. Regarding point sources, the 50 % HELCOM reduction target was achieved for phosphorus by almost all the Baltic Sea countries. Comprehensive data are not available for the Mediterranean Sea or for the Black Sea.

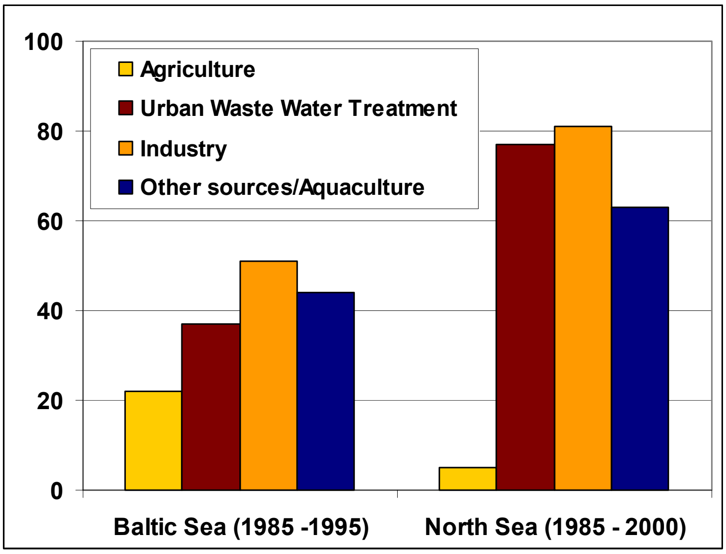


Figure 4: Percentage reduction in phosphorus discharges from different sources to the Baltic Sea and the North Sea (Source: HELCOM, 2004; OSPAR, 2003).

2. Environmental effects of P from agriculture

2.1 Introduction

2.1.1 Role and behaviour of P in soil, plant, animals

In the natural environment, phosphorus (P) is supplied through the weathering and dissolution of rocks and minerals with very slow solubility. Therefore, P is usually the critical limiting element for plant and animal production, and throughout the history of natural production and human agriculture, P has been largely in short supply.

Many natural ecosystems and low-input farming systems have adapted to low P supply by recycling from litter and soil organic materials. Increases in productivity require external nutrient inputs if they are not to cause a decline in fertility. External P-inputs have become available on large scale with the mining of phosphate deposits. This has decoupled patterns of supply, consumption and waste products from natural nutrient cycles, and has made them dependent on economics (Tiessen, 1995).

Phosphorus plays a series of functions in the plant metabolism and is one of the essential nutrients required for plant growth and development. It has functions of a structural nature in macromolecules such as nucleic acids and of energy transfer in metabolic pathways of biosynthesis and degradation. Unlike nitrate and sulphate, phosphate is not reduced in plants but remains in its highest oxidized form (Marchner, 1993).

Phosphorus is absorbed mainly during the vegetative growth and, thereafter, most of the absorbed P is re-translocated into fruits and seeds during reproductive stages. After absorption into the plant much of the phosphate reacts very quickly to form organic compounds (Wild, 1988).

Phosphorus deficiency often appears early in plant growth as stunting, with purple or reddish tints in the leaf and vegetative tissues of corn, barley, and some mustard crops (Figure 5 next page). Within the plant, phosphorus compounds from older leaves can be relocated to younger leaves and developing buds. But as the deficiency becomes more severe, the symptoms first seen in the older leaves can progress to the youngest leaves. Deficiency in wheat is generally shown by a thinner than normal wheat leaf and stunting. Deficiency in potatoes often resembles late blight symptoms. Phosphorus deficiency can sometimes be induced through situations that inhibit root growth, such as soil compaction or cold soil temperatures. A deficiency of phosphorus affects not only plant growth and development and crop yield, but also the quality of the fruit and the formation of seeds. Deficiency can also delay the ripening of crops which can set back the harvest, risking the quality of the produce.

To successfully produce the next generation of plants, seeds and grains must store phosphorus so that the seedling has enough to develop its first roots and shoots.

Then, as the root system develops, the growing plant will be able to take up the phosphorus it requires from the soil, providing there are adequate reserves.

Figure 5: Phosphorus deficiency in young maize leaves

In common with other major elements, the concentration of total P in soils is high relative to both crop requirements and to the available P fraction. The typical range for total P content of agricultural soils is estimated at between 0.20 to 2.0 g/kg (McGrath, 1994). Phosphorus exists in soils either in the dissolved (i.e. solution) or solid form (particulate P), with the solid form being dominant. Dissolved P is typically less than 0.1 percent of the total soil P and usually exists as orthophosphate ions, inorganic polyphosphates and organic P (Magette and Carton, 1996). Phosphorus is absorbed by plants from the soil solution as monovalent (H_2PO_4) and divalent (HPO_4) orthophosphate anions, each representing 50 percent of total P at nearly neutral pH (pH 6-7). At pH 4-6, H_2PO4 is about 100 percent of total P in soil solution. At pH 8, H_2PO_4 represent 20 percent and HPO_4 80 percent of total P (Black, 1968). Figure 7 illustrates the process of transfer of phosphate between soil and plants.

Phosphorus in solid form can be classified as inorganic P (i.e. bound to Al, Fe, Ca, Mg etc) and organic P (P bound to organic material such as dead and living plant material and micro-organisms, soil organic matter etc.). In a mineral soil, 33 percent up to 90 percent of the total P is in the inorganic form. Organic P compounds undergo mineralization (into inorganic forms) and immobilisation with the aid of soil bacteria and growing plants (Magette and Carton, 1996).

In the soil two sources of inorganic phosphorus exist: inorganic phosphorus is set free from organic matter by micro-organisms and mineral fertilisers bring in inorganic phosphate. Microbial organisms immobilise part of the phosphate by using it for their own growth.

Different forms of P are also partitioned as between soluble P, labile soil P and non labile soil P. Soluble P represents P in the soil solution that is readily extracted with either water or weak salt and measures the concentration of ortho-phosphates ions in solution. Labile P describes forms of P which are chemically mobile, exchangeable and reactive in soil and water. Labile P can replenish the soil solution P concentrations for uptake of P by the crop. Non-labile P is thought to represent a fraction of P which is physically encapsulated within a mineral compound (e.g. apatite) in complexes of metal oxides and hydroxide. These latter forms of P are protected from chemical reactions and can only be released by very strong chemical treatments (Daly, 2000).

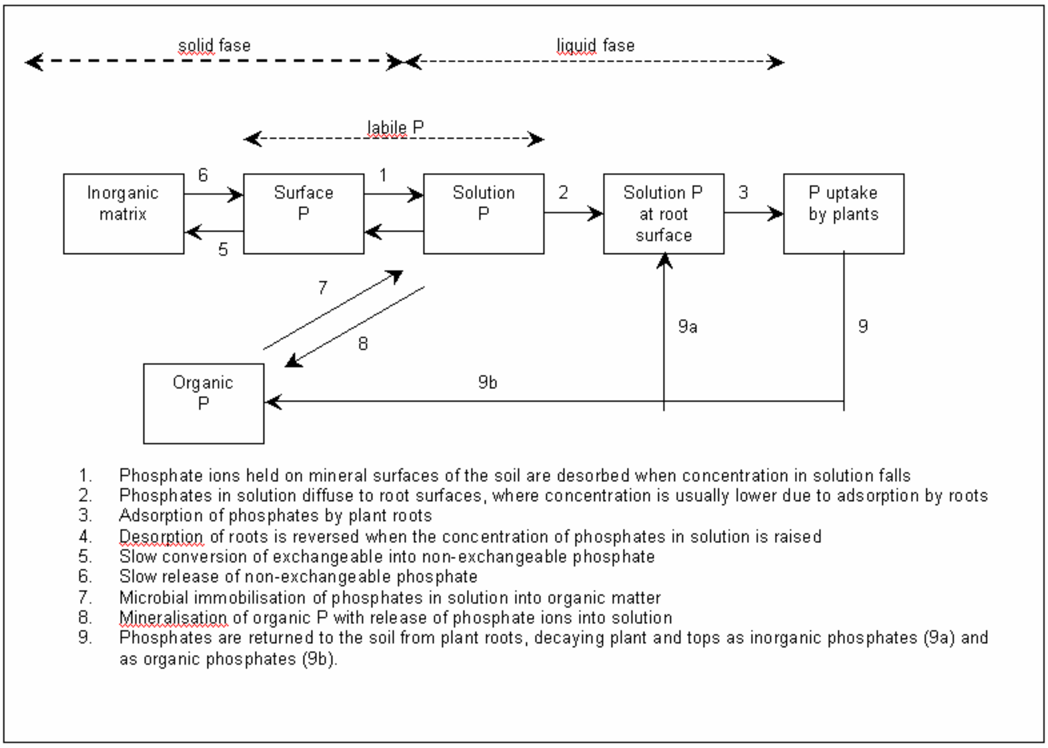


Figure 6: Transfer of phosphate between soil, plant and water (Wild 1998 cited in Brogan et al., 2001)

2.1.2 P-fixation

Soil solution P is usually quite low due to the complex interactions of phosphate with various soil components. Sorption is considered to be the most important process controlling P availability in soils. The dominant reactions are these with Fe-Al oxides and Ca-carbonates. Since sorption is to some degree reversible, sorbed P is a source of plant-available P either immediately or over a long term. It has been estimated that 25 percent or less of P applied annually is actually taken up in the growing crop (Morgan, 1997). The remaining 75 percent becomes bound in the soil profile or is lost to water. The crop uptake of P is in contrast to the crop use of N and K fertilisers, where the recovery in the season of application can be as high as 80 percent.

The reaction between phosphate and reactive surface Fe and Al oxides is typical of acid soils. It is highly dependent on the crystallinity and surface area of the oxides present in soils, and thus on the mineralogy of the clays in soils. Experiments on the reversibility of P sorption have shown that the plot of sorbed P against concentration is not retraced during desorption (Barrow, 1983b), suggesting that sorbed P undergoes further transformations with time (Parfitt et al., 1989), perhaps also changing its availability for exchange into the soil solution and thus for plant uptake.

Organically bound P may also undergo precipitation and fixation reactions with Fe and Al. Much of the secondary Al- and Fe-bound P remains unavailable to plants, as does the P associated with organic matter of a molecular weight >50.000 (Goh and Williams, 1982).

Mechanism of P sorption and the strength and reversibility of sorption in medium to high pH systems can differ substantially. Adsorption of P onto $CaCO_3$ and the co-precipitation of Ca-P minerals is considered to be dominate in both alkaline aquatic and terrestrial systems where carbonates are present (Cole and Olsen, 1959; Lajtha and Bloomer, 1988). However, calcareous soils may still have significant levels of Fe and Al oxides, either as discrete components or as coatings on other soil particles, and thus phosphate sorption may also be controlled by the presence of metal oxides as in more acidic soils (Lajtha and Harrisson, 1995).

In soils derived from limestone parent material, weathering decreases total $CaCO_3$ content, but increases specific surface area of the smaller $CaCO_3$ particles (Holford and Mattingly, 1975b). Thus any relationship between $CaCO_3$ and sorption is obscured by these opposing trends.

Two basic P-sorption reactions are distinguished with Al and Fe oxides and hydroxides, which differ in the time scale over which they take place and the stability of products formed. The initial adsorption appears to be a fast ligand exchange of surface hydroxyl groups with phosphate and the formation of inner-sphere surface complexes. Spectroscopic evidence for these complexes have been presented by various researchers (Laiti et al., 1996, 1998; Nanzyo, 1984, 1986; Nanzyo and Watanabe, 1982; Parfitt et al., 1975; Persson et al., 1996; Tejedor-Tejedor and Anderson, 1990; Tejedor-Tejedor and Anderson, 1986).

Less information is available on the slower P-sorption reaction, which can continue over months. Two mechanisms have been suggested for this reaction. One proposed mechanism involves slow diffusion of phosphate into micropores or through a metal phosphate coating (van Riemsdijk et al., 1984; van Riemsdijk and Haan, 1981; van Riemsdijk and Lyklema, 1980) and subsequent adsorption to internal surfaces. The slow weathering of the surface in the presence of phosphate and the formation of a surface precipitate of metal phosphate have been proposed as another possible mechanism. Both mechanisms explain the increasing irreversibility of phosphate sorption with time. Spectroscopic evidence (Bleam et al., 1991; Laiti et al., 1996, 1998; Lookman et al., 1996; Lookman et al., 1997; Lookman et al., 1994) as well as evidence from potentiometric titrations (Li and Stanforth, 2000) exist in favor of the surface precipitate hypothesis. A recent study by Arai and Sparks (Arai and Sparks, 2001) has, however, placed this hypothesis in doubt by showing very clearly using P X-ray Absorption Near Edge Spectroscopy (XANES) that no metal phosphate phase is formed during the sorption of phosphate to soils and hydrous ferric oxide. Thus, the mechanism of the slow reaction involved in the fixation of phosphate to aluminum and iron minerals in soils and the structure of the products formed, which mainly affect the bioavailability of P, is still elusive (Sparks and Hunger, 2002).

2.1.3 Phosphorus in animal nutrition

Plant adaptations to P stress can be loosely classified into strategies to maximise P uptake and strategies for the efficient use and conservation of P once it is obtained (Lajtha and Harrisson, 1995). Many strategies to maximise soil P uptake are general responses to any nutrient stress and may also be found when other nutrients, such as nitrogen, are limiting.

Phosphorus is also one of the essential elements needed for animal growth and milk production. It has many vital functions:

- The participation in metabolic processes in soft tissues;
- The maintenance of stable conditions for biological reactions;
- The maintenance of appetite, optimal growth, fertility and bone development;
- The prevention of bone disease, such as rachitis.

By far the greatest proportion of phosphorus is used for building up and maintaining the skeleton. A constant exchange of phosphorus occurs between bones and blood.

Since animals also need a wide range of other elements including calcium, magnesium and sodium, inorganic feed phosphates are usually supplied as mixtures of these essential elements.

Phosphorus nutritional requirements for most farm animals are well documented (dairy cattle 85-95 g/day, beef cattle 35-40 g/day). The phosphorus content of natural feed varies from one plant species to another. For example, grass contains only a few grams of phosphorus per kilogram dry weight. The phosphorus content of feed grains such as barley, maize and oats is also very low. Feeds, which contain high amounts of phosphorus, include rape seed meal, by-products from the milling industry and especially animal products like fish and bone meal. Animals digest only a small part of the phosphorus in this material.

The mechanisms of phosphorus digestion and metabolism differ substantially between ruminant and monogastric animals. The former can utilise the organically bound phosphate (phytates) found in grains while monogastrics cannot. Diets, which contain a high proportion of roughage with low phosphorus content, can be considerably improved by the use of feed supplement.

To provide the daily requirement for phosphorus, phosphates are used in the form of compound feed or as separate mineral supplements. Phosphate supplements are manufactured in many chemical and physical forms to suit different feeding and handling practices (http://www.nhm.ac.uk/mineralogy/phos/).

A generalised P-cycle for agricultural soils at farm level is illustrated in the following figure.

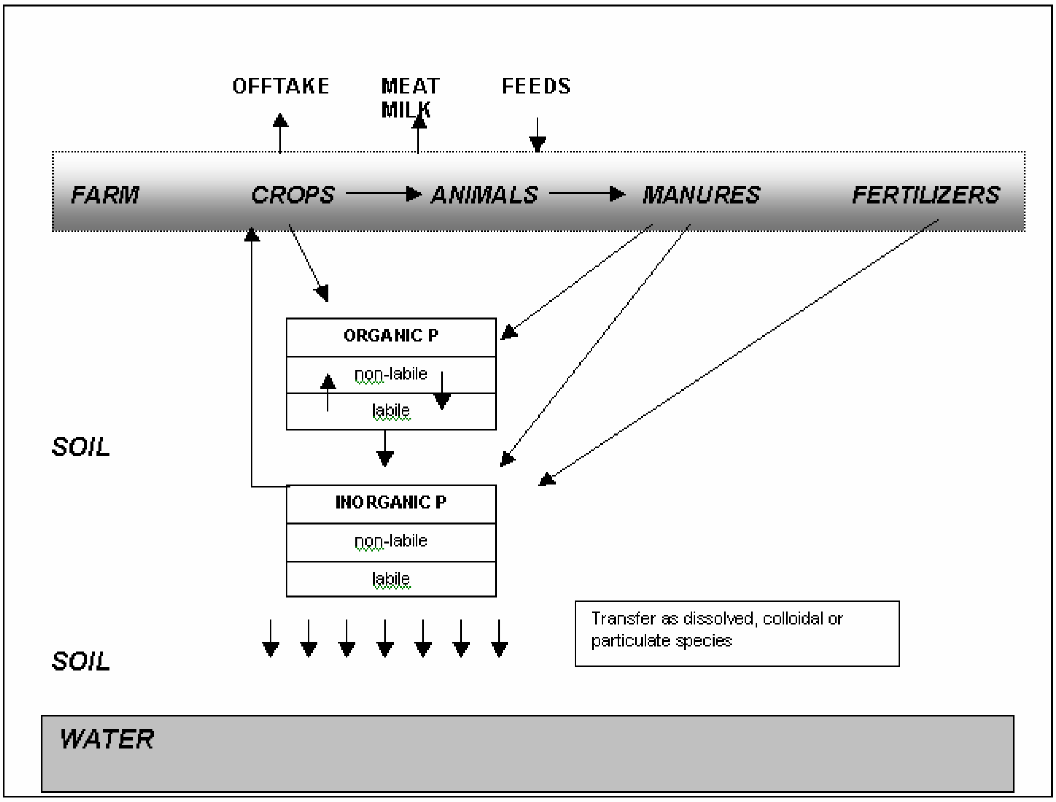


Figure 7: Generalised P-cycle at farm level

2.1.4 Accumulation of P in soil and water and its effects on biodiversity[1]

2.1.4.1 Buildup of P and pathways of loss

Phosphorus remains in short supply over large parts of the globe, where economic and political constraints mean that naturally low P availability is only insufficiently supplemented by imported fertilisers (Runge-Metzger, 1995). In many regions, where the use of N fertiliser is favoured over other nutrients, this may cause a nutrient imbalance and lead to inefficient N use.

Meanwhile, in some developed countries elaborated systems of fertility management and a long history of P fertiliser use have built up soil P levels to such an extent that additional P is currently not or hardly needed to produce food for the resident population. When such countries or regions continue to import both large amounts of animal feeds and P fertilisers, and where significant amounts of waste phosphates are produced by households and industry, phosphorus becomes a pollutant.

[1] *based on Howarth et al., 2000*

In Europe, intensive animal production on farms with little land produces manure in excess of the nutrient requirements of crops and pasture lands (Sibbesen and Runge-Metzger, 1995). The excess P from the animal manure, even when not directly dumped as wastewaters, accumulates in the surface soils, which leads to increased leaching and erosion losses of P to aquatic environments.

Phosphorus can easily be leached from highly organic (especially peat) soils and from sandy soils with low retention capacity. Small amounts are lost from most soils, but when they become phosphate saturated, leaching will be enhanced.

In general contrast to N, P is primarily lost from agricultural systems in run-off and "interflow" i.e. lateral movement of water in poorly drained soils. Losses of P in run-off tend to be higher from "heavy" soils (with high clay contents) than from "light" soils (with high sand contents) because the former have lower infiltration capacities.

Phosphorus transferred in this way can be either in soluble (dissolved) or "attached" (sorbed to, or part of, soil inorganic and organic materials) forms.

The potential P loss from agricultural land is largely dependent on the relative importance of surface and subsurface runoff in the watershed. Subsurface runoff can be accelerated by artificial drainage, and P concentrations and losses in natural subsurface runoff are lower than in tile drainage because of shorter contact time resulting in reduced removal of soluble P. Subsurface drainage of a soil can reduce P loss in runoff by decreasing runoff volumes. However, subsurface runoff can be an important contributant to P export from a watershed. High water tables in some agricultural soils reduce crop yields and increase the transfer of P between ecosystems. Consequently, subsurface drainage is essential in these cases from both economic and environmental aspects (Sharpley et al., 1995).

Almost invariably practices designed to increase the biological productivity of agricultural soils increase the biological productivity of waters draining these soils and may accelerate eutrophication. This causes problems with water use for fisheries, recreation, industry, or drinking, due to the increased growth of algae and aquatic weeds, and oxygen shortages caused by their decomposition.

Phosphorus losses that are not regarded as significant in agronomic terms can be significant in environmental terms due to the fact that a very small concentration (ca. 20 μg/l) in susceptible surface waters can lead to eutrophic conditions.

The major nutrients that cause eutrophication and other adverse impacts associated with nutrient over-enrichment are N and P. Nitrogen is of paramount importance both in causing and controlling eutrophication in coastal marine ecosystems. This is in contrast to freshwater (or non-saline) lakes, where eutrophication is largely the result of excess P inputs.

2.1.4.2 Eutrophication and loss of biodiversity

Eutrophication of aquatic systems results from two sources of nutrient supply: (1) nutrient inputs from outside the aquatic system (external loading), and (2) nutrient recycling within the water column and sediments (internal loading). Natural and anthropogenic processes influence both components of the nutrient supply.

External loading is usually enhanced by man through nutrient inputs to streams and rivers from the fertilisation of soils, soil erosion and disposal of municipal or industrial effluents (Reckhow et al., 1980). Atmospheric deposition of both N (Swank, 1984; Levy and Moxim, 1987; Galloway et al., 1987; Brown, 1988; Fanning, 1989) and P (Peters, 1977; Brown et al., 1984; Lewis et al., 1985) may be enhanced by anthropogenic emissions. The presence of large numbers of animals may also disturb the watershed and increase the nutrient supply to aquatic systems (Grobbelaar, 1974).

Nutrient inputs to lakes, estuaries, and oceans from streams draining disturbed watersheds are often accompanied by high turbidity, which results in light limitation of algal production, particularly at high river flows, and in most estuaries. Many rivers and estuaries with high concentrations of N and P do not develop high algal biomass because deep mixing in a turbid water column prevents adequate exposure to light for photosynthesis. These turbid aquatic systems eventually deliver their plant nutrients to lake or coastal waters where there is sufficient light available in the water column, and the plant nutrients are consumed until one or more are depleted from surface waters.

Internal loading results from seasonal or annual return to the water column of nutrients which have sunk and accumulated in sediments, even in undisturbed landscapes with unchanging nutrient inflows. This recycling of nutrients is particularly important in shallow lakes, estuaries, and near-shore seas. In deep lakes and ocean basins, nutrient cycling from sediments is less important because of the greater distance between sediments and photic surface waters.

In general, the effects of anthropogenic eutrophication are negative, and the beneficial effects are rare or accidental.

Fertilising lakes, rivers, or coastal waters with previously scarce nutrients such as N or P usually boosts the primary productivity of these systems – that is, the production of algae (phytoplankton) that forms the base of the aquatic food web. This eutrophication is linked to a number of problems in aquatic ecosystems. As the mass of algae in the water grows, the water may become murkier; and particularly as the algae die and decompose, periods of oxygen depletion (hypoxia and anoxia) occur more frequently. Even living algae can contribute to oxygen depletion due to their oxygen consumption at night. These changes in nutrients, light, and oxygen favour some species over others and cause shifts in the structure of phytoplankton, zooplankton, and bottom-dwelling (benthic) communities. For instance, blooms of harmful algae such as red and brown tide organisms become more frequent and extensive, sometimes resulting in human shellfish poisonings and even marine mammal deaths. Oxygen depletion can cause fish kills and create "dead zones." Just as important, subtle changes in the plankton community and other ecological factors may trigger reduced growth and recruitment of fish species and lowered fishery production. Coral reefs and submerged plant communities such as sea grass beds can be harmed by loss of light from reduced water clarity, or from nutrient-induced growths of nuisance seaweeds.

Some ecosystems are more susceptible to nutrient over-enrichment than others because a host of additional factors can influence the extent of plant productivity. These factors include how much light is available, how extensively algae are grazed by zooplankton and benthic suspension feeders, and how often a bay or estuary are flushed and its nutrients diluted by open ocean water. Thus, a given increase in nutrient inputs to coastal rivers and bays will boost primary production more in some systems than others. Yet susceptibility to nutrient over-enrichment is not static and can shift in response to such factors as climate change.

In some ecosystems, moderate nutrient enrichment can occasionally lead to increased populations of economically valuable fishes. More severe nutrient enrichment of these same waters, however, leads to losses of catchable fish. And even in systems where fish abundance is increased by nutrient inputs, other valued attributes such as biological diversity may decline. Other coastal ecosystems are highly vulnerable to eutrophication so that even small increases in nutrient inputs can be quite damaging. Coral reefs and sea grass beds, for instance, are particularly susceptible to changed conditions.

Eutrophication leads to changes in the structure of ecological communities by at least two mechanisms: indirectly through oxygen depletion and directly by increased nutrient concentrations.

Hypoxia and anoxia can change the makeup of a community by killing off more sensitive or less mobile organisms, reducing suitable habitat for others, and changing interactions between predators and their prey. For instance, recurring periods of low oxygen tend to shift the dominance in the seafloor community away from large, long-lived species such as clams to smaller, opportunistic, and short-lived species such as polychaete worms that can colonize and complete their life cycles quickly between the periods of hypoxia. Zooplankton that normally graze on algae in surface waters during the night and migrate toward the bottom in the daytime to escape the fish that prey on them may be more vulnerable to predation if hypoxia in bottom waters forces them to remain near the surface. Also, planktonic organisms such as diatoms, dinoflagellates, and copepods that live in surface waters (pelagic species) yet spend some life stages resting on the bottom may be unable to resume development if bottom layers remain oxygen depleted.

Nutrient over-enrichment alters community structure directly by changing competition among algal species for nutrients. Algal species have wide differences in their requirements for and tolerances of nutrients and trace elements. Some species are well adapted to low-nutrient conditions while others prefer high levels of N and P. These differences allow a diverse phytoplankton community to maintain productivity in the face of broad shifts in nutrient supplies.

Eutrophication alters the phytoplankton community by decreasing availability of silica, which diatoms require to form their glasslike shells. Some silica that would otherwise be flushed into estuaries is used up in nutrient-induced diatom blooms upstream. As diatom production increases, silica is trapped long term in bottom sediments as diatoms die and sink. A decline in available silica can limit growth of diatoms or cause a shift from heavily silicified to less silicified types of diatoms. Studies off the German coast lasting more than two decades documented a general enrichment of coastal waters with N and P, along with a four-fold increase in ratios of available N and P to silica. This shift was accompanied by a striking change in the composition of the phytoplankton community, as diatoms decreased and flagellates increased more than ten-fold. Also, harmful blooms of colony-forming algae known as Phaeocystis became more common.

The availability of biologically useable forms of iron and other essential metals also can be affected by eutrophication, creating another factor that favours some algal species over others and alters the structure of the phytoplankton community. Because iron hydroxides have extremely low solubility, organic molecules must bind with iron if it is to remain in solution in seawater. Thus, dissolved organic matter (DOM) plays a critical role in enhancing biological availability of iron in coastal waters. A variety of factors can affect DOM levels in estuaries and coastal systems, but in general, eutrophication results in higher DOM levels and increases iron availability.

Because phytoplankton forms the basis of the marine food chain, changes in the species composition of this community can have enormous consequences for animal grazers and predators. In general, these consequences are poorly studied, yet some outcomes are known. For instance, as noted above, eutrophication can lead to a change in dominance from diatoms towards flagellates, particularly if silica is depleted from the water. Such a change can potentially degrade the food webs that support commercially valuable fish species since most diatoms and other relative large forms of phytoplankton serve as food for the larger copepods on which larval fish feed. The presence of small flagellates may shift the grazer community to one dominated by gelatinous organisms such as salps or jellyfish rather than finfish.

Among the thousands of microscopic algae species in the phytoplankton community are a few dozen that produce powerful toxins or cause other harm to humans, fisheries resources, and coastal ecosystems. These species make their presence known in many ways, ranging from massive blooms of cells that discolour the water – so-called red or brown tides — to dilute, inconspicuous concentrations of cells noticed only because of damage caused by their potent toxins. Impacts can include mass mortalities of wild and farmed fish and shellfish, human poisonings from contaminated fish or shellfish, alterations of marine food webs through damage to larval or other life stages of commercial fisheries species, and death of marine mammals, seabirds, and other animals.

Although population explosions of toxic or noxious algal species are sometimes called red tides, they are more correctly called harmful algal blooms. As with most algal blooms, this proliferation and occasional dominance by particular species results from a combination of physical, chemical, and biological mechanisms and interactions that remain poorly understood. Although harmful algal blooms have occurred for at least thousands of years, there has been an increased incidence and duration of such outbreaks worldwide over the past several decades. This increase in harmful algal blooms has coincided with marked increases in nutrient inputs to coastal waters, and in at least some cases, nutrient pollution is to blame for the outbreaks.

Eutrophication frequently leads to the degradation or complete loss of seagrass beds. Plant growth in these beds is often light limited, and eutrophication can lower light availability further by stimulating the growth of phytoplankton, epiphytes on the seagrass leaves, and nuisance blooms of ephemeral seaweeds (macroalgae) that shade out both seagrasses and perennial seaweeds such as kelp. In addition, eutrophication can lead to elevated concentrations of sulfide in the sediments of seagrass beds as algae and plant material decompose on the oxygen-depleted seafloor and seagrasses lose their ability to oxygenate the sediments. These elevated sulphide levels can slow the growth of seagrasses, which draw most of their nutrients from the sediments rather than the water column, or even poison them and lead to their decline.

Nutrient-induced changes generally lower the biological diversity of seagrass and kelp communities. Since these plant communities provide food and shelter for a rich and diverse array of marine animals, the degradation of seagrasses and kelp or their replacement by nuisance seaweed blooms brings marked changes in the associated animal life. These systems are particularly important as spawning and nursery grounds for fish. Further, the roots and rhizomes of seagrasses stabilize bottom sediments, and their dense leaf canopy promotes the settling out of fine particles from the water column. Loss of seagrass coverage, therefore, allows sediments to be stirred up. This not only reduces water clarity directly but allows nutrients trapped in the sediment to be released into the water column, promoting additional algal blooms. The short-lived nuisance seaweeds that result from eutrophication can also wash up in enormous quantities on beaches, creating a foul smell for beachgoers and coastal residents.

Coral reefs are among the most diverse ecosystems in the world, and also among the most sensitive to nutrient pollution. The world's major coral reef ecosystems are found in naturally nutrient-poor surface waters in the tropics and subtropics. It was once commonly thought that coral reefs preferred or thrived in areas of nutrient upwelling or other nutrient sources, but this idea has been shown to be incorrect. Instead, high nutrient levels are generally detrimental to reef health and lead to shifts away from corals and the coralline algae that help build the reef structure toward dominance by algal turfs or seaweeds that overgrow or cover the reefs.

Other elements – particularly silica – may also play a role in regulating algal blooms in coastal waters and in determining some of the consequences of eutrophication.

Extensive studies in the early 1970s led to consensus that P was the nutrient most responsible for over-enrichment in freshwater lakes. Since that time, tighter restrictions on P inputs have greatly reduced eutrophication problems in these waters. However, more recent research indicates that in numerous estuaries and coastal marine ecosystems — at least in the temperate zone — N is generally more limiting to phytoplankton growth than P, and N inputs are more likely to accelerate eutrophication. A "limiting" nutrient is the essential plant nutrient in shortest supply relative to the needs of algae and plants, and adding it increases the rate of primary production.

There are exceptions to the generalization that N is limiting in coastal ecosystems. For instance, several estuaries on the North Sea coast of the Netherlands appear to be P limited. In the case of the North Sea estuaries, P limitation most likely results from stringent controls the Dutch government has imposed on P releases, combined with high and largely unregulated human N inputs.

In tropical coastal systems with carbonate sands and little human activity, P is generally limiting to primary production because the sand readily adsorbs phosphate, trapping it in the sediment and leaving it largely unavailable to organisms. However, such lagoons may move toward N limitation as they become eutrophic. The primary reason is that as more nutrients enter these waters, the rate at which sediments adsorb phosphate slows and a greater proportion of the P remains biologically available.

The identity of the nutrient that limits plant production switches seasonally between N and P in some major estuaries. Runoff in these systems is highest in the spring, and at that time the N:P ratio of the runoff determines which nutrient is limiting. In the summer, when runoff drops sharply, however, processes that occur in the sediment such as P adsorption and the bacterial breakdown of N compounds (denitrification) play a more important role in determining which nutrient is in shortest supply.

2.1.5 Heavy metals associated with P in inorganic and organic fertilisers[2]

Commercial phosphate (P) fertilisers may contain small amounts of heavy-metal contaminants which were minor constituents in phosphate rock (PR). Animal manure and sewage sludge (biosolids) are the main organic fertilisers and the latter also may contain heavy-metal contaminants. Heavy metals in biosolids may be found in the inorganic form or may be organically complexed, which could affect their chemical reactions in soil. These heavy metals may accumulate in soil with repeated fertiliser applications.

Phosphate rock (PR) contains various metals and radionucleides as minor constituents in the ores. Varying amounts of these elements are transferred to phosphate fertilisers in production processes, and later are applied to soils together with these fertilisers. Cadmium (Cd) is the heavy metal of most interest because it is potentially harmful to human health, and much attention is being given to its avenues of entry into the human food chain. Among these avenues is the application of Cd to soil with fertilisers, and the subsequent uptake by vegetable and grain crops. Numerous reports indicate significant differences among plant species in their ability to take up Cd and other heavy metals. Leafy vegetables are well known as Cd accumulators. Evidence for varietal effects on heavy metal uptake also is being gathered, because it may be possible to select varieties for low heavy metal accumulation in order to decrease the transfer of these metals into the human food chain. Phosphorus is a major limiting factor to crop production on many acid, infertile soils. Bioavailability of heavy metals, especially Cd, is greatest on acid soils. Therefore, Cd uptake may be increased in some crops fertilised by P fertilisers containing appreciable levels of Cd.

Concentrations of other heavy metal and radionuclide contaminants in P fertilisers vary considerably, depending on the PR source. Some metals of possible

[2] *based on Mortvedt and Beaton, 1995*

significance are: arsenic (As), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and vanadium (V). However, these metals are of less concern than Cd, either because they are not as readily absorbed by plants from P-fertilised soils or their apparent relative effects on human health are less than that of Cd. The main radionuclide contaminants in PR are uranium (U), radium (Ra), and thorium (Th).

Most known PR deposits have been assayed for their heavy metal contents (Kongshaug et al., 1992) (*Table 1*). Concentrations vary considerably by metal (highest variation for Cr and lowest for Hg) and by region.

Table 1: Average heavy metal concentrations in phosphate rock (PR) deposits and estimated input to soil by P fertilisers (Kongshaug et al., 1992)

	Heavy metal concentration								
PR Deposit	***As***	***Cd***	***Cr***	***Cu***	***Pb***	***Hg***	***Ni***	***V***	***Zn***
	mg kg^{-1} of PR								
Russia (Kola)	*1*	*0.1*	*13*	*30*	*3*	*0.01*	*2*	*100*	*19*
USA	*12*	*11*	*109*	*23*	*12*	*0.05*	*37*	*82*	*204*
South Africa	*6*	*0.2*	*1*	*130*	*35*	*0.06*	*35*	*3*	*6*
Morocco	*11*	*30*	*225*	*22*	*7*	*0.04*	*26*	*87*	*261*
Other N. Africa	*15*	*60*	*105*	*45*	*6*	*0.05*	*33*	*300*	*420*
Middle East	*6*	*9*	*129*	*43*	*4*	*0.05*	*29*	*122*	*315*
	mg kg-1 of PR								
Avg of 91% of PR reserves	*11*	*25*	*188*	*32*	*10*	*0.05*	*29*	*88*	*239*
	mg kg-1 of P								
	71	*165*	*1226*	*209*	*66*	*0.29*	*189*	*578*	*1561*
Applied with 20 kg P ha-1	*g ha^{-1}*								
	1	*3.3*	*25*	*4*	*1*	*0.01*	*4*	*12*	*31*
Tolerable limit (Finck, 1992)	*mg kg^{-1} of soil*								
	-	*2*	*100*	*100*	*100*	*2*	*50*	*50*	*300*

Varying proportions of heavy metal contaminants in PR will be transferred into P fertilisers, depending on the manufacturing process. Ordinary single superphosphate (SSP) is produced by reacting H_2SO_4 with PR. The resulting product will contain all of the heavy metal constituents found in the PR. A large percentage of today's P fertilisers is produced from wet-process H_3PO_4. By-product phosphogypsum also will contain a fraction of the heavy metals in the PR.

Several chemical processes to remove Cd from H_3PO_4 before it is converted to P fertilisers have been studied. Examples are the extraction of wet-process H_3PO_4 with amines (Stenstrom and Aly, 1985) and by anion exchange (Tjioe et al., 1988) and cation exchange (Anon, 1989).

A study (Oosterhuis F.H. et al., 2000), carried out on behalf or the European Commission, assessed the cost of decadmiation for different technologies ranging from 6 to 32 USD per tonne of P_2O_5, hence concluding that the maximum cost of decadmiation could be around 10% of the fertiliser production costs.

2.1.6 Risk assessment of HM accumulation in soils

Both Cu and Zn are micronutrients required for crop production. Average application rates for Cu- and Zn-deficient soils range from 1 to 5 kg ha^{-1}, which are 100 to 1,000 times higher than the rates listed in *Table 1*. Some countries have set tolerable limits for heavy metal additions to soil such as the values set for German soils shown in *Table 1* (Finck, 1992). Such limits generally are set for the surface plow layer (20-30 cm) of soil where most root activity exists.

In an ongoing EU risk assessment study on the accumulation of Zn in agricultural soils the following provisional conclusions were drawn:

"The outcome of the risk assessment for the scenario of accumulation of zinc and zinc compounds in agricultural soil was discussed at the 9th risk reducion strategy meeting in March 2005. It was discussed that no immediate risk reduction measures were needed, but there might be a concern for zinc accumulation and exceedance of critical zinc concentrations in soil in the future. It was suggested that the information gathered and produced in theframework of ESR should be transferred to the appropriate legislative frameworks where it should be taken into account for future policy.

At the Joint meeting of the Competent Authority for the implementation of Directive 67/548/EEC and Council regulation 793/93 in June 2005 the item was discussed again and the following conclusion was decided :'the risk assessment regarding the scenario of accumulation of zinc in soil has not presented a risk that currently needs to be limited. There is therefore at present no need for risk reduction measures beyond those which are being applied'. This conclusion was based on the results of the risk assessment and because the legislation currently in force relating to sludge and manure management (86/278/EEC; 91/676/EEC; 1831/2003) was generally considered to give an adequate framework to anticipate to the extent needed and prevent future risks of zinc accumulation.

It was also concluded in the CA-meeting in Helsinki (as was suggested already in the 9th RRSM) that the risk assessment and the information contained therein regarding the possible accumulation of zinc in soils, and the rapporteur's analysis of current risk reduction measures should be communicated to the relevant (EU) policy frameworks. Policy makers in these frameworks should take the information into account when developing their future policies. "

As regards the accumulation of Cd in the soil, separate risk assessments carried out by 9 Member States have concluded that, although dependant on agro-climatic conditions, the application of phosphate with the current Cd amount will lead to accumulation of cadmium in soils.

Based on these 9 risk assessments, the Scientific Committee on Toxicity, Ecotoxicity and Environment (SCTEE) was required to answer the questions:

"*Is it scientifically justified to conclude that the modelling of cadmium accumulation in agricultural soils in the various assessments suggests the following trends:*

- *For low fertilizer cadmium concentration (between 1 and 20 mg/kg P_2O_5) cadmium in soils tends to accumulate relative slowly and decreases after 100 years of application due to net removal rates exceeding inputs*

- *For fertilizers with Cd concentrations of 60 mg/kg P_2O_5 and above accumulation in agricultural soils over 100 years is relatively high* "

The opinion of the SCTEE stated that

- *"Based on the evidence presented in the reports and some additional calculations, fertilizers containing 20 mg Cd/kg P_2O_5 or less are, in most soils, not expected to result in long-term soil accumulation, if other cadmium inputs are not considered.*

- *Based on the evidence in the reports and some additional calculations, fertilizers containing 60 mg/kg P_2O_5 and above are, in most soils, expected to result in long-term soil accumulation.*

- *A derivation of a limit of Cd in fertilisers which is exclusively based on soil accumulation, does not take into account the level of risk for human health and environment.*

Furthermore, the Committee included explicitly in its opinion two crucial caveats. The conclusion:

- does not consider other Cd inputs into agricultural soils (such as atmospheric deposition, land spreading of waste, etc)

- has solely addressed the environmental problem of soil accumulation setting aside other environmental impacts such as leaching to other environmental compartments (e.g. water contamination) and impacts to human health and human exposure through the food chain and drinking water.

2.1.7 Legislation concerning cadmium in agricultural soils

Because of concerns regarding heavy metal effects in the human food chain, various governments have introduced controls on heavy metal concentrations in sewage sludge for land application since the 1980's. The 1986 Sewage Sludge Directive (86/278/EEC), as part of the Framework Directive on Waste, deals with the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. The Directive lays down limit values for concentrations of heavy metals (including cadmium) in the soil, in sludge as well as for the maximum annual quantities of heavy metals that may be applied on the land.

Also cadmium in fertilisers has been a long standing concern for EU and national policy makers. In 1984, a research programme on cadmium removal from phosphate rock and phosphoric acid was started jointly by the World Bank and the European Commission. In 1988, the Commission adopted a resolution outlining an action programme aiming at the reduction of cadmium in soil from fertilisers.

More recently, several risk assessment concerning accumulation in soil have been carried out by 9 Member States which were used as the basis by the STCEE (see previous paragraph) to adopt an opinion on soil accumulation. Furthermore, work is ongoing to complete a comprehensive risk assessment of cadmium, taking place within the framework of EU Regulation 793/93 on the evaluation and control of the risks of existing substances. The main preliminary conclusions (as it is not yet finished) are that the opinion of the SCTEE concerning the accumulation in soil is endorsed, and that caution is needed, as the risk to human health can not be excluded for all local and regional situations. Even risk factors below 1.0 may not be protective enough for all sections of the general population because of the large variability in food Cd concentrations, dietary habits and nutritional status.

While there is no harmonised EU regulation regarding the cadmium content of fertilisers as yet, several member states have already set up national legislations or industry commitments to limit the maximum concentration of cadmium in fertilisers, the yearly amount of cadmium input on agricultural land and/or the cadmium concentration in agricultural soils (see *Table 2*).

The use of economic instruments for this purpose is limited to Sweden, where a charge on cadmium in commercial fertilisers was introduced in 1994, replacing an earlier charge on phosphorus. According to the Swedish Board of Agriculture, this measure, in combination with voluntary efforts by the sector, has been successful in reducing the amount of cadmium in phosphorus fertilisers, which dropped from 35-40 mg Cd per kg of P (before the introduction of the tax) to 16 mg in 1995/96.

Table 2: Existing restrictions on the Cd concentration in selected member states

Member state	**Maximum concentration**	**Remark**
Finland	20 mg/kg P_2O_5	Binding limit
Denmark	48 mg/kg P_2O_5	Binding limit
Sweden	50 mg/kg P_2O_5	Binding limit
Austria	75 mg/kg P_2O_5	Binding limit
Germany	50 mg/kg P_2O_5	To be officialised
Netherlands	-	Voluntary agreement with fertiliser industry to reduce Cd in fertilisers
Belgium/Lux.	90 mg/kg P_2O_5	Not a legal limit

From the above table it appears that cadmium standards are not harmonised. The European Commission envisages the possibility of restricting the maximum content of cadmium in fertilisers, both aiming at the protection of the environment and the establishment of an internal market for fertilisers in the EU.

According to a study (Oosterhuis F.H. et al., 2000), carried out on behalf or the European Commission, measures to reduce the cadmium content of phosphate fertilisers, whether of a legislative or an economic nature, would have no significant impact on the phosphate fertiliser consumption as such. On the other hand, it could cause a major shift in the supply of phosphate rock and derived products from countries such as Morocco and other North- and West-African countries to South-Africa and possibly Russia, if decadmiation technologies are not used.

2.1.8 Radionucleids

Phosphate rock varies considerably in content of U, Ra, and Th, depending on the geographical area from which it was mined. Typical levels of gamma radiation from the PR deposits listed in Table 3 ranged from 5 to 30 kBq kg^{-1} P (Kongshaug et al., 1992).

In a comprehensive study of PR from four deposits in the USA, Wakefield (1980) reported that about 33% of the U in beneficiated PR concentrate, the feedstock for acidulation by the wet-process, was found in the phosphogypsum by-product. The remainder of the U was found mainly in the H_3PO_4, which subsequently is processed to several types of P fertilisers. Some companies remove the U from the H_3PO_4 and sell the "yellow cake" for purification as a nuclear power plant fuel.

Mustonen (1985) analysed 81 samples of NPK fertilisers in Finland for 238U, 235U, 226Ra, and 228Th. These samples represented 28 grades of fertilisers used for agriculture, forests, and gardens, with a mean N-P-K grade of 16.5/6.2/11.3. The mean activities of radionuclides per unit weight of P varied among fertiliser plants (Table 3).

It was estimated that the annual contribution of 238U in P fertilisers was about 0.25% of the total U naturally occurring in the surface 10 cm layer. Because applied P eventually is mixed with greater depths of soil (probably a 25-cm layer), the annual U contribution would be less than the above percentage. More (1977) estimated that P fertilisation would cause an annual increase of about 0.04% of the total Ra concentration in tilled agricultural soils in Sweden.

Table 3: Mean concentrations of radionuclides in compound fertilisers from various fertiliser factories in Finland (Mustonen, 1985).

Factory	Concentration in Bq/kg P				
	238U	**235U**	**226Ra**	**228Ra**	**228Th**
I	2900	160	830	87	210
II	980	42	290	59	140
III	2400	130	770	95	220
IV	7400	420	1500	62	200
V	4100	230	2000	100	160
Weighted mean	3800	210	1100	78	190

Few papers have been published on uptake of the radionuclides in P fertilisers by agricultural crops, but there seems to be little evidence for the entry of harmful levels of radionuclides into the human food chain from P fertilisers (Mortvedt and Beaton, 1995), neither from phosphogypsum (a residue of the phosphate fertiliser industry that has relatively high concentrations of Ra-226 and other radionuclides) that is applied as a Ca amendment on agricultural soils.

3. Current situation on P-use and P-management at farm level

3.1 Current practices in P-management

3.1.1 Role of phosphorus in crop production

As was explained in paragraph 2.1.1 (Role and behaviour of P in soil, plant, animals), phosphorus is an essential element for plant growth and its input in crop production has long been recognised as essential to maintain economically viable yield levels. In agricultural systems, P is needed for the accumulation, transfer and release of energy associated with cellular metabolism, flower, seed and root formation, maturation of crops, crop quality and strength of straw (in cereals).

In natural systems, P is efficiently recycled through litter, plant residues, animal excretions and remains. In agricultural production recycling mainly takes place in crop residues and animal manure. At the same time, considerable quantities of P are removed in crop and animal products. In most soils, the pool of native soil P is unable to supply and maintain adequate amounts of soluble plant available orthophosphates, and even less to compensate for the net uptake removal by the crops. Therefore mineral P fertilisers and feed supplements are injected into the agricultural production system to increase and maintain production levels. However, the reactions which applied P undergoes in the soil result in relatively poor efficiency in uptake. It has been estimated that 25 percent of less of P applied annually is actually taken up by the growing crop (Morgan, 1997). The remaining 75 percent joins the pool of soil P is a more or less soluble form, or is lost to water. The crop uptake of P is in contrast to the crop use of the more mobile elements nitrogen or potassium, where the recovery rate may be as high as 80 %).

In common with other elements, the concentration of total P in the soil is relatively high compared with both crop requirements (as reflected by actual uptake) and the available P fraction.

Due to its role in crop development, phosphorus is required in fairly large amounts as are nitrogen and potassium, and has to be available in equilibrium with all other essential elements.

Contrary to certain other elements; overabundance of phosphorus is not known to have any specific harmful effects on plant development or on crop production, nor does it negatively affect crop quality.

3.1.2 General P-fertilising strategies and the effect on the P-status of the soil

In their natural non-amended state, most soils contain too little readily available phosphorus for plants to produce good yields of currently available cultivars. Therefore P-fertilisers are an essential input to agricultural soils. The question is how much P should be applied, and when.

As phosphorus is not very mobile in the soil and can, to some extent, switch from readily available to less available forms, most fertilising strategies aim at building up and maintaining a certain soil reserve. Once a sufficient reserve has been built up, only limited rates of P are needed in the following years. Some advocate a mere compensation for uptake, others are in favour of higher annual rates.

In long term field experiment carried out by the Soil Service of Belgium and the University of Ghent on a typical loamy soil near Ath (Belgium) the P-balance of a cereal-sugarbeet-potato rotation was followed during 23 consecutive years. These soils have a rather high P-retention capacity due to their clay content.

The P-status of the soil (plant available phosphorus) was measured at the start and at the end of the trial using the AL-extraction method. Every season, phosphorus was applied at 5 different levels, including a zero-application. Removal of P by the crop was estimated from the yield levels of the various crops.

The following table shows the results of the trial. The cumulative P-balance varied from minus 506 kg of P on the control plot to plus 1,5 tons of P on the plot with the highest P-dose. From its original level of 16.3 mg of P per 100 g of dry soil, the plant available P decreased to 8 mg on the non fertilised plot, and rose to 27 on the plot with the highest P-application rate.

The cumulative surplus level needed to maintain the available content of this soil at its original, not particularly high level appears to be in the order of around 550 kg of P, or about 24 kg of P (± 54 kg of P_2O_5) per cropping season.

Table 4: P-balance in kg P/ha and evolution of the P-status in a long term (1965-1987) trial including 5 rates of P (P0 to P4)

Cumulative balance	**P0**	**P1**	**P2**	**P3**	**P4**
Import	0	746	1 484	1 734	2 270
Export	506	591	680	671	697
Balance	- 506	+ 155	+ 804	+ 1 093	+ 1 573
*P-content in 1987** *(mg P/100 g dry soil)*	*8*	*13*	*19*	*22*	*27*

* the overall level in 1965 was 16.3 mg/100g

This example clearly illustrates that maintaining the soil fertility level of the soil, as measured by the soil test, can not be achieved by simply compensating for uptake by the plants.

On the other hand it is clear that on soils with declining soil test levels for P, the yield potential does not necessarily drop significantly, at least not in the first years. This was shown in a 6 years experiment carried out on various locations in Europe and coordinated by Imphos (The effect on phosphate fertiliser management strategies on soil phosphorus status and crop yields in some European countries, Imphos, 2001). In this trial, not replacing the P removed by the previous crop on soils with an adequate initial P-status, had no consistent effect on the yield of all crops. This can be attributed to the fact that P in less available form, and as such not measured by the routine methods of soil analysis, would be released sufficiently quickly to supply the P-needs of the crop, at least initially. Very long term experiments would be needed to assess how long the P-reserves would be effective in maintaining yields.

In the same trials, none but a few crops (potatoes and sugar beet) responded well to P-applications above the maintenance rate. This means that any policy for maintaining the P-status of the soil should consider the whole rotation, applying more on the most responsive crops.

After six years of different, and sometimes large application of P-fertiliser there were only small changes in the P-status of the topsoil, and no consistent changes in the P-status of the subsoil. Therefore, six years seems to be too short a period to get reliable data on the movement of P from the subsoil and its retention in the subsurface horizons.

3.1.3 Supply and output of phosphorus at farm level

The most commonly used sources of P in agriculture are organic or inorganic (mineral) fertilisers. The latter include the so-called chemical fertilisers, produced by chemical treatment of phosphate rock.

Mineral P-fertilisers applied to agricultural land include:

- Natural rock phosphate, finely ground in order to increase the specific surface and to boost the solubility of the phosphorus

- Simple mineral fertilisers, containing only phosphorus as plant nutrient (e.g. superphosphate or triple superphosphate). Chemical treatment increases P-content and speeds up the release of phosphate ions.

- Complex mineral fertilisers (e.g. NP and NPK mixtures) contain other elements next to phosphorus, in various rates and mixtures can be prepared for specific purposes.

Depending on the agricultural system, organic fertilisers can be an important, if not the major source of nutrients.

- Livestock manure is most often produced on farm, but can also be transferred to other farms. Applying manure usually is a form of recycling within the agricultural production unit. On the other hand considerable amounts of phosphorus can enter the cycle via bought feedstuff.

- Spreading on agricultural land of various waste products from non agricultural sources such as urban compost or sewage sludge form sewage or water treatment plants is widely practised, but does not contribute significantly to the total input in Europe. Often farmers are reluctant to use such products for fear of contamination or because of the rather unpredictable efficiency.

Locally, phosphorus may also be supplied as waste products from industries. Such is the case for slag from steel production, the use whereof has regressed in Europe together with the declining steel industry.

Atmospheric deposition of phosphorus compounds is known to occur f.i. in the vicinity of certain industries, but does not contribute significantly to the input of P on agricultural land, and is not taken into consideration in any P-fertilising strategy.

3.1.4 Recommended fertiliser rates

The rates of phosphorus recommended and/or applied vary widely in function of crops, soils, agro-ecological conditions and agricultural system. Historic factors (f.i. availability of cheap sources of certain materials) may also play a role. The following table gives an overview of average P-fertiliser recommendations used in various member states, as compiled by the FAO. It should be underligned that these figures are average recommended rates only. More detailed figures on actual P-use per crop and per MS are provided in Table 6 on page 34.

Rough phosphorus recommendations are sometimes provided as so-called blanket recommendations, whereby no distinction is made between individual fields. More often, and preferably they will be based on soil analysis of the particular field. In the latter case, the applied rates will be specific and much more precise. It should be noted that recommendations are usually considered in a crop rotation and as part of a long term fertilising strategy.

Table 5: Example of average recommended rates of P on major crops

	Fertiliser use (kg P_2O_5/ha)					
	Barley	**Maize, silage**	**Wheat**	**Potato**	**Sugar beet**	**Grassland**
Belgium	25	30	25	50	50	35
Denmark	16	25	17	35	35	15
Estonia	13		18	35		
France	48	22	80	30	38	25
Germany	30	30	30	70	70	7
Italy	50		60	70	60	5
Latvia	19.8		19.8	33.6	82	4.2
Netherlands	9	28	9	68	50	23
Spain	51	52	53	81	100	32

Source: FAO 2002

3.1.5 Application methods and timing

As plants need relatively large amounts of phosphorus early in the life cycle, phosphorus is most often applied (well) before planting or at a very early stage of development.

As phosphorus is not very mobile in the soil, fertilisers (in particular organic fertiilsers, have to be worked under in order to be available within the root zone and to avoid losses by runoff and erosion. For the same reasons, application to waterlogged or frozen soil should be avoided.

Broadcasting is the most widely used method. Root development is limited in cool, wet soils and very little phosphorus is released from soil organic matter. Some studies have found banded phosphorus to be nearly twice as efficient as broadcast phosphorus in cold soils. In well-drained, fertile soils that warm up early in the spring however, row and broadcast applications are often equally effective (Schulte et al., 1996).

Manure is applied in various ways according to the type and the available equipment: from simple surface spreading to sophisticated direct injection into the soil. As in the case of mineral fertilisers, manure (or other forms of organic fertilisers) have to be applied early in the season and to be well mixed with the soil in order to improve the availability of P to the plant.

Precision farming technology enables optimum application of nutrients throughout farmers' fields and is feasible on larger fields and farms in Europe.

3.2 Trends in consumption and production of P-fertilising agents at farm level

In European farms use of fertilisers or other supplies of nutrients on arable land and grassland to increase production has been a common practice for many years, or even centuries. Depending on the type and intensity of agriculture, phosphorus is supplied in small or larger quantities in one or more of the three following forms: mineral fertilisers, animal manure and, to a smaller extent, other forms of organic materials such as compost of sludge.

3.2.1 Mineral P-fertiliser use

Mineral fertilisers exist in a wide range of forms: from simple ground rock phosphate to more sophisticated custom made compound fertilisers that combine nutrients in various ratios. The consumption of mineral fertilisers and its evolution in time is well documented, among others in various publications or the International Fertilizer Industry Association (IFA).

During the period 1950 to 1989, with temporary setbacks notably due to the oil crises in the 1970s, there was a sustained increase of world mineral fertiliser consumption from 14 to 143 million tonnes $N+P_2O_5+K_2O$, or almost 6% per annum. The oil crisis had a stronger impact on N consumption (directly dependent on energy prices) than on mineral P-consumption.

Between 1989/90 and 1993/94 world fertiliser consumption fell by 23 Mt, from 143 to 120 Mt total nutrients. The reduction was due to a strong decline of fertiliser use in the countries of Central Europe and of the Former Soviet Union, and also, to a lesser extent, a fall of almost 5 Mt in West Europe. The falls were only partly offset by increases in Asia.

During the period 1993/94 to 1999/2001 world total nutrient consumption increased again to an average of 138 Mt. Consumption in Socialist Asia, South Asia and Latin America increased, that of West Europe stabilized while demand in the former Soviet Union fell again.

In 1979/80, P-fertiliser consumption in West Europe rose to a peak of 6,44 million tons of P_2O_5, after which it gradually declined to around 3 million tons by the year 2000. In Eastern Europe and the former Soviet Union, a peak consumption of 8,5 million tons of $P_2O_5$was reached in 1988/89, followed by a dramatic fall of up to 90%.

The following figure shows the evolution of P-fertiliser consumption in a number of EU member states. For each country P-fertiliser use is expressed as a percentage of the 1960/61 figure. Distinct patterns in P consumption can be distinguished.

In the 'old' EU member states of North- and West-Europe (Belgium, the Netherlands, Sweden, Denmark, France, but also Austria), the P-fertiliser consumption slightly rose until the 1970's, then gradually dropped to a level well below the figure of 1960. This can be explained by a certain build-up of P reserves in the soils during the years of higher consumption reducing the need for P-fertilisers, and growing substitution of mineral fertilisers by manure.

In Mediterranean member states such as Spain, Portugal or Italy, the current P-fertiliser use is around or even well above the 1960 figure. This is due in part to a different development pattern of agriculture in those countries, but also to the nature of the soils, generally deficient in phosphorus and not allowing rapid increase of P-reserves. Also the substitution effect by organic P (manure) may be less pronounced then in the northern member states.

In the new member states of Eastern Europe or the former Soviet Union, a big drop in P-fertiliser consumption was noted immediately after the events of 1989-90. This is for instance the case in Poland, where P-use increased fourfold between 1960 and 1975. After 1989, P-consumption dropped well below the 1960 figure, but rose again thereafter.

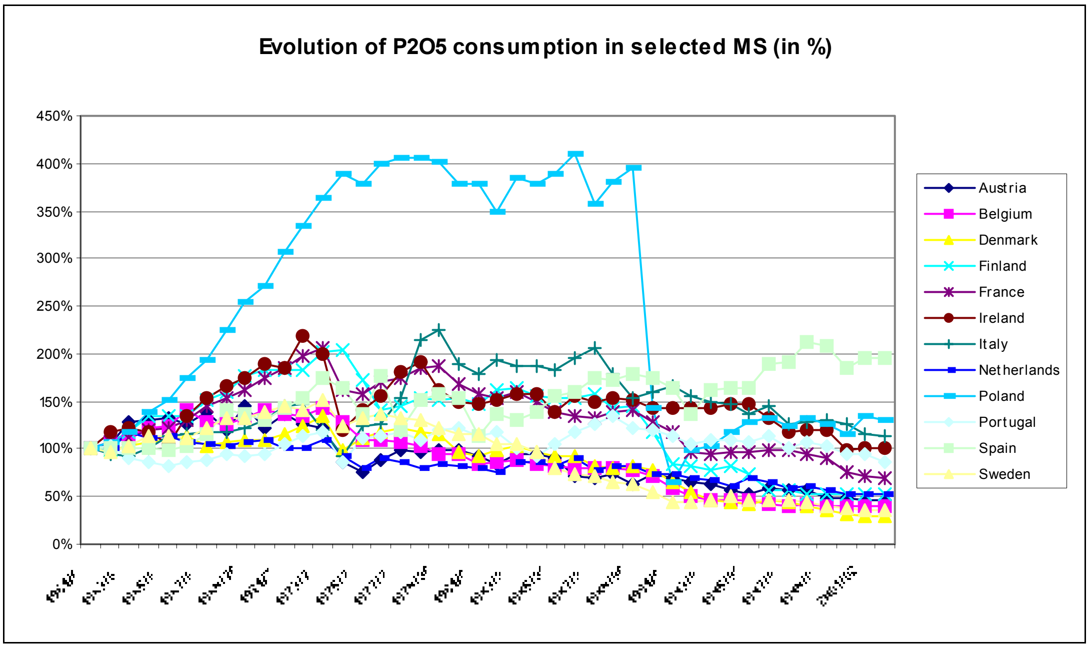


Figure 8: Evolution of P- consumption in selected MS (source IFA)

The following table presents average rates of P2O5 currently used on major crops in different EU member states. The data have been borrowed from the FAO publication 'Fertiliser use by crop, Fifth edition 2002' and were compiled by FAO in collaboration with a number of institutes in the fertiliser industry (IFA, IFDC, IPI and PPI) on the basis of questionnaires sent to member countries, research and development institutes and individual experts. The data relate to the year 1995 onward. As only a very limited number of countries have government agencies that collect such data on a systematic basis, not all data refer to the same year, and figures are not always available for all crops.

From the table it appears that potato, sugarbeet and vegetables receive the highest rates of mineral phosphorus. Within a specific crop, rates tend to be higher in the Mediterranean member states. Rates are also high in UK, Ireland and Finland compared the neighbouring countries.

Table 6: Average rate of P_2O_5 applied on crops in various member states (in kg/ha)

MS	Fruits/ Vineyards	Grassland (fertilised)	Maize (silage)	Potato	Rape seed	Sugarbeet	Vegetables	Wheat
AT	18	27	56	55	58	52	60	27
BE	-	35	30	50	50	50	50	25
CZ	-	-	22	66	19	29	-	17
DK		15	25	35	16	35	40	17
EE	12	12	-	35	18	-	33	18
ES		32	52	81	72	100	95	53
FI	-	25	-	115	30	80	80	24
FR	20	25	22	30	45	38	40	80
GE	25	7	30	70	45	70	40	30
GR	34	20	50	115	-	65	90	20
HU	9	-	-	71	23	53	-	30
IE	-	30	-	225	70	130	-	60
IT	40	5	-	70	40	60	70	60
LT	-	10	6	16	10	24	22	15
LV	2	4	-	34	-	82	17	20
NL	-	23	28	68	25	50	78	9
PL	-	14	28	18	35	45	25	25
PT	-	30	30	80	70	90	80	55
SK	9	2	6	31	17	19	40	12
SW		14	-	75	36	40	70	20
UK		18	48	163	45	50	65	40

Source FAO

3.2.2 *Manure production and use*

Since the beginning of sedentary farming, animal manure, as an intermediary step in the nutrient cycle, has been recognised as a major supplier of phosphorus on arable land all-over Europe. By collecting manure produced from extensive grazing land and applying it on the arable land, transfer and local accumulation of fertility in the form of organic matter and nutrients was possible, be it at the expense of the soil fertility of the surrounding land. Even today areas are found in Flanders or in the Netherlands with anthropogenic horizons of up to 1 m thick, rich in organic matter and phosphorus that find their origin in centuries of hard labour. In the FAO-Unesco soil classification, P-content is among the criteria to define an 'antropic horizon'.

However, as long as there was equilibrium between livestock numbers and available land area, the risk of excessive large scale surpluses of P remained small, even when the use of mineral P fertilisers became more common.

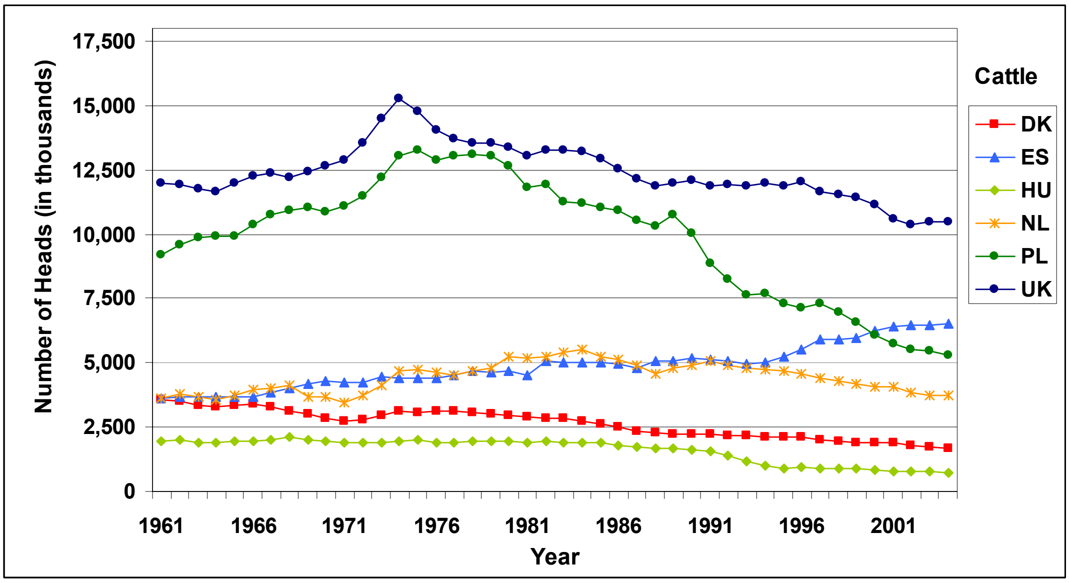
After the second world war, an explosive development of intensive livestock keeping with no or weakened links with arable production, took place in those areas of Western Europe where conditions were favourable to such developments: small farms on poor soils, availability of cheap imported feed, presence of processing industries and markets for pork and poultry. At the same time intensification took place in dairy farming and beef production. Such was the case in parts of Flanders, the Netherlands, Denmark, Brittany and northern Germany, but also in the Po-valley of Italy. In the Benelux countries and Denmark, meat production is mainly export oriented. Other large producers such as Italy and Germany remain net importers of meat. In EU member states formerly belonging to Soviet-bloc, similar developments of intensification and concentration took place, be it in a state controlled economy, but often in connection with large arable farms.

At the beginning, not much attention was paid to the manure production that accompanied this development. Manure was seen as a by-product that could conveniently be spread on the available land often far beyond the nutrient needs of the crops, or even be disposed of in lagoons, rivers or ditches. Effects on crops from the continuous overdoses of manure went unnoticed or were counterbalanced by a shift to new, more tolerant crops such as fodder maize replacing traditional more sensitive cereals like oats or barley. Excess nitrogen was easily leached out on the highly permeable sandy soils, and few or no crops are known to suffer from P-excess.

Concern about the environmental effects of nutrient surpluses only grew later, and little by little measures were enforced to reduce the pressure: transfer of manure to neighbouring regions, adapted feeding strategies, manure application standards, reduction in livestock numbers, etcetera. In countries with a centrally organised economy, intensive livestock keeping came to an abrupt halt in 1989 - 1990, and only a very partial recovery took place in the meantime.

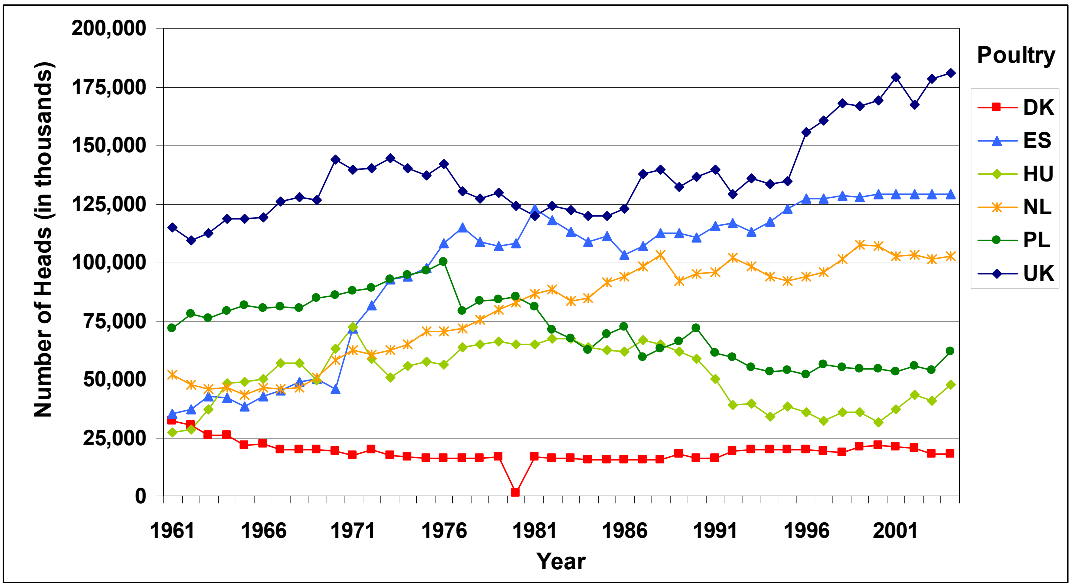
While in the 'traditional' areas with high livestock density there was a tendency in recent years to stagnation or even to decrease in livestock numbers, other countries such as Spain and to a lesser degree Portugal and Italy, saw a significant increase. By 2003, according to statistical figures Spain held nearly a fifth of the pig population in the EU 25 making it the second largest producer after Germany.

In the future we may see an east-to-west shift in European animal production induced by growing demand for meat in the new member states and stagnation or further natural or forced decline of livestock numbers in the old member states.



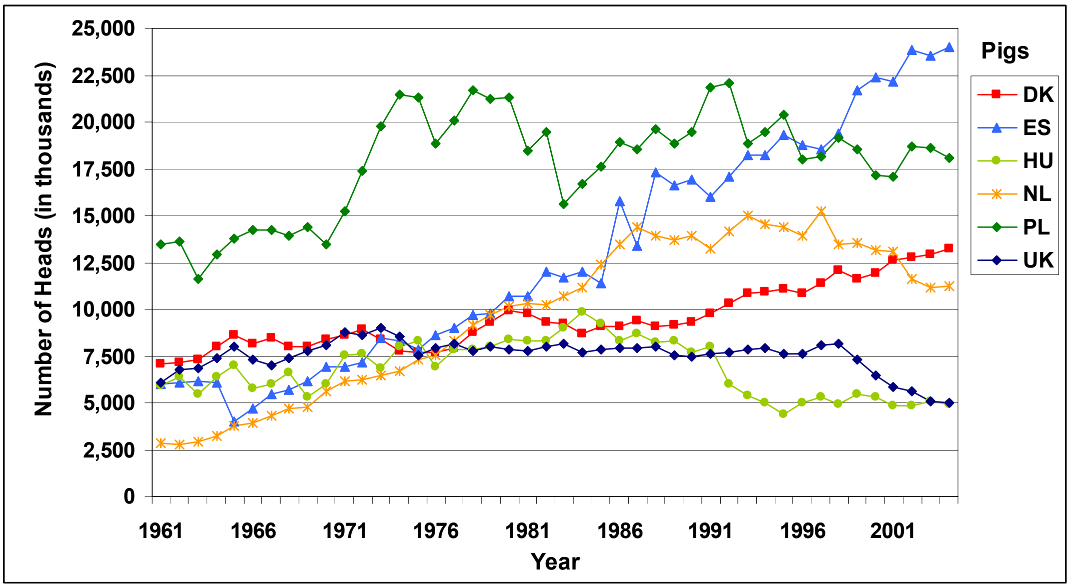
(Source: Eurostat/FAO Statistics Division – Data from 27/01/2005)

Figure 9: Evolution of cattle numbers in selected countries



(Source: Eurostat/FAO Statistics Division – Data from 27/01/2005)

Figure 10: Evolution of poultry numbers in selected countries



(Source: Eurostat/FAO Statistics Division – Data from 27/01/2005)

Figure 11: Evolution of pig numbers in selected countries

3.2.3 Relative importance of the various sources of P

In Europe the agricultural sector in general still generates a P surplus, with possible impacts on the soil and water system.

It should be noted that nowadays it is chiefly (but not exclusively) livestock farming that has excessive phosphorus count. The varying bioavailability of P in the soil encourages farmers to overcompensate when considering the required amounts of fertiliser and manure required to satisfy crop requirements. Moreover, this pattern is aggravated by the common practice of not adequately accounting for P inputs associated with the use of manures (Smith and Chambers, 1995).

On the other hand there is usually (but not always) a balance between the input and output of phosphorus in the case of cropping systems that use no or little livestock manure, but use mineral P instead. As the latter input is to be paid for, unlike manure, farmers can be expected to adapt the rates in function of the fertiliser cost and the expected return.

The following table and figure provide an overview per member state of the input of P as manure or as fertiliser, as well as the ratio between the two sources of phosphorus. In all but a few states, manure is at present the chief provider of phosphorus. Countries with relatively high consumption of mineral P-use are all situated around the Mediterranean, or have a high proportion of P-deficient soils. A notable exception is Finland. Here the relatively high consumption of mineral P can be explained by the presence of a traditionally strong fertiliser industry.

It should be emphasized that local variations that exist within countries (f.i. France, Italy, Spain) are averaged out in these figures.

Table 7: Input of P as manure and fertiliser and ratio P-manure/P-mineral (2003)

	Phosphorus input (tons of P)		
Member state	**P-manure (tons)**	**P-fertiliser (tons)**	**P-ratio manure/fertiliser**
Cyprus	?	?	?
Luxemburg	1 941	?	?
Malta	672	?	?
Italy	134 727	197 560	0.68
Finland	16 557	22 880	0.72
Spain	206 910	264 440	0.78
Slovenia	8 002	9 108	0.88
Hungary	27 051	29 920	0.90
France	314 661	320 760	0.98
Greece	48 739	47 080	1.04
Czech Republic	28 195	21 604	1.31
Poland	188 221	133 320	1.41
Sweden	23 421	16 280	1.44
UK	190 312	124 520	1.53
Lithuania	16 326	10 500	1.55
Slovakia	12 958	8 228	1.57
Portugal	42 026	25 080	1.68
Germany	246 636	143 880	1.71
Ireland	74 080	42 680	1.74
Austria	39 051	20 680	1.89
Belgium	44 926	19 800	2.27
Latvia*	6 685	2 183	3.06
Netherlands	86 306	22 880	3.77
Estonia*	4 667	1 123	4.16
Denmark	68 303	14 520	4.70

Source: Eurostat, IFA * = 1996 figure for mineral fertiliser use

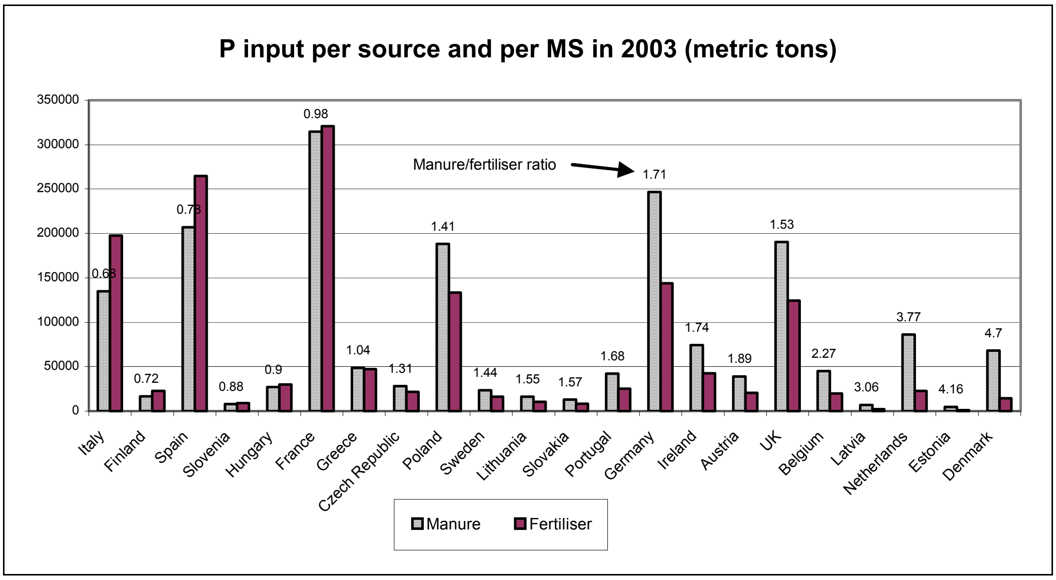


Figure 12: P input per source and per MS (2003)

3.2.4 Other sources of P (sludge, compost, ...)

A number of waste products or secondary products for instance from dredging, waste water treatment, urban composting or industrial processes are being recycled in agriculture. These products contain variable quantities of organic matter and nutrients, and therefore have a potential as soil conditioner or fertiliser.

Compared with animal manure and mineral fertiliser, their contribution to the total P input on agricultural land remains in general low, and their use is usually limited to areas close to the place production because of high transportation and application cost.

While from both ecological and economic points of view, recycling of these products on agricultural land seems to be a logic step (and is in fact favoured by the EU), farmers are not always eager to do so for fear of contaminating the land with unwanted elements but also because the fertilising value of these products is often unpredictable.

3.3 P-management per region and per farming system

European agriculture is extremely diverse, ranging from large, highly intensive and specialised commercial holdings to subsistence farming using mainly traditional practices. The agriculture-holding concept of Eurostat refers to a single farm unit both technically and economically, which has single management and which produces agricultural products. Other supplementary (non-agricultural) products and services may also be provided by the holding. The regional area and structure of agricultural holdings in terms of farming system and sector have significant impacts on nutrient (phosphorus) use and management.

3.3.1 Regional differences

In **Western Europe**, the common agricultural policy (CAP) and several national policies have encouraged farm intensification and specialisation. Supported by public investment, this resulted in mechanisation combined with the abandonment of traditional practices, reliance on non-renewable inputs such as inorganic fertilisers and pesticides, the cultivation of marginal land and improvements in production efficiency. Market pressures and technological development have also contributed to the general trends farm intensification and specialisation which are very strong in some sectors that benefit from little public support (e.g. pigs, poultry, potatoes). Intensified farm management led to discontinuation of traditional fallowing practices and crop rotations resulting in a displacement of leguminous fodder crops with increased use of silage and maize. Specialisation and intensification have resulted in a decrease in the number of farm holdings, the sustained use of chemical inputs, increasing field sizes and higher stocking densities.

During the communist era in **Eastern and Central Europe**, government planning determined agriculture and food production with little regard to suitability of production for the environment. Farm specialisation and investment in animal production were all associated with the push to increase output, and resulted in a greater reliance on non-farm resources. For example the application of fertilisers nearly trebled between 1970 and 1987 (Libert, 1995). Since the nineties, economic restructuring rather than policy, consumer or technological developments, has scaled back many environmental pressures. The decline in fertiliser use is more attributable to reduced market opportunities for agricultural products, the declining profitability of agriculture, reduced state support and the widespread reorganisation of farming in the region. However, inorganic fertiliser consumption is expected to increase as a response to expected new market opportunities and integration with the CAP (EFMA, 2000).

3.3.2 Farming types per major orientation

The major **cropping systems** in Europe can be divided into arable cropping, permanent grassland and permanent cropping.

In 2000, the utilised agricultural area (UAA) of the EU-15 was 127 million ha, representing 40% of the territory. Arable cropping accounted for 57% of the UAA, permanent grassland for 35% and permanent crops for 8%. The UAA for EU-12 decreased by 2.5 % (2,883,520 ha) between 1990 and 2000 according to the Farm Structure Survey (Source: DG-Eurostat). There are large variations in the changes within the UAA across the European Union (Figure 13). The areas of permanent grassland and permanent crops decreased by 4.8% (2,079,700 ha) and 3.8% (389,170 ha), respectively. The area of arable land decreased with 0.7% or 414,650 ha between 1990 and 2000.

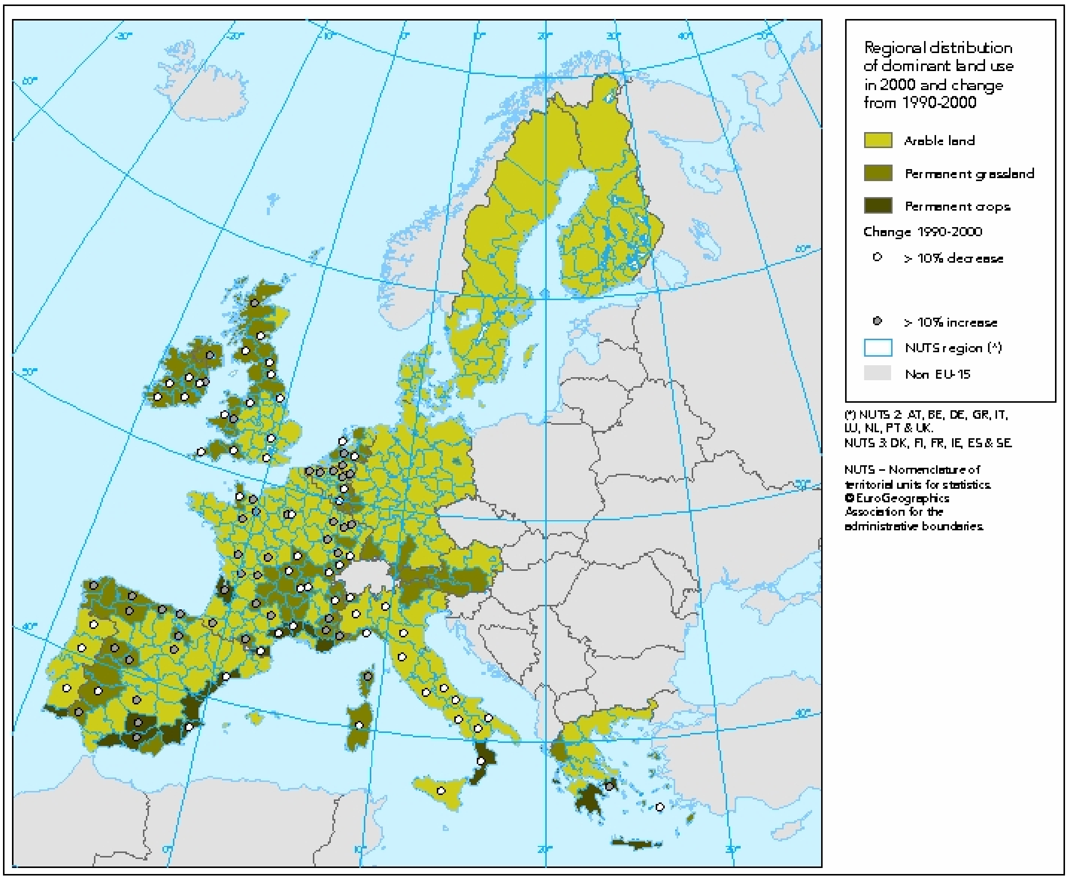


Figure 13: The regional importance of the major agricultural land uses and the trend 1990-2000 (Source: Community Survey on the Structure of Agricultural Holdings (FSS), DG Eurostat and IRENA-EEA, 2005)

For **arable cropping systems** it is important to have insight in the nutrient needs and uptake by the crop. Blanket recommendations or average rates such as those provided in Table 5 are still practised, but are increasingly being replaced by fertiliser recommendations based on careful soil and plant analysis. Nutrient removal by crops varies considerably (Table 8) and ideally nutrient supply has to be carefully adapted to the needs of the plant. Section 3.3.4 provides more information on nutrient balances per farming type.

Table 8: Average nutrient removal of some important crops in kg/t harvest

Crop		**% dry matter**	**Phosphate (P_2O_5)**
Wheat	- Grain	86	8.5
	- Straw	86	3.0
Maize	- Grain	86	8.5
	- Straw	86	6.0
Oilseed Rape	Grain	91	18.0
-	- Straw	86	3.0
Sugar Beet	- Tuber	23	9.5
	- Leaf	16	9.5
Potato	- Tuber	22	1.4
	- Leaf	25	1.5

Source : EFMA (2004)

Permanent grassland systems are very diverse and range from very extensive to highly intensive managed systems in Europe. No or very little external inputs of nutrients are applied on extensive grassland. Intensively managed grassland receives considerable amounts of nutrients. Section 3.3.4 provides more information on nutrient balances per farming type.

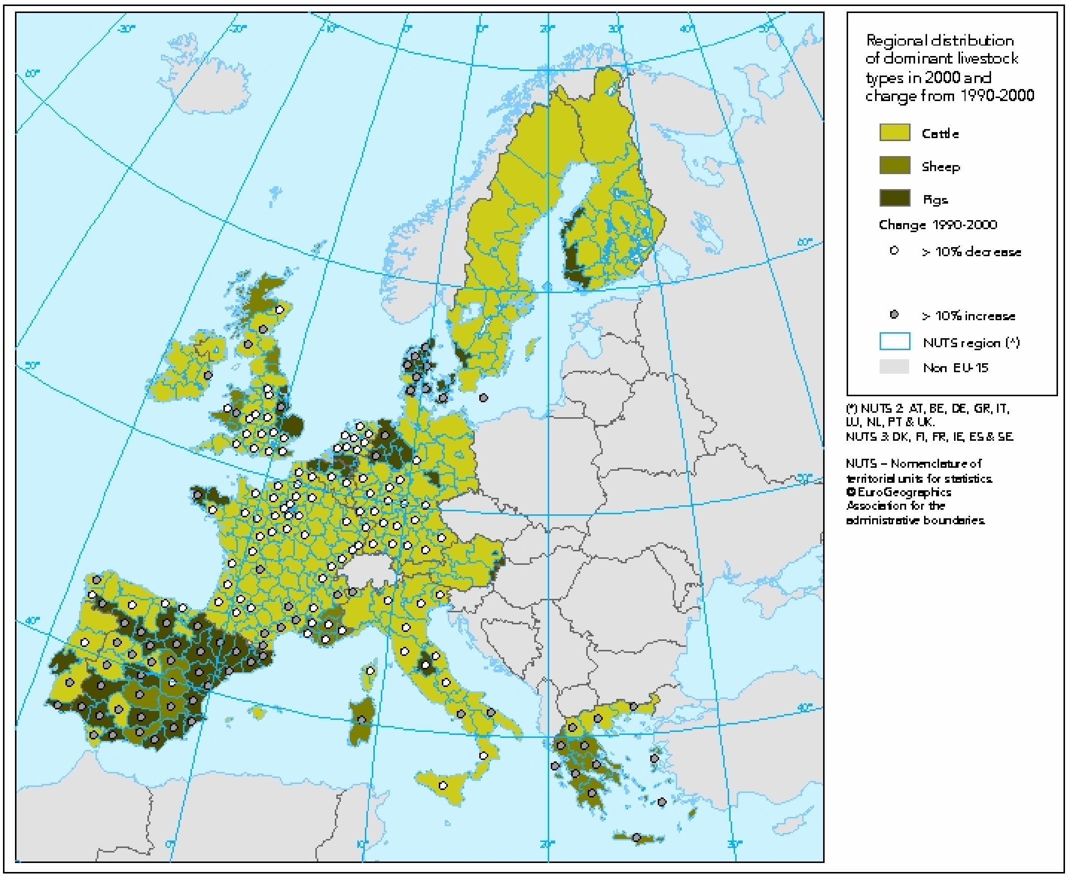


Figure 14: The regional importance of the major livestock types (expressed as LSU/UAA) and the trend 1990-2000 (Source: Community Survey on the Structure of Agricultural Holdings (FSS), DG Eurostat and IRENA-EEA, 2005)

The importance over time of the major agricultural land use and livestock types (i.e. farm types) provides information on the state of farming with consequent influences on the environment. Trends are evident from agricultural land use and livestock data and are indirectly linked to Community environmental policies, such as the Nitrates Directive and agri-environment programmes (IRENA-EEA, 2005). Grazing livestock systems (cattle and sheep on permanent grassland), forage cropping and cereal based farming systems show a decline in area (Figure 15). Among the major agricultural land use types, permanent grassland is generally the most important from an environmental perspective; grasslands are seldom prone to erosion unless they suffer from overgrazing. On the other hand there is an increase in the share of the agricultural land managed by crop/fallow land systems, in the mixed crops systems and in the permanent crop systems. Finally, also the pig and poultry systems show a relatively high increase in area. Generally, these trends can be expected to have a negative influence on environmentally friendly nutrient management. However, local and regional differences should be taken into consideration as should the level of management (see next section).

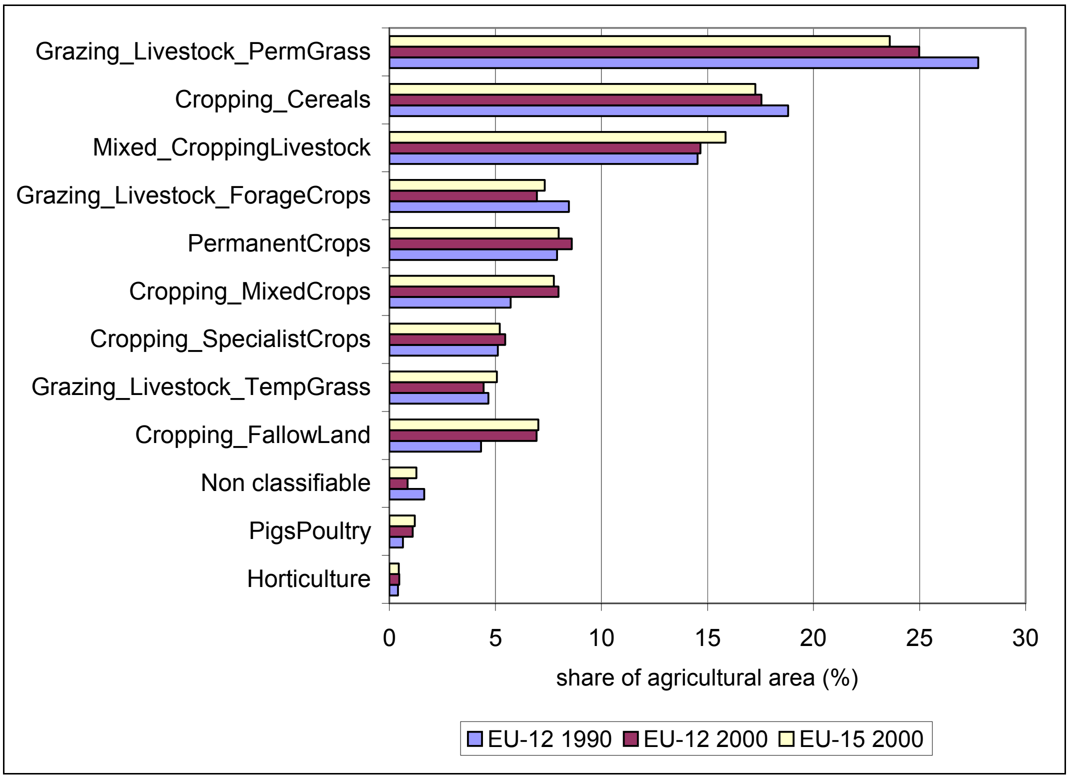


Figure 15: Trends in farm types defined by the IRENA typology 1990-2000. Share of the agricultural area managed by the different types of systems (Source: FADN-CCE-DG Agriculture/A-3, adaptation LEI as reported by IRENA-EEA, 2005)

3.3.3 Farming systems according to management

Many of the current farming types and patterns have developed over centuries. One and the same farming type can, however, have very different impacts on nutrient management depending on local characteristics and management intensity. Cereal crops, for example, are often managed very intensively, for example in the Paris basin or parts of the United Kingdom and Germany. On the other hand, cereal crops are also the key land use in one of the most important low-intensive traditional farming systems of high nature value in Europe, e.g. the cereal steppes in the Iberian Peninsula. Similarly, intensively managed pastures along the North Sea coast are very different in terms of habitat value from extensively grazed permanent grassland in the Scottish uplands or the alpine region. This section therefore describes the differences in management system and their relation to nutrient management.

Changes in agricultural subsidies in Europe and the ready availability of fertilisers have allowed a spatial decoupling of livestock and crop production. This has increased the flow of nutrients that occurs between farms compared to within individual farms. In terms of nutrient cycling, **mixed farming systems** provide the opportunity to reintegrate aspects of agricultural production. The degree of integration between crop and livestock production is defined by the reliance on the use of home-produced feed compared to imported feed, and is independent of intensity. Management of inputs and/or internal flows offers the scope to improve nutrient use efficiency on mixed farms. Greatest uncertainties in calculating nutrient use efficiency are associated with variation in yield and composition of home-produced feed, and consequent manure composition. Three key areas are involved concerning the interchange of nutrients (and risks for losses) between crop and livestock production: (1) the role of livestock diet in manipulating the amount and availability of manure nutrients; (2) the impact of manure management on nutrient losses; and (3) nutrient management through the integration of crops and livestock in rotations. While not all the associated issues are unique to mixed farming systems, the three key areas all influence nutrient use efficiency.

Low-intensive farming and traditional systems account for millions of hectares of land farmed throughout Europe. Typical farming systems are low-intensive arable crops, low-intensive permanent crops, off-farm grazing, permanent grasslands, arable grazing livestock and low-intensive poultry or pig farms. In general, these farming systems are characterised by low stocking densities and high nature value farmland, i.e. farmland with a high proportion of semi-natural vegetation or farmland dominated by low intensity agriculture or a mosaic of semi-natural and cultivated land and small-scale features. Low-intensive farming and traditional systems comprise methods that tend not to damage the environment and contribute to local communities and rural economies. In a study of low-intensive agriculture in nine countries, Bignall and McCracken (1996) calculate that there are some 56 million hectares of farmland in this category, representing some 38% of all utilised agricultural area (Table 9). Other estimates based on land characteristics state that 35 million hectare or ca. 27% of the EU-15 (EEA-UNEP, 2004). Many are under threat from modern farming methods and from rural abandonment.

Table 9: Extent and characteristics of traditional and low-intensive agricultural systems in seven Member States of Europe

MS	mio ha	% of UAA	Examples
FR	7.75	25	wet and dry grasslands (e.g. *garrigue* and *maquis*)
EL	5.6	61	migratory livestock systems (high mountain pastures), olive groves
HU	1.5	22	traditional grasslands, mixed *tanya* holdings
IE	2	31	traditional mixed farms
IT	7.1	14	mountain pastures, traditional olive groves, lowland steppes, hill pastures, coppiced woodland grazing, traditional arable
PL	2.74	60	traditional mixed farming
PT	2.74	35	low-intensive cereal on steppes, montado tree-livestock-cereals, sheep and goat grazing in mountains
ES	25	82	*dehesa* grasslands and open woodland, dryland arable, olive groves, extensive livestock
UK	2	11	upland low-intensive grasslands and moors, grasslands by rivers, marshes and dunes (*Machair* in Scotland)
Total	**56.4**	**38**	

By definition, the use of fertilisers in extensive farming systems, in particular fertilisers of external origin, is low, and so is P-load from manure. On the other hand, extensive farming is often practiced on marginal land types vulnerable to P-surplus either by erosion (mountainous areas) or by leaching (moors), or in the immediate neighbourhood of sensitive ecosystems such as marshlands.

Organic farming is a production system that avoids or largely excludes the use of synthetically compound fertilisers, pesticides, growth regulators, medicinal products and livestock feed additives. Organic farming can be defined as a method of production that places the highest emphasis on environmental protection and, with regard to livestock production, animal welfare considerations (Eurostat, 2005). To the maximum extent feasible organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, and aspects of biological pest control to maintain soil productivity and soil structure, to supply plant nutrients and to control insects, weeds and other pests. The area organically cultivated in the European Union increased at a rate of about 21 % per year between 1998 and 2002; this amounts to 4.9 million hectares in 2002 or 3.8 % of the total Utilised Agricultural Area (Eurostat, 2005). Forage plants as well as pastures and meadows are the main organic crop areas and their share exceeded 50 % of organic land in 2003 in most Member States. Cereal crops are the second most important organic crop with shares between 3% and 31% of the total organic land in each Member State. Figures per Member State can be found in the publication ‘organic farming in Europe’ by Eurostat (2005).

With respect to nutrient management and the related risk to the environment, organic farming does not necessarily offer better guarantees than conventional farming types, as organic manure is not a synonym for balanced and rational fertilisation. Therefore organic farming should not automatically been associated with low risk as far as phosphorus losses are concerned.

Conventional specialist farming remains by far the most important farming system in Europe. As was explained earlier, its development was largely a consequence of the European policy to encourage larger, more efficient and more specialised types of farming. The fertility management on six types of conventional farming are discussed in the following paragraphs: cereal farms, dairy and beef production, intensive livestock, horticulture, vineyards and tree crops, and mixed farms. P-balances per farming type are discussed in section 3.3.4.

- Cereal farming

Soil fertility on specialised cereal farms is most often maintained by mineral fertilisers, in particular when nearby or cheap sources of manure or other organic fertilisers are lacking. Although fertilisers only make up a part of the farming budget, the cost of the mineral fertiliser is a natural barrier to massive overdose. On the other hand, effects of phosphorus overdose on the yields or on the crop quality are unknown, contrary to nitrogen. Except where transportation cost is forbidden or other constraints apply, cereal farms are receptors of excess nutrients from other sectors, in particular intensive livestock holdings. Typical examples are the cereal regions of Northern France that receive mainly dry poultry manure from the Netherlands and Flanders.

- Dairy farming and beef production

Dairy farming requires grassland often complemented by bought feedstuff and fodder crops. This means that cattle farmers usually have an outlet for at least part of the manure produced. In other words, part of the phosphorus can be recycled within the farm. In the more intensive types of dairy farming, additional P may be introduced in the farm balance through the use of mineral P-fertilisers.

- Intensive livestock (not land based)

Intensive livestock holdings of mainly pigs and poultry (but other species as well) often produce meat or eggs entirely on bought feedstuff. In most cases, this type of farming is concentrated in relatively small areas situated near ports, or in zones with relatively low agricultural potential. This means that the possibilities for recycling the manure within the vicinity of the farms are often limited. These units therefore have to rely on third farms to recycle the manure, with or without prior treatment. Especially in this sector efforts are made to reduce the output of nutrients (nitrogen and phosphorus) by acting on the feedstuff.

- Horticulture (greenhouse - open air)

Horticulture, be it in greenhouse or in the open air covers relatively small areas of land, and therefore sometimes escapes from the discussion on nutrient management. Fertiliser use in horticulture is particularly high because of the intensive nature of this sector and the high crop rotation intensity. Areas with a high density of horticultural farms may absorb important quantities of animal manure from zones with intensive livestock activity. Hydroponics systems are a specific type of horticulture whereby crops are grown on inert substrates fed with nutrient solutions. Basically these are closed systems whereby nutrient removal is systematically topped up. However, when such solutions are to be replaced entirely, care should be taken with respect to their disposal.

- Vineyards and tree crops

Vineyards and fruit orchards are permanent cropping systems. Fertilisers (mainly mineral) are applied in limited quantities except in young plantations. However when planted on sloping grounds, care should be taken to avoid loss of nutrients by runoff and erosion.

- Mixed farms

In many cases, conventional European farms are actually a combination of two or more of the above farming types, in varying proportions. Diversification of the activities creates possibilities to spread the natural and economic risk inherent to the agricultural profession, to distribute the available work force more evenly, and to bring about synergies. A typical example of the latter is the creation of intensive poultry farms on cereal farms, incorporating grain produced on farm in the animal feed, or even replacing bought feed entirely by the own cereal production.

Compared with specialised farming types, mixed farming creates new or additional options with respect to improved, environment friendly nutrient management.

Integrated farming systems have emerged in recent years as another more environment-friendly approach to conventional specialist farming. The emphasis is upon integrating technologies to produce site-specific management systems for whole farms, incorporating a higher input of management and information for planning, setting targets and monitoring progress. Integrated Farm Management (IFM) is based on an understanding of the scientific processes in the farming environment, e.g. nutrient flows, factors influencing soil quality, and the application of this knowledge to identify aspects of the farming practice that need attention. A Common Codex for Integrated Farming published by the European Initiative for Sustainable Development in Agriculture (EISA) provides the basis for nutrient management in the IFM system:

1. Farmers select the most effective crop variety and rotation to meet their environmental, agronomic and economic objectives;
2. They are committed to monitoring and auditing as a basis for maintaining or improving economic or environmental performance;
3. They use responsible soil and water management practices to preserve or improve soil condition, and safeguard natural water resources;
4. They approach crop nutrition in a balanced and measured way, taking into account the farm's organic resources;
5. They manage energy efficiently to minimise wastage and limit their dependence on fossil fuels; and,
6. They follow principles of waste management, re-using or recycling waste products and protecting the soil, water and air against pollution.

Strategies developed to satisfy the crop's needs for nutrients (Table 8) in combination with regular soil analysis allows farmers to use nutrients in a responsible and environment-conscious manner and decide on the type and amount of fertiliser to use (provided the nutrient content of the fertiliser is known or analysed). Already a European-wide downward trend can be observed in the use of mineral fertilisers due to improved nutrient management and the assimilation of more organic waste in farmers' nutrient balances.

3.3.4 Nutrient balances per farming type

Nutrient requirement and nutrient management vary widely between farm types. The efficiency of nutrients with which the nutrients, in particular nutrients of external origin, are used also differ considerably from one farm type to the other. Within a same farm type, gradations of intensification can be distinguished. These factors taken together have direct implications on the nutrient balance at farm level.

The following table provides examples of P-balance (calculated according to the farmgate approach) established for various farm types in Europe. The data are ranked by increasing surplus. In general arable farming and low input or organic livestock rearing show the lowest balance surpluses. The highest surpluses are found in horticulture and in dairy farming. The examples of arable farming in the Netherlands and cotton growing in Greece have high surpluses too. The latter can probably be attributed to the high P-binding capacity of the soils.

Table 10: Phosphorus farm gate balances per farming type (ranked by surplus)

MS	Farm type	Balance surplus (kg P/ha)	Comment
Austria	Dairy	1	Organically managed farm
Sweden	Arable	2	Cereal farm
Austria	Dairy	2	Organically managed farm
Belgium (Fl)	Dairy/arable	3.3	Mixed farm
Finland	Arable	4	Average of 4 farms
Sweden	Arable	4	Cereal farm
Sweden	Dairy	4	Mountainous region
Spain	Arable	5	
Germany	Arable	6	Average of 341 farms
Portugal	Livestock	7.5	Extensive (Alentejo region)
Sweden	Dairy	8	
Denmark	Arable	6 ± 5	Average 11 farms
Spain	Dairy	11	
Finland	Dairy	13	Average of 2 farms
France	Dairy	13	Farm in Brittany
Germany	Forage	13	Average of 392 farms
Spain	Pig	14	
France	Pig	14	Farm in Brittany
Netherlands	Arable	18	
Portugal	Dairy	19	Intensive (Entre Douro e Minho)
Netherlands	Dairy	20	
Belgium (Fl)	Dairy	23	
Italy	Dairy	25.7	Average of 28 farms in North Italy
UK	Dairy	26.9	High use of concentrates
Denmark	Dairy	22 ± 5	Average 26 farms
Spain	Horticultural	27	
Ireland	Dairy	32.8	'Typical farm'
Denmark	Pig	23 ± 13	Average 13 farms
Greece	Cotton	40	
Sweden	Pig	41	

Source: Numalec 2001

3.4 Soil-P diagnosis and fertiliser recommendation systems

3.4.1 Soil P analysis methods and their applicability

With respect to soil phosphorus, a distinction is usually made between total phosphorus content and available phosphorus content. An analysis of total phosphorus is not helpful in estimating the rate at which nutrients will become available during the period of crop growth. Therefore analysis of the available phosphorus fraction is considered to be more relevant when used for the purpose of establishing the short-term soil fertility status of the soil.

Routine analysis of phosphorus consists of extracting a fraction of the soil phosphorus by means of a more or less aggressive extractant, ranging from mere water to mixtures of relatively strong acids. The idea behind using acids is to imitate the solvent action of the root excretions of plants. This fraction is then called 'available' phosphorus.

Methods of P extraction were developed simultaneously by scientists in different countries and in various conditions of soils and climate. While various extraction methods co-exist, none is universally applicable, but certain appear to be better suited for particular conditions. For instance in France the DYER method is considered to be unsuitable on soils that were fertilised with natural phosphates, and the JORET-HEBERT method is equally influenced by these fertilisers, be it to a lesser degree (Castillon et al, 1991). The OLSEN method is considered by the same authors to be unsuitable in soils with a low pH (pHwater < 6).

Table 11on the following page provides a non-exhaustive overview of extraction methods used in various countries (member states and others) to measure plant available phosphorus in soil. Many methods are derivates or local adaptations of a few basic models. Extraction in ammonium-lactate (AL method) or in sodium acetate (Olsen method) is widely practiced in Europe, but other types of extracting agents are used too. Water extraction is commonly practised in the Netherlands (the Pw system). The Bray and Kurtz method, popular in the United States and elsewhere is less common in Europe.

In some countries, two or more method co-exist and are being applied in specific conditions of soil and/or climate. However they may as well reflect the diverging paths of thinking concerning plant nutrition followed by various institutions or schools.

Table 11: Overview of soil P extraction methods

Country	P test	Method (soil:solution ratio)	Reference
Austria	CAL	1:20 (w/v) 0.05 M calcium lactate + 0.05 M calcium acetate + 0.3 M acetic acid, pH 4.1, 2 h shaking	Schüller, 1969
	DL	1:50 (w/v), 0.02 m calcium lactate + 0.02 M hydrochloric acid, pH 3.7, 1 h shaking	Egnér and Riehm, 1955
	Water	1:20 (w/v) extraction with water	1
Belgium	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
	EDTA-Ac	1:5 (w/v), 0.5 N ammonium acetate + 0.002 M EDTA, pH 4.65, 0.5 h shaking	Cottenie et al., 1979 Lakanen-Erviö, 1975
Czech Republic	*Olsen*	*1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking*	*Olsen-Cole-Watanabe-Dean, 1954*
	Mehlich III	-	*Mehlich, 1984*
Denmark	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954
Finland	Morgan	6.5:30 (v/v), sodium acetate, pH 4.8. 0.5 h shaking	Morgan, 1994
France	*Joret/Hébert*	*0.2 ammonium oxalate, 1.25, 2 h shaking*	
	Olsen	*1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking*	*Olsen et al, 1954*
	Dyer	*1:10, 1% citric acid, 2h + 24 h + 1h shaking*	-
Germany	CAL	1:20 (w/v) 0.05 M calcium lactate + 0.05 M calcium acetate + 0.3 M acetic acid, pH 4.1, 2 h sh.	Schüller, 1969
	DL	1:50 (w/v), 0.02 m calcium lactate + 0.02 M hydrochloric acid, pH 3.7, 1 h shaking	Egnér and Riehm, 1955
Greece	Bray-1	1:7 (w/v) 0.03 M ammonium fluoride + 0.0125 M HCl, 1 min shaking	Bray & Kurtz, 1945
	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954
Hungary	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
	Lak.-Erv.	*Ammonium lactate*	*SZ-20135:1999.02*
Ireland	Morgan	6.5:30 (v/v), acidified sodium acetate, pH 4.8., 0.5 h shaking	Morgan, 1994
Italy	Bray-1	1:7 (w/v) 0.03 M ammonium fluoride + 0.0125 M HCl, 1 min shaking	Bray & Kurtz, 1945
	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954

Latvia	-	*Determination of total phosphorus*	*LVS 398:2002*
Malta	*Olsen*		*ISO11263:1994*
Netherlands	Water	C, 22 h□1:60 (v/v) with water at 20 incubation, 1 h shaking	Sissingh, 1971
	Water	1:2 (v/v) water, 20 minutes shaking	Sonneveld et al., 1990
	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
	CaCl2	1:10 (w/v) with 0.01 M calcium chloride, 2 h shaking	Houba et al, 1994
Norway	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
	DL	1:50 (w/v), 0.02 m calcium lactate + 0.02 M hydrochloric acid, pH 3.7, 1 h shaking	Egnér and Riehm, 1955
Poland	CaCl2	1:10 (w/v) with 0.01 M calcium chloride, 2 h shaking	Houba et al, 1994
	DL	1:50 (w/v), 0.02 m calcium lactate + 0.02 M hydrochloric acid, pH 3.7, 1 h shaking	Egnér and Riehm, 1955
	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954
Romania	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
	MoCa	ammoniummolybdate in calcium chloride, pH 4.3	
Slovakia	*Mehlich III*		
Spain	Bray-1	1:7 (w/v) 0.03 M ammonium fluoride + 0.0125 M HCl, 1 min shaking	Bray & Kurtz, 1945
	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954
Sweden	AL	1:20 (w/v) with 0.1 M ammonium lactate + 0.2 M acetic acid, pH 3.75, 2 h shaking	Egnér et al., 1960
Switzerland	AmAc	ammonium acetate	
	Water	1:10 (w/v) with CO2-enriched water	
	Water		
United Kingdom	Olsen	1 : 20 (w/v), 0.5 M sodium acetate, pH 8.5, 1 h shaking	Olsen et al, 1954
	Anion-exchange		

Source: COST action 832, completed with data based on the questionnaire (italic)

3.4.2 Comparability of extraction methods

A measure for the quality of an extraction method is its correlation with the actual nutrient uptake by the crop. This correlation will vary in function of the crop, soil type and climate. For instance in an experiment by Verloo and Liekens of the University of Ghent, a very good correlation (0.93) was found between P-uptake by barley on the one hand and extraction by ammonium lactate (AL method Egner Riehm) or by ammonium oxalate (Joret/Hébert method) on the other hand, while other methods such as extraction by ammonium oxalate + EDTA or citric acid appeared to be much less efficient especially in calcareous soils (0.83 to 0.63).

The correlation between the methods varies widely in function of soil type. In a pluriannual experiment by the World Phosphate Institute (Johnston et al. 2001), six of the commonly used extraction methods were compared on 445 samples from ploughlayers, 202 samples of subsurface layers and 191 samples from deep horizons. The following tables provide the correlation found between the methods in the three cases. While the correlation is relatively high for topsoils, it is weak to absent in the deepest horizons. This can be explained by the higher variability between soil horizons with increasing depth, as by the lower concentrations of phosphorus found.

Table 12: Correlation matrix for P-analysis of plough-layers

	P-Olsen	**P-EDTA**	**P-CAL**	**P$CaCl_2$**	**P-H_2O**	**P-w**
P-Olsen	1.000					
P-EDTA	0.868	1.000				
P-CAL	0.838	8.842	1.000			
P-$CaCl_2$	0.556	0.582	0.534	1.000		
P-H_2O	0.633	0.693	0.565	0.759	1.000	
P-w	0.863	0.897	0.801	0.763	0.825	1.000

Source: Johnston et al. 2001

Table 13: Correlation matrix for P-analysis of subsurface soils

	P-Olsen	**P-EDTA**	**P-CAL**	**P$CaCl_2$**	**P-H_2O**	**P-w**
P-Olsen	1.000					
P-EDTA	0.667	1.000				
P-CAL	0.688	0.647	1.000			
P-$CaCl_2$	0.446	0.419	0.782	1.000		
P-H_2O	0.488	0.426	0.766	0.831	1.000	
P-w	0.740	0.752	0.715	0.663	0.695	1.000

Source: Johnston et al. 2001

Table 14: Correlation matrix for P-analysis of C-horizons

	P-Olsen	P-EDTA	P-CAL	$PCaCl_2$	$P\text{-}H_2O$	P-w
P-Olsen	1.000					
P-EDTA	-0.074	1.000				
P-CAL	0.750	0.150	1.000			
$P\text{-}CaCl_2$	0.075	-0.030	-0.051	1.000		
$P\text{-}H_2O$	0.636	-0.402	0.470	0.027	1.000	
P-w	0.768	-0.121	0.666	-0.016	0.692	1.000

Source: Johnston et al. 2001

At present, it is obvious that not much harmonization has taken place as yet, although methods have been compared extensively, for instance in the framework of the COST action 832. Anyway when used for the purpose of formulating fertiliser recommendations, many authors (f.i. Baeyens, 1967) agree that harmonization in this matter is certainly not an absolute necessity, as the quality of the P-extraction method is to be measured by the outcome of the fertiliser advice and not by the analysis itself.

As a consequence, while they are differences between methods, no single method can be pointed out as being the better one, as all methods have been conceived to serve within a specific range of conditions and should judged on their merits. In addition, they should never be considered separately from the advice system of which they form a part.

3.4.3 P-fertiliser advisory systems

In nearly all the EU member states, fertiliser recommendations are available from state institutes, farmer’s organizations or private laboratories. However, large differences exist with respect to actual the frequency of soil analysis for recommendation purposes. Especially in some of the new member states of Central and Eastern Europe, where the formerly centrally organized soil laboratories and extension services have all but ceased to function, soil testing is no longer a common practice especially on the smaller farms, nor is it seen as a first priority by farmers always short of investment funds.

Most fertiliser advice methods have become accepted by trial and error in that they have been found to satisfactorily categorize soils and soil P-status according to the responsiveness of crops to applied fertiliser and/or manure. In the process of estimating plant available phosphorus, extraction is an important step in the process of formulating fertiliser recommendations. However even more important are the expert systems (algorithms) used to translate actual figures on available phosphorus into crop and soil specific recommendations. These are normally established on the basis of extensive field trials, and are therefore specific for a given crop, soil and agroclimatic condition.

Each country has its own fertiliser advisory system (or systems), having however in common that soils are sampled and analysed according to standardised methods.

The soil P-content figures are then appreciated by comparing it with a reference value or reference zone, on the basis whereof a certain quantity of phosphorus is recommended.

The recommended rate has a double aim: build up of the available P reserves of the soil to the desired level and replacing the nutrients removed from the soil by the crops or by the grazing animals. Sometimes (f.i. Ireland) the rate is split up in two parts: one to build up reserves, the second to compensate the expected uptake.

As examples of advisory systems, the following tables give the assessment (sometimes called soil index) of the P-status of arable land as used in the official Dutch advisory system (water extraction) and of grassland as developed by the Teagasc institute in Ireland (Morgan extraction).

Similar tables are being used in other countries too. They differ by the number of classes and can be soil or land use specific (arable land, grassland.

When comparing methods, due attention should also be paid to the units used. Soil phosphorus status can be expressed in mg P or P_2O_5, per 100 g, per kg or per litre soil, while fertiliser recommendations are usually given in P_2O_5/ha.

Table 15: Assessment of the P-status of arable soils in the Dutch system

Assessment	**P range (mg P_2O_5/100 g soil)**
Very low	< 11
Low	11 - 20
Sufficient	21 - 30
Largely sufficient	31 - 45
Rather high	46 - 60
High	> 60

Source: van Dijk 1999

Table 16: Assessment of the soil P-status of grazing areas in the Teagasc system

Soil index	**Phosphorus range (mg P/l)**	
	Peat soils	**Mineral soils**
1	0 - 10	0.0 - 3.0
2	11 - 20	3.1 - 6.0
3	21 - 30	6.1 - 10
4	> 30	> 10

Source: TEAGASC 1998

The actual P-fertiliser advice will also differ from country to country and even within countries, as the systems are based on local fieldwork.

As an example of a P-advisory system, the following table provide the P-recommendation for 4 types of crops (according to P-requirements) on two groups of soils in function of the measured P-status of the soil, as used in the official Dutch advisory system.

Table 17: Advised P-rates per crop in kg P2O5/ha in function of soil type and soil P analysis in the Dutch advisory system (source van Dijk, 1999)

Pw	Sand, valleybottoms, river clay, loess				Marine clay, marine sand			
	1	2	3	4	1	2	3	4
10	185	160	130	100	185	150	110	60
15	170	145	110	80	170	130	90	40
20	150	125	95	60	150	115	65	20
25	135	110	75	40	135	95	45	0
30	120	90	55	20	120	75	20	0
35	105	75	40	0	105	55	0	0
40	85	55	20	0	85	40	0	0
45	70	40	0	0	70	0	0	0
50	55	20	0	0	55	0	0	0
55	35	0	0	0	35	0	0	0
60	20	0	0	0	20	0	0	0
65	0	0	0	0	0	0	0	0

Pw: P number in mg P2O5 per 100 g soil obtained by water extraction
1: High P requirement: potatoes, maize, onions, sprouts, spinach, peas, beans, ...
2: Medium P-requirement: sugarbeets, fodder beets, flax, ...
3: Normal P requirement: bulbs, clover, barley, ..
4: Low P requirement: other cereals, grass seed, rapeseed, other crops

From the previous table it appears that at high soil-P levels, zero P recommendations can be issued. While such recommendations are likely to be followed by arable farmers using mineral fertilisers, this will be less the case for farmers having stocks of manure, where dosage will be based on other criteria (nitrogen), without taking into account the unnecessary gifts of phosphorus.

In the TEAGASC system, the nutrient advice for grazing areas is formulated following a three step approach:

1. Decide on the target index. This is normally Index 3, but in certain conditions Index 2 is desirable.

2. Determine the P required for the buildup to the selected target index (Table 18)

3. Add to that the P maintenance requirement (Table 19) to replace P removed by the animal production system

Table 18: P required for buildup in the TEAGASC system for grassland

Soil P index	**P required for buildup to Index 3**
1	20 kg P/ha
2	10 kg P/ha
3	0 kg P/ha
4	None

Table 19: P maintenance requirement in grassland in function of stocking rate in the TEAGASC advisory system

	Stocking rate LU/ha			
System	**1.0 - 1.5**	**1.6 - 2.0**	**2.1 - 2.5**	**>2.5**
Dairying	6 kg P/ha	9 kg P/ha	13 kg P/ha	16 kg P/ha
Dry stock	3 kg P/ha	5 kg P/ha	7 kg P/ha	9 kg P/ha
***Rule of thumb**: To estimate P maintenance requirement, multiply the stocking rate (in LU/ha) by 5 for dairy or 3 for dry stock. Alternatively, allow 1 kg P per 100 l of milk and per 100 kg of Live weight gain (LWG).*				

Contrary to the Dutch advise systems, no allowance is made for any zero P fertilisation, as expected uptake is always to be compensated for by new fertiliser applications.

3.4.4 Fertiliser advice for manure application

When manure is used to supply part or all of the required phosphorus, special precautions have to be taken. Not only has the nutrient content of the manure to taken into account but also the effectiveness (the relative effect as compared with mineral fertiliser) of the nutrients supplied. The short-term effectiveness of manure will vary in function or the type of manure, timing and method of application. On the long term, the difference with mineral fertiliser becomes smaller

Contrary to mineral fertilisers, the nutrient content of manure varies significantly, depending on many factors such as the animal species, diet, growth and age, as well as rearing methods.

As an example the following graphs illustrated the variation of the P-content of cattle manure in absolute figures and in relation to the dry matter content measured on 717 manure samples analysed by the Soil Service of Belgium between 2002 and 2004. A large variation means that the use of standard figures for nutrient content of manure for the purpose of fertilisation planning may lead to major errors.

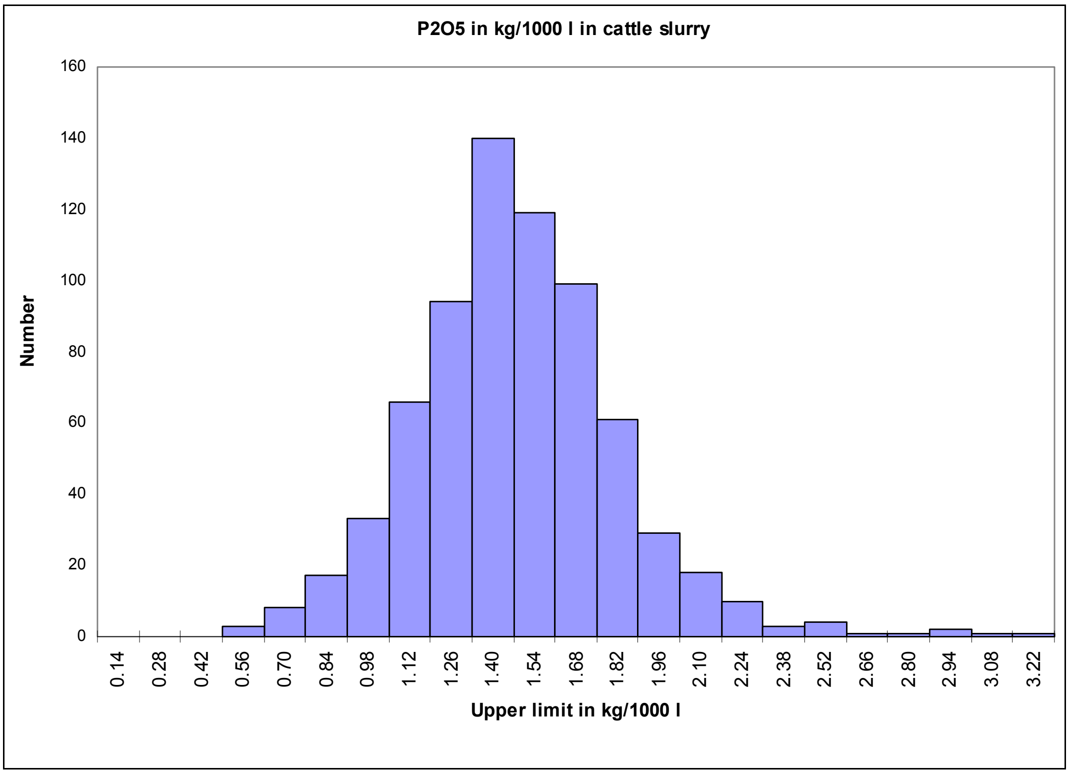


Figure 16: Phosphorus content of cattle manure (source SSB)

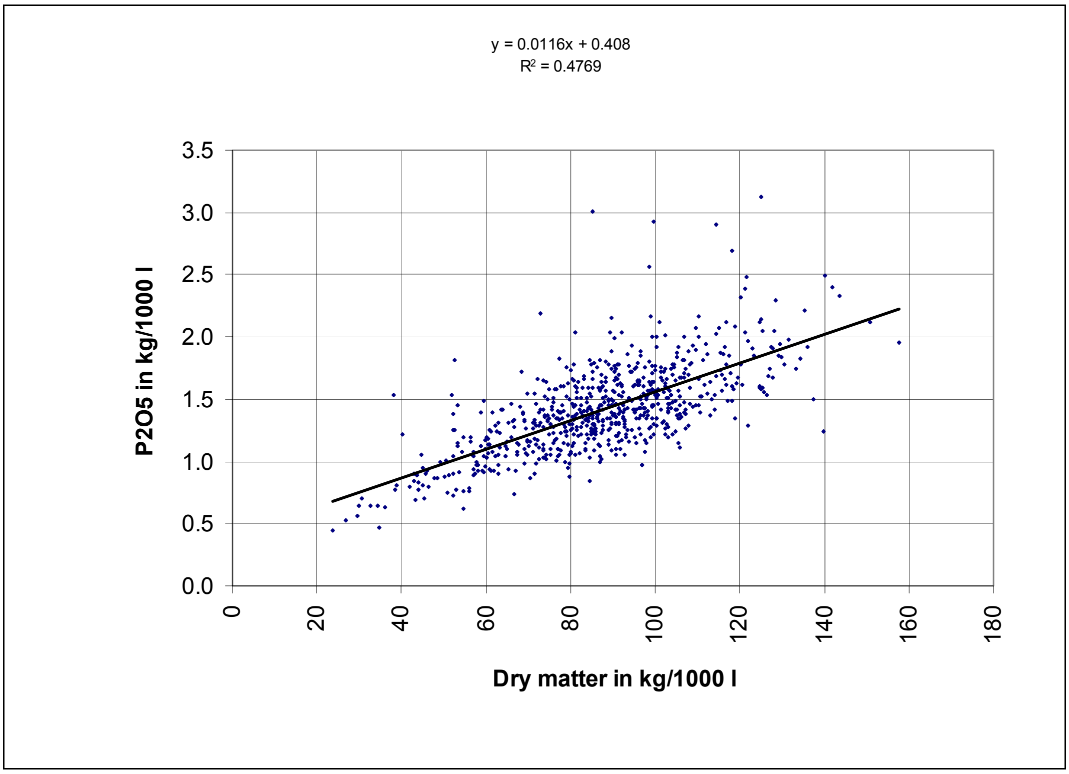


Figure 17: Phosphorus content of cattle manure in relation to dry matter (source SSB)

These examples show that using standard coefficients for the nutrient content of manure (averages), as is common practice in many countries, may lead to erroneous applications rates. That is one of the reasons why systematic analysis of animal manure is being practiced more and more.

In the official Dutch advisory system, the short-term effectiveness of phosphorus in manure, as compared with mineral fertiliser, is set at 60% for cattle manure, 100% for pig slurry and 70% for poultry manure. For compost the effectiveness is estimated between 60 and 80 %. For sludge from water treatment plants, the range is even higher: between 40% and 100 %. With respect to long term effects, organic fertilisers are put on equal foot with mineral fertilisers.

Regarding the short term effect of animal manures, the Soil Service of Belgium applies the following working coefficients for phosphorus. The effectiveness is expressed as a percentage of the effect of Triple Super Phosphate (TSP). On the long term, all types of manure are assumed to have 100 % effectiveness. Contrary to more volatile or more mobile nutrients such as nitrogen and potassium, the timing or method of application do not play a significant role in the effectiveness of phosphorus from animal manure.

Table 20: Working coefficients for P in animal manure in the SSB advisory system

Type of manure	Working coefficient
Cattle slurry	70 %
Pig slurry	90 %
Poultry manure	70 %
Solid pig manure	60 %
Solid cattle manure	60 %

3.4.5 *Overview of advisory systems per member state*

In the framework of this study, the member states were interrogated through a questionnaire on the availability of fertiliser advice systems. Replies were received from the Czech Republic, Latvia, Sweden, Hungary, Slovakia, Poland, Austria, Belgium (Flanders), Denmark, Spain, the Netherlands, Malta, Belgium (Walloon region) and Ireland.

Austria

Fertilizer advice ("Guidelines for appropriate fertilisation", "Richtlinien für die sachgerechte Düngung", Bundesministerium für Land- und Forstwirtschaft, 1999) has been worked out by the advisory forum for soil fertility and soil protection (office: Austrian Agency for Health and Food Safety) at the Ministry for agriculture, forestry, environment and water management. The recommendations are based on soil analyses (mainly PCAL, see page 4), soil and site information as well as P supply from manure and crop residues are taken into consideration, too.

Belgium

In the Flanders region of Belgium fertiliser recommendations are provided by the independent institute Soil Service of Belgium (SSB), and to a lesser extent by other private or public laboratories. P-advice by the SSB is based on soil analysis using AL-extraction. Soils are analysed in principle every three years. Around 50.000 P-recommendations are issued every year. Manure analysis is on the increase, with several thousands of samples analysed every year.

In the Walloon region of Belgium, fertiliser recommendations are also provided by the Soil Service of Belgium but mainly by a number of provincial laboratories. These are members of the Requasud network, an organism funded by the Region to harmonize methods and to carry out quality control. Around 20 000 recommendation are issued per year. Analysis of manure is available, but not widely practiced.

Czech republic

Previously the fertilization advice provided mostly the state extension service of advisers with use of the data obtained in the Agrochemical soil survey (made every spring, determination of pH/KCl; CO3"; plant-available nutrients (P, K, Mg, Ca); CEC-value.

Presently there are mostly private advisers who provide the recommendations generally on the base of the soil analyses, leaf analyses and compensation of expected uptake of nutrients by plants.

On the base of the plant-available P content determined in the frame of the yearly made Agrochemical soil survey, the evaluation and recommendation for the fertilization has been made for the individual categories. Phosphorus is analysed according to the Mehlich III method

Table 21: Assessment of the soil P-status in the Czech Republic

P-content in mg $P.kg^{-1}$	Assessment	Evaluation of the necessity of fertilization
< 50	Low	Distinct necessity for finishing of the saturation process with Phosphorus
51 - 80	Sufficient	Need of moderate saturation with Phosphorus
81 - 115	Good	Favourable content; for its maintenance only substitutive fertilization is to be used
116 - 185	High	Fertilization with phosphorus is to be omitted until the category "good" is reached
> 186	Very high	The increasing of the phosphorus content is improper from the ecological point of view; the fertilization would be superfluous and non permissible

Denmark

The farmer`s extension service (Danish Agricultural Advisory Service) provides advice. Mostly advice is based on soil analysis and expected uptake of individual crops. It is important to underline that most advice is given independent of commercial firms. Units of the extension service are located in local areas all over the country.

Hungary

Fertiliser advice is generally based on soil analysis and leaf analysis. The calculations are based on the compensation of nutrient loss by the expected uptake by the crop according to the expected yield.

Experts who are registered in the inventory of the Ministry of Agriculture and Rural development can give fertilizer advice. The persons have to have certain degree (agricultural engineer with specialization in nutrient management or demonstration of expertise in fertilizer advice).

Fertilizer advice can be provided by private persons and companies specialized for soil conservation and fertilizer advice research institutes and the Hungarian Plant Protection and Soil Conservation Service . Nowadays the fertiliser factories have experts and give fertilizer advices for the customers.

Ireland

Teagasc (the Agriculture and Food Development Authority) provides advice to farmers on fertiliser use. This advice depends on the quantity of a particular element in the soil that is available to the crop. Apart from nitrogen this is determined by soil analysis.

Latvia

No comments provided on this item

Malta

The Ministry for Rural Affairs and the Environment’s Nutrient Management Unit provides technical assistance and advice on fertiliser programmes and planning to farmers. Fertiliser advice is based on the compensation for the expected uptake, at times complemented with soil analysis data.

Although there are regional agricultural extension services offices, these do not provide fertiliser advice; farmers are referred to the centralised Nutrient Management Unit.

Netherlands

Committees are responsible for the establishment and follow-up of the fertiliser recommendations (including P): (1) arable crops and field vegetable crops, (2) grassland and fodder crops, (3) flower bulbs, (4) nursery crops, and (5, at present not active) fruit trees.

These committees are financed by the farmers' organisations, and include representatives of stakeholders (research, extension/advisory, industry and farmers). P recommendations are based on soil analysis and aim at an optimal P status of the soil and compensation for expected P uptake in the harvested products.

The fertiliser recommendations published by the committees are the standards in The Netherlands and are used by many organisations and industries providing advice to the farmers, like the Laboratory for Soil and Crop Testing (BLGG) at Oosterbeek, DLV Adviesgroep NV (privatised farm extension organisation), Nutrient Management Institute (linked with the fertiliser industries), and many smaller specialised organisations and independent advisers. The most important organisation for P recommendations is BLGG that provides the recommendations together with the results of soil analyses. It is common practice for many farmers to have their soils analysed every 4 years, as recommended.

Poland

Fertiliser advise is based on P-balance, soil analysis and compensation for expected uptake.

Regional Agriculture Extension Service as well as agrochemical stations are obliged to provide fertiliser recommendations for farmers willing. Nutrients balance calculation and fertilization planning is obligatory for farmers with very intensive animal production, for farms located in vulnerable zone and for farmers, who accomplish agro-environmental programmes co-founded by EU.

Slovak Republic

Advisory bodies (state or private) can give recommendations based on crop demand for expected uptake corrected by available soil P level and P applied in animal/organic manure. Usually farmers use NPK combined fertilizers to partly cover P inputs without assistance of advisors.

Laboratories of the Central Control and Testing Institute of Agriculture (Bratislava, Zvolen, Košice) and research institutes (Research Institute of Plant Production Piešťany, Soil Science and Conservation Research Institute Bratislava) provide recommendations on request. Their capacities are in the last period used minimally.

Results of regular agrochemical soil testing are indicating the degree of P-status by categories (low, suitable, good, high, very high). Average results prom previous control cycle 1995-199 are published (Kotvas,F., Koutný,B., Kobora,M.: Results of agrochemical soil testing in Slovakia in period 1995-1999 (Xth cycle). CCTIA, Bratislava, 2000, 100 p.).

Spain

Fertiliser advice is provided by the fertiliser companies, professional organisations and services of the Autonomous Communities. These organizations usually have their own laboratories that base their recommendations on soil and/or leaf analysis. The Catalunya region gives advice on the use of organic wastes as fertilisers taking into account the P-content of the soil.

The national agricultural extension services have disappeared since their function has been taken over by the services of the Autonomous Communities.

Sweden

Swedish Agricultural Board provides fertiliser recommendations based on the compensation for expected uptake. The Rural Economy and Agricultural Societies and some others organisations have their own extension services providing fertilizer advice.

NPK balances are being calculated at farm level by advisors using the STANK programme.

The campaign 'Focus on Nutrients' in the south part of Sweden (www greppa nu) provides education to farmers and educate advisers. The campaign will become launched also in the Central Sweden. To some extent these services is also provided in other parts of Sweden by activities financed to by the environmental and rural development program.

3.4.6 Need for a harmonised advice system ?

With respect to the role of soil analysis and fertiliser advice the following points should further be emphasized:

- Most if not all existing advisory systems for phosphorus fertilisations are aiming at an agronomic advice designed to achieve optimum (technical or economic optimum) yield of crops or grass, with efficient use of fertilisers and organic manure. Although this implies that potential losses of P to the environment are reduced in a certain way, this is not the prime objective of the existing systems. As will be seen later on in chapter 9.3.1, the current approach of P-advice may not always be compatible with environmental objectives.

- Measuring plant available P is only one step in the process to reach the ultimate goal of formulating P-fertiliser advices. If methods of chemical analysis are relatively easy to standardize, this is not the case for the complete chain from analysis to recommendation. Indeed, field trials on the relation between available P and actual fertiliser need have to be carried out in the local conditions of soils, climate and technological level, and form the base of any good expert system. The chain is only as strong as its weakest link. The best analysis from the sheer chemical point of view not complemented by a good method of formulating recommendations is worthless from the farmer's or even from the environmentalist's point of view. Therefore, analysis methods should not be judged in terms of better of less good than others, but rather in terms of more appropriate or less appropriate for certain conditions.

- Contrary to for instance total analysis of waste products or water, there seems not much point in imposing legal standard methods of soil analysis carried out for fertiliser recommendation purposes. Indeed the analysis result should never be seen separately from the following steps of the recommendation process. Considering the relatively strong correlation between extraction methods (with the exception of a few uncommon methods), the algorithms to convert analysis results into fertiliser advice (so called expert systems) may be more important than the sheer method of analysis. These need to be backed by extensive crop- and soil specific fieldwork. Ultimately it is the accuracy of the fertiliser advice that matters, not the methods to achieve it. This accuracy can only be measured on the field.

4. Assessment of the P-pressure through P-balances

4.1 Models for balance calculations

Plant nutrients are present in the soil, enter the crop production cycle as fertilisers or manure, and leave the cycle as harvested crops or as animal products. Nutrients can be stored temporarily in the soil, or can be leached to the groundwater or be lost by erosion.

When considering the land, a farm or an entire region as a system characterised by an inflow and outflow of nutrients, balances can be established with relative ease, providing input ant output of the particular nutrient are known. The surplus in the balance for this nutrient is a measure of the potential loss of this particular nutrient to the environment, or, in the case of a deficit, for the degree of 'nutrient mining'.

Simple as the balance approach looks, the correct interpretation of the results is not always easy, as various phenomena such as irreversible fixation by soil particles, or natural weathering of soil minerals may interfere. Balance results should therefore always be interpreted with caution. In no case should they be taken as net losses of a nutrient to the environment.

In recent years, various models have been developed and applied for different purposes and at different scales, from very simple 'black box' surface balance to the more elaborate 'farmgate' balance. Examples of both models are given in the following paragraphs.

Another important topic is the scale at which the balance is calculated. The larger the geographical unit chosen, the more local peaks and lows will be concealed and averaged out.

In the framework of the current study, a model was selected mainly on the basis of the following criteria:

- Availability of data at a sufficiently low level of aggregation
- Transparency
- Ease and speed of calculation
- Relevance of the balance result as measure of the P-pressure in a given study area

4.1.1 Farm gate balance method

In the farm gate balance method, all plant nutrients entering and leaving the study object within a period of time are measured and entered on respectively the input and on the output sides of the balance sheet. The difference between input and output is a measure for the nutrient losses.

The study object itself, presented by the dotted box in the following diagram, can be the agricultural system of a single farm, but also of a larger geographical unit such as a region or a country, and can be treated as a black box. This means that transfers within the study object need not to be further specified. Establishing the nutrient flows within the agricultural system however will provide complementary information on the type of losses occurred, and gives the possibility to check the results for consistency.

The main advantage of the model is that it can give valuable indication on how to influence the balance.

The major inconvenience of this model is the need for large amounts of information, which will rarely be available at the required level of aggregation or for a wide range of conditions.

Nutrient flows in an example of a farm gate model are presented in the following diagram.

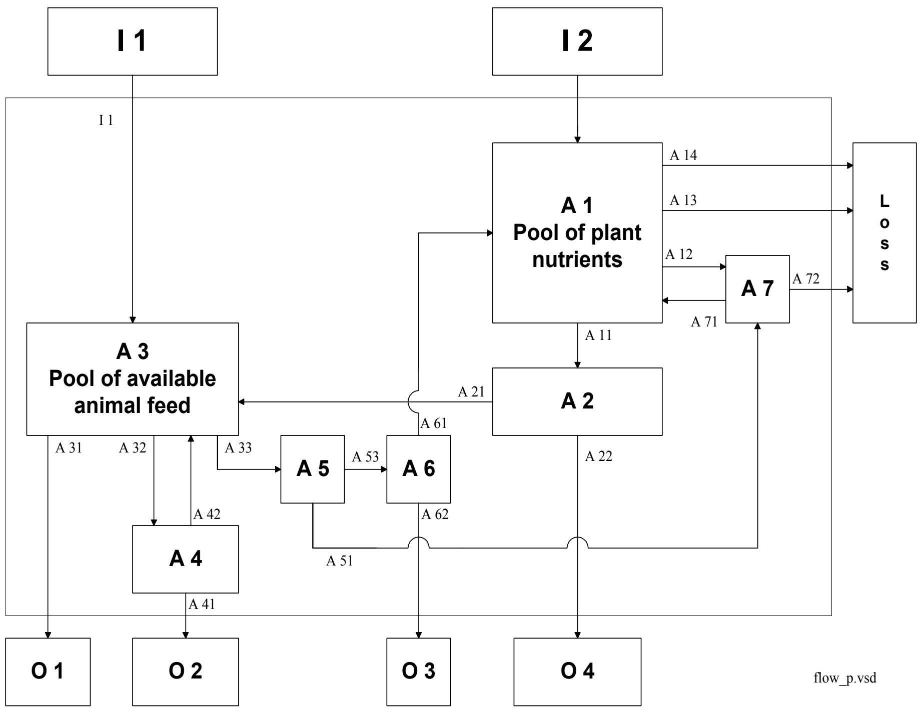


Figure 18: Flow of phosphorus in the farmgate balance method.

Input factors (I)

I_1: External supply to the pool of available animal feed

- *I_{11}: Imported concentrates*
- *I12: Imported mixed feed*
- *I13: Addition of inorganic phosphates to mixed feeds*
- *I14: Waste products from agro-industries used as cattle feed*
- *I15: Imported roughage*
- *I16: Imported livestock*

I_2: External supply of minerals to agricultural land

- *I21: Mineral fertilisers*
- *I22: Biological nitrogen fixation*
- *I23: Deposition*
- *I24: Recycling of organic products*
- *I25: Seeds and planting materials*
- *I26: Imported manure*
- *I27: Irrigation*
- *I28: Others*

Output factors (O)

O_1: Withdrawal as cattle feed or pet food

- *O11: Exported or re-exported concentrates*
- *O12: Exported or re-exported mixed feeds*
- *O13: Exported roughage*
- *O14: Feed for non-farm animals and petfood*

O_2: Withdrawal in animal products

- *O21: Slaughtered animals*
- *O22: Milk*
- *O23: Eggs*
- *O24: Wool*
- *O25 Export of live animals*
- *O26 Others*

O_3: Withdrawal by export and/or destruction of animal manure

O_4: Withdrawal by crops other than forage crops

Movement of nutrients within the system (A)

A_1 Pool of available plant nutrients

A_2: Net removal of nutrients by agricultural crops

- *A21: Regroups all the nutrients removed by crops intended for use as animal feed (forage crops), including uptake during grazing, locally produced concentrates and roughage. Silage maize, hay, alfalfa, all fall within this category.*
- *A22 Net removal of nutrients by crops, others than those intended for cattle feed.*

A3: Pool of available cattle feed

A4: Withdrawal in live animal products

A5: Excretions

A6: Available manure and sludge

A7: Losses to the soil and to the groundwater

4.1.2 *Surface balance method*

The surface balance method reflects the actual application and withdrawal of minerals on the field. As the livestock production is left out of the system, this method requires less information than the previous one. Often its use at different levels of aggregation is also easier.

In theory, both methods should provide similar results, when used at a regional or supra-regional level. The surface balance approach however only considers losses from the agricultural land, and does not take into account all the losses occurring during animal production (f.i. ammonia volatilization from stables or during storage of manure, leaching from sludge tanks, ...). Therefore, the surface balance method may be less suitable when comparing between regions with widely different agricultural systems.

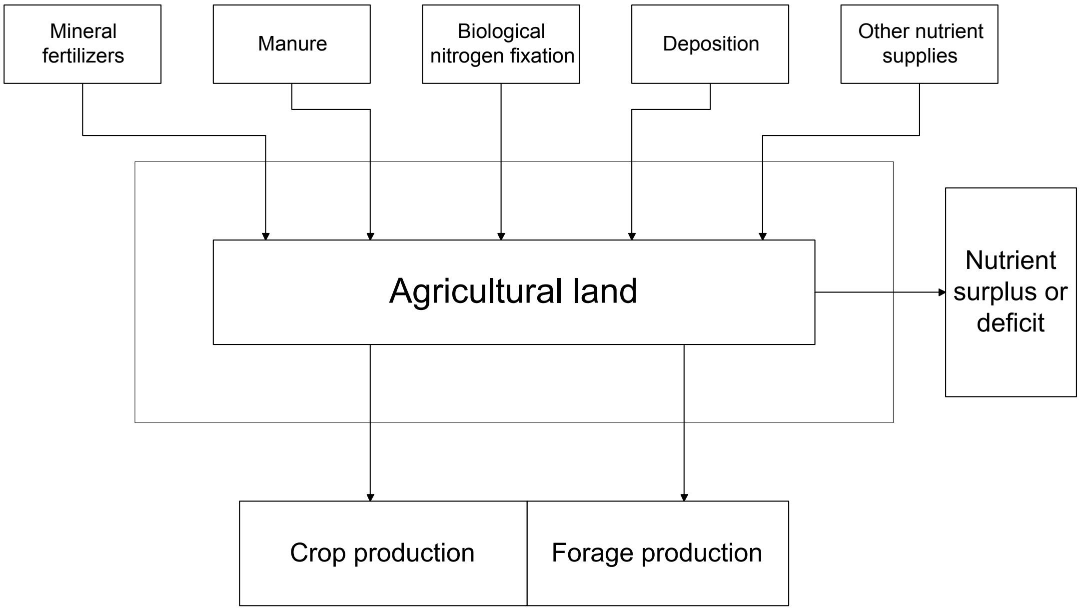


Figure 19: Flow of nutrients in the surface balance model.

Calculating nutrient balances through the surface balance method requires a lot less information than doing the same through the farmgate balance method, as only the inputs and outputs on the agricultural land have to be studied. Moreover, the required data are among those that are in general reliable and easily available, or that can be generated from existing data.

In the surface balance model, nutrients contained in manure and applied on the land are considered to be just another external input, while uptake of nutrients by forage becomes part of the total output, as shown in the previous diagram.

Nutrient surplus or deficit is calculated as being the difference between input and output, and includes any losses to the atmosphere, to the groundwater and to surface waters, as well as reversible and irreversible fixation in the soil. Again, the term nutrient surplus/deficit simply means the amount of nutrients not accounted for in the known output.

A major general inconvenience of the model is that it allows the estimation of nutrient surplus/deficit from the land only, but it gives no idea at all about important phenomena such as volatilisation of ammonia from livestock stables or direct losses from stored manure.

However, due to the nature of phosphorus and it compounds, this effect plays a far lesser role when calculating balances for P compared with nitrogen. Moreover, atmospheric deposition is known not to be a significant source of phosphorus, and phenomena such as biological nitrogen fixation have no equivalent in the phosphorus cycle.

For these reasons, the surface balance method was preferred over the farmgate model for the purpose of this study.

The year 2003 was chosen as the reference year, as this was the most recent year for which sufficient and sufficiently detailed data were available as well on the input as on the output side.

4.2 Input-output data

4.2.1 Mineral P-fertilisers

The IFA (International Fertilizer Industry Association) database (IFADATA) comprises statistics on the production, imports, exports and consumption of nitrogen, phosphate and potash fertilisers, by country / region / world, product by product, from 1973/74 to 2002/2003 with 1961/62 as a reference year (between 1961/62 and 1973/74 only the totals for nitrogen, phosphate and potash are given). The figures are given in term of nutrients N, P_2O_5 and K_2O.

Detailed P-fertiliser consumption figures (at NUTS II/III level) are not readily available from any source. Even when such figures are available (f.i. Belgium), they appear not entirely trustworthy. Therefore where applicable, the national figures were broken down to lower NUTS II/III level based on actual land use, assuming that mineral P is applied mainly to arable crops rather than on (extensive) grassland. In practice, NUTS II/III regions were assigned a share of the national consumption of mineral P proportional with their relative share of the national arable land area.

While there is no doubt that this gives a better approximation of the real situation as compared with a distribution based on total agricultural land area, doing so will still introduce a certain bias. Indeed mineral fertiliser use can be expected to be relatively lower in those areas with high livestock density, where other sources of P are abundant, or in zones with extensive forms of land use where the use of inputs per hectare is generally lower. On the other hand, mineral fertiliser is known to be used on intensively managed grassland too. However, it has not been possible to take into account these factors in the current report.

4.2.2 Livestock manure P-production

The quantities of P excreted by livestock and spread on agricultural land as manure are related to the number and category of livestock present. The quantities of phosphorus in livestock manure are estimated by multiplying the total numbers of live animals (dairy cattle, beef cattle, pigs, poultry, sheep, goats, other livestock) by a manure coefficient for each category of livestock.

The total number of animals is defined as the recorded number on a given census day during the year and the manure coefficient is expressed as kg P/head/year. Using this method, short production lifecycles for animals like fattening pigs and poultry are taken into account. Detailed statistics on livestock population in EU countries are available from EUROSTAT. The database contains both livestock population data at MS level (annual data) and at regional level (NUTS II and NUTS III) (1990, 1993, 1995, 1997, 2000 and 2003).

The standard manure P-coefficients are those used for OECD phosphorus balances calculation described in “OECD/EUROSTAT Gross Phosphorus balances Handbook”, available and last revised on 3 February 2005 for Austria, Belgium, Finland, France, Germany, Hungary, Ireland, Netherlands, Poland and Sweden at http://www.oecd.org/agr/env/indicators.htm. P-balances for the other countries were calculated with figures from countries with comparable conditions.

Not all MS/regions report on the import and export of livestock manure beyond the borders of their territories, but in most cases such transfers can be considered to be negligible as compared with other in- or outputs of P. For a few specific regions with high livestock density and with important internal or external movement of manure, the effect of the transfers is discussed in chapter 4.5.5.

4.2.3 P from recycled organic matter (sewage sludge, urban compost, …)

A minor part of the P supply to agricultural crops comes from sludge from sewage or from water treatment plants. Other sources are material from urban compost plants. Complete, consistent and detailed data on these supplies are not available from EU sources.

The OECD has data at national level for a limited number of EU countries (Austria, Belgium, Finland, Germany, Hungary and the Netherlands) (http://webdomino1.oecd.org/comnet/agr/nutrient.nsf), but applies standard coefficients for N and P-content of these materials. Because of the uncertain quality of the data, this source of input has not been considered in the calculations at this time, except for a few member states (at the national level only). This was commented in chapter 4.5.3.

4.2.4 Atmospheric deposition of phosphorus compounds

Atmospheric deposition of P-compounds is sometimes mentioned in literature. Deposition on the land takes place in rainfall containing certain phosphorus compounds coming from combustion or industrial processes. Dry deposition also occurs. However, reported inputs of P from deposition or biological sources remain low, and are considered to be irrelevant and insufficiently documented to be used in the framework of the current study.

4.2.5 Other inputs

The contribution of phosphorus contained in seeds and other planting materials is considered to be small and can be ignored.

4.2.6 Crop production

Data on crop yields and cultivated areas are available from EUROSTAT. Productions can be estimated by simply multiplying these parameters.

The P removed in these crops can be calculated by applying coefficients for the amount of P removed per ton of crop, for each of the major crop categories. The standard crop P-coefficients are those used for OECD phosphorus balances calculation described in "OECD/EUROSTAT Gross Phosphorus balances Handbook", available for Austria, Belgium, Finland, France, Germany, Hungary, Ireland, Netherlands, Poland and Sweden at http://www.oecd.org/agr/env/indicators.htm and last revised on 3 February 2005. For other countries, P-figures were taken from countries with comparable agro-environmental conditions.

For grassland, P uptake has been estimated from dry matter productions figures taken from literature, and differentiated per agro-ecological zone.

4.3 Aggregation level

The calculations have been carried out at the lowest NUTS II/III level for which sufficient data were available. A full list of geographical units is given in the table below.

Table 22: Overview of the NUTS II/III regions used in the balance calculations

Member state	NUT Regions	
AUSTRIA	at1 Ostösterreich at2 Südösterreich	at3 Westösterreich
BELGIUM	Flanders region	Walloon region
CYPRUS	-	
CZECH REPUBLIC	-	
DENMARK	-	
ESTONIA	-	
FINLAND	fi13 Itä-Suomi fi18_2 Etelä-Suomi, Åland	fi19 Länsi-Suomi fi1a Pohjois-Suomi
FRANCE	fr1 Île de France fr21 Champagne-Ardenne fr22 Picardie fr23 Haute-Normandie fr24 Centre fr25 Basse-Normandie fr26 Bourgogne fr3 Nord - Pas-de-Calais fr41 Lorraine fr42 Alsace fr43 Franche-Comté fr51 Pays de la Loire	fr52 Bretagne fr53 Poitou-Charentes fr61 Aquitaine fr62 Midi-Pyrénées fr63 Limousin fr71 Rhône-Alpes fr72 Auvergne fr81 Languedoc-Roussillon fr82 Provence-Alpes-Côte d'Azur fr83 Corse fr9 French overseas dep. (FR)n

GERMANY	de1 Baden-Württemberg	dea Nordrhein-Westfalen
	de2 Bayern	deb Rheinland-Pfalz
	de4 Brandenburg	dec Saarland
	de3_90_5_6 Berlin (1990), Bremen, Hamburg	ded Sachsen
	de7 Hessen	dee Sachsen-Anhalt
	de8 Mecklenburg-Vorpommern	def Schleswig-Holstein
	de9 Niedersachsen	deg Thüringen
GREECE	gr11 Anatoliki Makedonia, Thraki	gr24 Sterea Ellada
	gr12 Kentriki Makedonia	gr25 Peloponnisos
	gr13 Dytiki Makedonia	gr3 Attiki
	gr14 Thessalia	gr41 Voreio Aigaio
	gr21 Ipeiros	gr42 Notio Aigaio
	gr22 Ionia Nisia	gr43 Kriti
	gr23 Dytiki Ellada	
HUNGARY	hu10 Közép-Magyarország	hu31 Észak-Magyarország
	hu21 Közép-Dunántúl	hu32 Észak-Alföld
	hu22 Nyugat-Dunántúl	hu33 Dél-Alföld
	hu23 Dél-Dunántúl	
IRELAND	ie01 Border, Midlands and Western	ie02 Southern and Eastern
ITALY	itc1 Piemonte	ite3 Marche
	itc2 Valle d'Aosta/Vallée d'Aoste	ite4 Lazio
	itc3 Liguria	itf1 Abruzzo
	itc4 Lombardia	itf2 Molise
	itd1 Provincia Autonoma Bolzano-Bozen	itf3 Campania
	itd2 Provincia Autonoma Trento	itf4 Puglia
	itd3 Veneto	itf5 Basilicata
	itd4 Friuli-Venezia Giulia	itf6 Calabria
	itd5 Emilia-Romagna	itg1 Sicilia
	ite1 Toscana	itg2 Sardegna
	ite2 Umbria	
LATVIA	-	
LITHUANIA	-	
LUXEMBOURG	-	
MALTA	-	
NETHERLANDS	nl1 Noord-Nederland	nl3 West-Nederland
	nl2 Oost-Nederland	nl4 Zuid-Nederland
POLAND	-	
PORTUGAL	pt11 Norte	pt15 Algarve
	pt12 Centro(PT) (NUTS 95)	pt2 Região Autónoma dos Açores
	pt13 Lisboa e Vale do Tejo (NUTS 95)	pt3 Região Autónoma da Madeira
	pt14 Alentejo (NUTS 95)	
SLOVAKIA	sk01 Bratislavský	sk03 Stredné Slovensko
	sk02 Západné Slovensko	sk04 Východné Slovensko
SLOVENIA		

SPAIN	es11 Galicia es12 Principado de Asturias es13 Cantabria es21 Pais Vasco es22 Comunidad Foral de Navarra es23 La Rioja es24 Aragón es30 Comunidad de Madrid es41 Castilla y León	es42 Castilla-la Mancha es43 Extremadura es51 Cataluña es52 Comunidad Valenciana es53 Illes Balears es61_63_64 Andalucia, Ceuta, Melilla es62 Región de Murcia es7 Canarias (ES)
SWEDEN	se01 Stockholm se02 Östra Mellansverige se04 Sydsverige se06 Norra Mellansverige	se07 Mellersta Norrland se08 Övre Norrland se09 Småland med öarna se0a Västsverige
UK	ukc North East ukd North West (including Merseyside) uke Yorkshire and The Humber ukf East Midlands ukg West Midlands ukh Eastern	uki_j London, South East ukk South West ukl Wales ukm Scotland ukn Northern Ireland

4.4 Results

4.4.1 Balance sheets

The results of the balance calculations carried out as described above are summarized in the following tables.

For the EU 25, the surface balance was established at 3.1 kg of P per hectare of agricultural land, with very important differences between member states or NUTS II/III regions.

For each member states, and were appropriate per NUT region, the following data are presented: P input from manure, P input from mineral fertiliser, P uptake by crops, P uptake by grass, overall balance, balance per ha of agricultural land.

In the following balances, export or import of manure is not taken into account, nor is the use of inputs other than manure and fertiliser.

The impact of those factors on the balance will be discussed separately at the end of this chapter.

The full details of the balance calculations are presented in annex.

Table 23: P- balance(s) for Austria (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
AUSTRIA	**39 051**	**20 680**		**21 161**	**34 940**	**3 629**	**1.1**
at1 Ostösterreich	10 129	12 799		12 310	5 020	5 598	4.9
at2 Südösterreich	11 314	3 209		4 053	10 830	-361	-0.4
at3 Westösterreich	17 609	4 673		4 796	19 091	-1 605	-1.1

Table 24: P- balance(s) for Belgium (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
BELGIUM	**44 926**	**19 800**		**22 797**	**28 336**	**13 593**	**9.7**
Flanders Region	30 593	10 175		13 198	11 816	15 754	24.8
Walloon Region	14 330	9 625		9 597	16 519	-2 161	-2.8

Table 25: P- balance(s) for Cyprus (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
CYPRUS	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Table 26: P- balance(s) for the Czech Republic (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
CZECH REPUBLIC	**28 195**	**21 604**		**28 075**	**17 495**	**4 229**	**1.2**
Praha	8	74		128	8	-54	-5.7
Stredni Cechy	3 594	4 075		5 788	1 690	192	0.3
Jihozápad	6 686	4 114		4 337	4 718	1 745	2.2
Severozápad	1 543	1 659		2 283	1 673	-754	-2.3
Severovýchod	5 073	3 216		4 224	3 250	815	1.4
Jihovýchod	6 604	4 994		6 526	2 794	2 278	3.1
Stredni Morava	3 096	2 387		3 390	2 080	12	0.0
Moravskoslezko	1 591	1 085		1 399	1 280	-3	0.0

Table 27: P- balance(s) for Denmark (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
DENMARK	**68 303**	**14 520**		**32 174**	**23 285**	**27 364**	**10.3**

Table 28: P- balance(s) for Estonia (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
ESTONIA	**4 667**	**1 123**		**2 584**	**4 560**	**-1 354**	**-1.7**

Table 29: P- balance(s) for Finland (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
FINLAND	**16 557**	**22 880**		**12 892**	**2 116**	**24 429**	**10.9**
fi13 Itä-Suomi	3 034	3 378		1 031	581	4 799	14.4
fi18_2 Etelä-Suomi, Åland	4 701	8 431		5 971	394	6 767	8.2
fi19 Länsi-Suomi	6 212	7 958		4 846	623	8 700	11.2
fi1a Pohjois-Suomi	2 611	3 113		993	518	4 213	13.7

Table 30: P- balance(s) for France (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
FRANCE	**314 661**	**320 760**		**268 262**	**293 578**	**73 581**	**2.6**
fr1 Île de France	779	9 847		12 177	367	- 1 918	- 3.3
fr21 Champagne-Ardenne	7 889	21 743		24 440	6 962	- 1 770	- 1.1
fr22 Picardie	7 576	20 286		30 057	6 012	- 8 207	- 6.2
fr23 Haute-Normandie	8 079	9 903		14 327	7 548	- 3 893	- 5.0
fr24 Centre	10 011	36 182		35 870	7 613	- 2 709	1.2
fr25 Basse-Normandie	20 874	11 225		8 559	22 925	615	0.5
fr26 Bourgogne	16 055	17 660		14 549	15 829	3 337	1.9
fr3 Nord - Pas-de-Calais	10 227	11 693		16 563	7 464	- 2 107	- 2.5
fr41 Lorraine	11583	11 698		10 309	13 015	-43	0.0
fr42 Alsace	2 647	4 046		4 715	2 171	- 194	- 0.6
fr43 Franche-Comté	7 536	5 125		3 176	8 857	628	0.9
fr51 Pays de la Loire	40 352	28 911		15 740	33 006	20 517	9.4
fr52 Bretagne	53 851	25 914		13 218	28 412	38 135	22.8
fr53 Poitou-Charentes	14 405	25 544		21 577	11 399	6 973	4.0

fr61 Aquitaine	14 474	16 188		11 471	13 185	6 006	4.1
fr62 Midi-Pyrénées	23 510	28 543		15 093	24 513	12 447	5.3
fr63 Limousin	15 184	4 972		1 269	15 922	2 965	3.4
fr71 Rhône-Alpes	16 976	11 422		6 303	18 699	3 397	2.2
fr72 Auvergne	21 090	9 830		3 912	26 795	212	0.1
fr81 Languedoc-Roussillon	4 011	4 825		2 954	7 298	-1 416	-1.5
fr82 Provence-Alpes-Côte d'Azur	3 411	3 895		1 830	5 606	171	0.2
fr83 Corse	1 407	202		61	1 403	144	0.9
fr9 French overseas dep.	2 424	1 105		87	456	2 985	23.4

Table 31: P- balance(s) for Germany (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
GERMANY	**246 636**	**143 880**		**197 579**	**167 691**	**25 246**	**1.5**
de1 Baden-Württemberg	20 606	10 169		16 265	16 596	- 2 086	- 1.4
de2 Bayern	54 805	25 607		29 933	39 266	11 214	3.4
de4 Brandenburg	10 485	12 550		9 534	10 261	3 240	2.4
de3_90_5_6 Berlin, Bremen, Hamburg	274	100		132	361	- 119	- 5.1
de7 Hessen	8 891	5 832		8 869	8 039	- 2 183	- 2.9
de8 Mecklenburg-Vorpommern	9 605	13 059		19 319	9 100	- 5 755	- 4.3
de9 Niedersachsen	57 632	22 170		31 827	28 417	19 559	7.4
dea Nordrhein-Westfalen	33 687	13 132		20 957	16 034	9 829	6.5
deb Rheinland-Pfalz	6 325	4 775		10 334	6 998	- 6 232	- 8.8
dec Saarland	791	451		484	1 049	- 292	- 3.9
ded Sachsen	9 521	8 836		9 934	6 793	1 630	1.8
dee Sachsen-Anhalt	8 086	12 143		16 377	5 458	- 1 606	- 1.4
def Schleswig-Holstein	18 382	7 556		12 917	13 346	-324	- 0.3
deg Thüringen	7 542	7 499		10 590	5 952	- 1 502	- 1.9

Table 32: P- balance(s) for Greece (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
GREECE	**48 739**	**47 080**		**53 857**	**2 982**	**38 980**	**10.9**
gr11 Anatoliki Makedonia, Thraki	4 648	7 850		5 903	64	6 532	18.4
gr12 Kentriki Makedonia	7 727	12 686		9 279	227	10 907	17.2
gr13 Dytiki Makedonia	2 254	4 615		1 983	75	4 811	23.2
gr14 Thessalia	5 673	8 113		8 480	156	5 150	12.5
gr21 Ipeiros	5 010	1 023		1 665	319	4 050	32.6
gr22 Ionia Nisia	914	306		1 383	127	- 290	- 3.4
gr23 Dytiki Ellada	5 536	3 530		4 870	446	3 750	11.8
gr24 Sterea Ellada	4 011	4 862		5 519	239	3 115	8.9
gr25 Peloponnisos	3 641	1 673		6 607	301	- 1 595	- 4.2
gr3 Attiki	764	366		544	24	561	10.4
gr41 Voreio Aigaio	1 401	484		441	212	1 232	7.9
gr42 Notio Aigaio	1 829	922		435	159	2 158	19.9
gr43 Kriti	5 331	650		6 749	632	- 1 400	- 3.5

Table 33: P- balance(s) for Hungary (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
HUNGARY	**27 051**	**29 920**		**42 984**	**3 422**	**10 565**	**2.4**
hu10 Közép-Magyarország	1 519	1 981		1 900	241	1 359	4.5
hu21 Közép-Dunántúl	3 598	3 376		4 730	447	1 798	3.8
hu22 Nyugat-Dunántúl	2 955	3 639		5 289	532	772	1.5
hu23 Dél-Dunántúl	3 743	4 789		8 569	411	- 448	- 0.7
hu31 Észak-Magyarország	1 983	2 802		3 853	256	676	1.5
hu32 Észak-Alföld	6 654	6 390		9 324	874	2 845	3.0
hu33 Dél-Alföld	6 600	6 942		9 317	646	3 579	3.5

Table 34: P- balance(s) for Italy (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
ITALY	**134 727**	**197 560**		**112 462**	**133 373**	**86 452**	**6.6**
itc1 Piemonte	12 061	15 170		8 456	8 991	9 785	9.1
itc2 Valle d'Aosta/Vallée d'Aoste	450	4		5	429	20	0.4
itc3 Liguria	454	188		240	273	129	2.6
itc4 Lombardia	30 096	19 726		12 147	23 544	14 131	14.4
itd1 Provincia Autonoma Bolzano-Bozen	1 994	75		242	2 276	- 449	- 1.6
itd2 Provincia Autonoma Trento	1 168	131		134	1 385	- 219	- 1.5
itd3 Veneto	15 686	14 830		10 183	9 438	10 896	13.1
itd4 Friuli-Venezia Giulia	2 947	4 552		3 165	1 086	3 248	14.8
itd5 Emilia-Romagna	14 093	22 646		10 377	10 497	15 865	14.8
ite1 Toscana	3 306	14 181		3 644	5 193	8 651	10.7
ite2 Umbria	2 698	6 639		2 770	2 487	4 079	11.3
ite3 Marche	2 631	11 174		4 942	3 335	5 528	10.8
ite4 Lazio	6 177	10 444		3 202	11 290	2 128	2.9
itf1 Abruzzo	2 702	4 413		3 411	2 951	754	1.8
itf2 Molise	2 072	4 336		1 674	1 294	3 440	16.1
itf3 Campania	6 137	7 733		4 345	7 419	2 105	3.7
itf4 Puglia	2 793	17 242		18 492	4 045	- 2 502	- 2.0
itf5 Basilicata	3 042	9 298		2 336	3 092	6 912	12.5
itf6 Calabria	2 650	5 075		11 828	2 849	- 6 953	- 12.7
itg1 Sicilia	6 306	17 934		9 160	9 762	5 318	4.2
itg2 Sardegna	15 255	11 767		1 710	21 735	3 577	3.1

Table 35: P- balance(s) for Ireland (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
IRELAND	**74 080**	**42 680**		**8 099**	**74 334**	**34 327**	**7.9**
ie01 Border, Midlands and Western	30 496	14 499		1 531	33 998	9 466	5.0
ie02 Southern and Eastern	43 586	28 181		6 569	40 336	24 862	10.0

Table 36: P- balance(s) for Latvia (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
LATVIA	**6 685**	**2 183**		**4 640**	**9 092**	**- 4 864**	**- 3.3**

Table 37: P- balance(s) for Lithuania (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
LITHUANIA	**16 326**	**10 500**		**11 731**	**19 433**	**- 4 338**	**- 1.7**

Table 38: P- balance(s) for Luxemburg (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
LUXEMBOURG	**1 941**	**NA**		**698**	**3 086**	**NA**	**NA**

Table 39: P- balance(s) for Malta (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
MALTA	**672**	**NA**		**20**	**32**	**NA**	**NA**

Table 40: P- balance(s) for the Netherlands (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
NETHERLANDS	**86 306**	**22 880**		**15 801**	**65 663**	**27 722**	**13.8**
nl1 Noord-Nederland	15 507	5 741		3 981	18 056	- 789	- 1.4
nl2 Oost-Nederland	28 329	5 750		3 229	22 635	8 214	14.4
nl3 West-Nederland	10 891	5 448		4 783	11 785	- 229	- 0.5
nl4 Zuid-Nederland	31 570	5 941		3 718	13 186	20 607	54.0

Table 41: P- balance(s) for Poland (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
POLAND	**188 221**	**133 320**		**116 719**	**42 179**	**162 643**	**10.1**

Table 42: P- balance(s) for Portugal (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
PORTUGAL	**42 026**	**25 080**		**7 443**	**59 819**	**- 156**	**0.0**
pt11 Norte	8 290	3 739		1 577	13 777	- 3 325	- 4.9
pt12 Centro(PT) (NUTS 95)	9 348	3 626		1 738	14 361	- 3 125	- 5.3
pt13 Lisboa e Vale do Tejo (NUTS 95)	8 944	2 954		345	6 243	5 311	11.9
pt14 Alentejo (NUTS 95)	11 268	14 065		3 555	21 557	222	0.1
pt15 Algarve	809	491		170	636	495	4.9
pt2 Região Autónoma dos Açores	3 109	171		25	3 230	24	0.2
pt3 Região Autónoma da Madeira	259	33		40	13	239	42.3

Table 43: P- balance(s) for Slovakia (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
SLOVAKIA	**12 958**	**8 228**		**12 697**	**7 325**	**1 163**	**0.5**
sk01 Bratislavský	348	448		763	218	- 185	- 2.2
sk02 Západné Slovensko	6 129	4 405		8 296	2 084	153	0.2
sk03 Stredné Slovensko	3 526	1 291		1 351	2 492	974	1.7
sk04 Východné Slovensko	2 951	2 084		2 287	2 530	219	0.3

Table 44: P- balance(s) for Slovenia (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
SLOVENIA	**8 002**	**9 108**		**2 914**	**4 779**	**9 417**	**19.4**

Table 45: P- balance(s) for Sweden (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
SWEDEN	23 421	16 280		**23 360**	**15 890**	**452**	**0.1**
se01 Stockholm	380	522		526	458	- 82	- 0.8
se02 Östra Mellansverige	4 382	4 333		5 987	3 046	- 318	- 0.4
se04 Sydsverige	4 622	2 979		8 456	1 927	- 2 783	- 5.0
se06 Norra Mellansverige	1 614	1 456		1 215	1 659	196	0.7
se07 Mellersta Norrland	798	556		116	928	310	3.0
se08 Övre Norrland	859	644		276	794	433	4.0
se09 Småland med öarna	4 994	2 175		1 843	4 021	1 305	2.5
se0a Västsverige	5 772	3 615		5 001	3 056	1 331	2.0

Table 46: P- balance(s) for Spain (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	Fertiliser	Other	Crops	Grass	Total ton	kg P/ha
SPAIN	**206 910**	**264 440**		**142 243**	**302 346**	**26 762**	**1.1**
es11 Galicia	19 428	4 287		1 088	23 938	- 1 312	- 1.8
es12 Principado de Asturias	5 947	326		59	14 100	- 7 887	- 19.8
es13 Cantabria	4 434	114		27	10 016	- 5 494	- 18.8
es21 Pais Vasco	3 588	1 397		1 174	5 557	- 1 746	- 7.2
es22 Comunidad Foral de Navarra	4 980	6 568		2 867	8 670	10	0.0
es23 La Rioja	1 573	1 730		1 151	3 631	- 1 479	- 6.1
es24 Aragón	20 098	31 692		8 610	23 947	19 233	8.2
es30 Comunidad de Madrid	2 114	3 407		1 325	5 121	- 925	- 2.7
es41 Castilla y León	35 925	75 361		29 211	63 770	18 305	3.4
es42 Castilla-la Mancha	19 141	65 109		22 179	19 821	42 251	9.4
es43 Extremadura	22 262	17 335		10 064	60 042	- 30 509	- 10.6
es51 Cataluña	27 903	11 025		6 796	13 138	18 994	16.5
es52 Comunidad Valenciana	6 380	2 187		2 604	4 739	1 224	1.7
es53 Illes Balears	1 638	3 011		352	645	3 651	17.5
es61_63_64 Andalucia, Ceuta, Melilla	24 457	36 575		53 380	43 650	- 35 997	- 7.7
es62 Región de Murcia	5 387	3 978		1 138	661	7 565	18.3
es7 Canarias (ES)	1 653	337		215	894	881	14.2

Table 47: P- balance(s) for UK (2003) calculated by SSB

Member state or NUT region	INPUT (ton P)			OUTPUT (ton P)		BALANCE	
	Manure	**Fertiliser**	**Other**	**Crops**	**Grass**	**Total ton**	**kg P/ha**
UK	**190 312**	**124 520**		**101 966**	**283 315**	**- 70 449**	**- 4.4**
ukc North East	6 110	3 954		3 594	9 980	- 3 509	- 6.3
ukd North West (including Merseyside)	15 574	4 153		1 961	19 543	- 1 777	- 2.0
uke Yorkshire and The Humber	13 269	12 246		12 567	12 701	248	0.2
ukf East Midlands	11 012	17 269		17 241	9 278	1 763	1.5
ukg West Midlands	14 092	9 676		7 751	12 832	3 186	3.5
ukh Eastern	10 420	23 326		24 727	5 482	3 536	2.6
uki_j London, South East	9 802	13 428		11 544	11 845	- 159	- 0.1
ukk South West	26 362	14 762		8 983	30 218	1 922	1.1
ukl Wales	28 353	3 651		1 088	34 458	- 3 544	- 2.5
ukm Scotland	32 746	18 249		11 644	111 045	- 71 693	- 14.6
ukn Northern Ireland	22 572	3 806		865	25 934	- 420	- 0.4

4.4.2 Map of the balance per NUTS II/III region

The following map presents the balance results per NUTS II/III region as calculated above. It should be emphasized again that the figures do not take into account manure transfers between regions nor any withdrawal of phosphorus from the P-cycle (for instance by combustion of manure), and that the regional use of mineral P fertilisers within the member states was estimated on the basis of arable land area. Therefore in general the actual differences between regions will be less pronounced than suggested by the map.

As was expected most regions with high P-surplus correspond with areas with high livestock density. Regional differences in Denmark do not appear as the balance was calculated at the national level only. The high surplus of Slovenia and some Greek NUTS II/III regions cannot be fully explained at present, but is linked with the known ongoing erosion and run-off. Half of Slovenia is covered by forests, which protect the slopes and valleys from erosion and mass wasting. Despite this, erosion endangers about 44% of the Slovenian territory and causes an annual loss of around 2.5 million m^3 of soils (http://www.sigov.si/svo/svo/slovenija_e.htm).

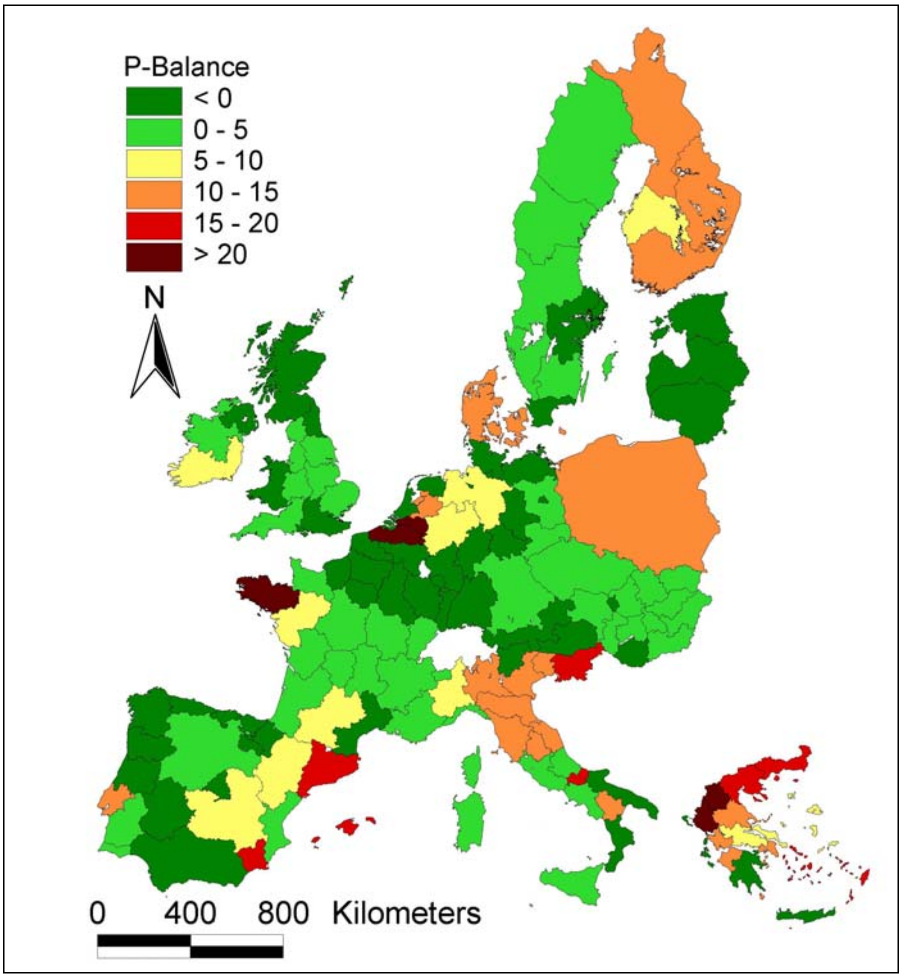


Figure 20: Balance result per NUTS II/III region

4.4.3 Balances at MS level

The following map presents the balances per Member State. In this map, the regional differences within Member States are averaged out.

Although it may look as a paradox, in some cases this may be a better approximation of the actual situation, in particular when important internal redistribution of manure takes place, as is for instance the case in the Netherlands. At the same time, the effect of the allocation of regional mineral fertiliser use on the basis of arable land area (which may still induce a certain bias) is cancelled.

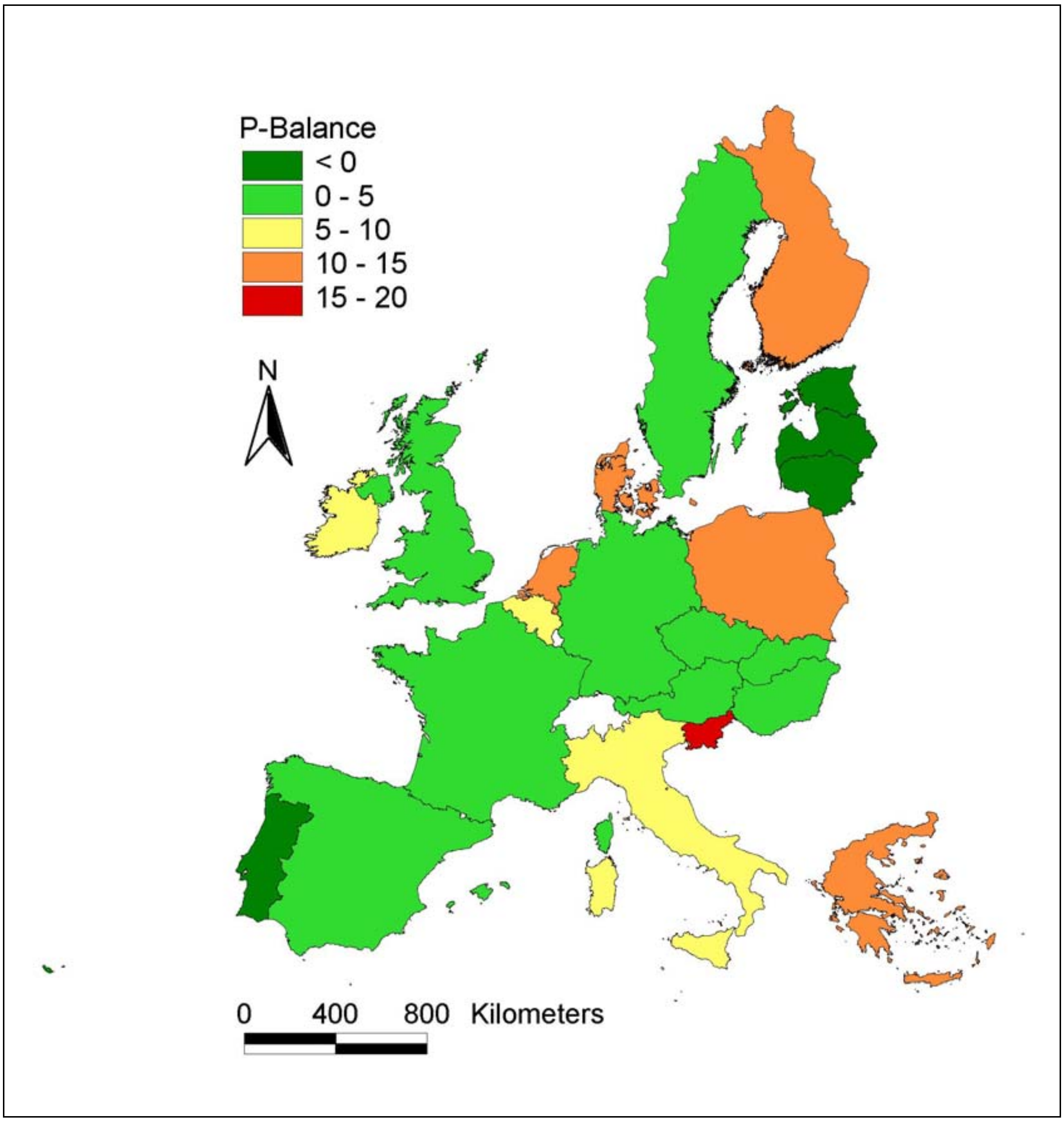


Figure 21: Balance result (in kg P per Ha) for each Member State

4.5 Comments

4.5.1 Factors explaining the differences in P-balance

In order to explain the differences, the following table provides the following key figures per member state: average total input of P per hectare of agricultural land, the ratio between P-input as manure and P-input as mineral fertiliser as well as the balance result (in kg/ha).

Table 48: Average P-use, ratio P-manure/P-fertiliser and balance result (2003)

Member state	Average P-use kg P/ha	P-consumption ratio manure/fertiliser	P-Balance kg P/ha
Austria	17.6	1.89	1.1
Belgium	46.4	2.27	9.7
Czech Republic	13.7	1.31	1.2
Cyprus			
Denmark	31.2	4.70	10.3
Estonia	7.3	4.16	- 1.7
Finland	17.6	0.72	10.9
France	22.9	0.98	2.6
Germany	23.0	1.71	1.5
Greece	26.7	1.04	10.9
Hungary	13.1	0.90	2.4
Ireland	26.7	1.74	7.9
Italy	25.3	0.68	6.6
Latvia	6.0	3.06	- 3.3
Lithuania	10.8	1.55	- 1.7
Luxemburg			
Malta	62.3		
Netherlands	54.4	3.77	13.8
Poland	19.9	1.41	10.1
Portugal	17.4	1.68	0.0
Slovakia	9.9	1.57	0.5
Slovenia	35.2	0.88	19.4
Spain	18.7	0.78	1.1
Sweden	12.7	1.44	0.1
UK	19.5	1.53	- 4.4

In some countries, a high balance surplus can be explained by high inputs. For example, Finland is a traditional producer of mineral P-fertilisers and high inputs can therefore be explained by historic reasons. However, high balance surpluses are not only due to high input, but also due to low efficiency and low output. That is for instance why for Poland, Slovenia or Mediterranean regions, the balance surplus may be higher than expected.

National balances are to be interpreted with caution and the regional figures are more relevant than the national figures. In particular in the larger member states but also in smaller states, huge differences may occur between regions. The national balance surplus of Belgium is rather low, but the large surplus of the Flanders region is compensated for by the low figure for the Walloon region.

For The Netherlands, the regional balances were calculated in the same way as in other countries, but the effect of internal manure transfers is extremely important (see also paragraph 4.5.5.2).

The two following figures present the relationship between the balance surplus (or deficit) on the one hand and the manure/fertiliser ratio and the average P-load per hectare on the other hand.

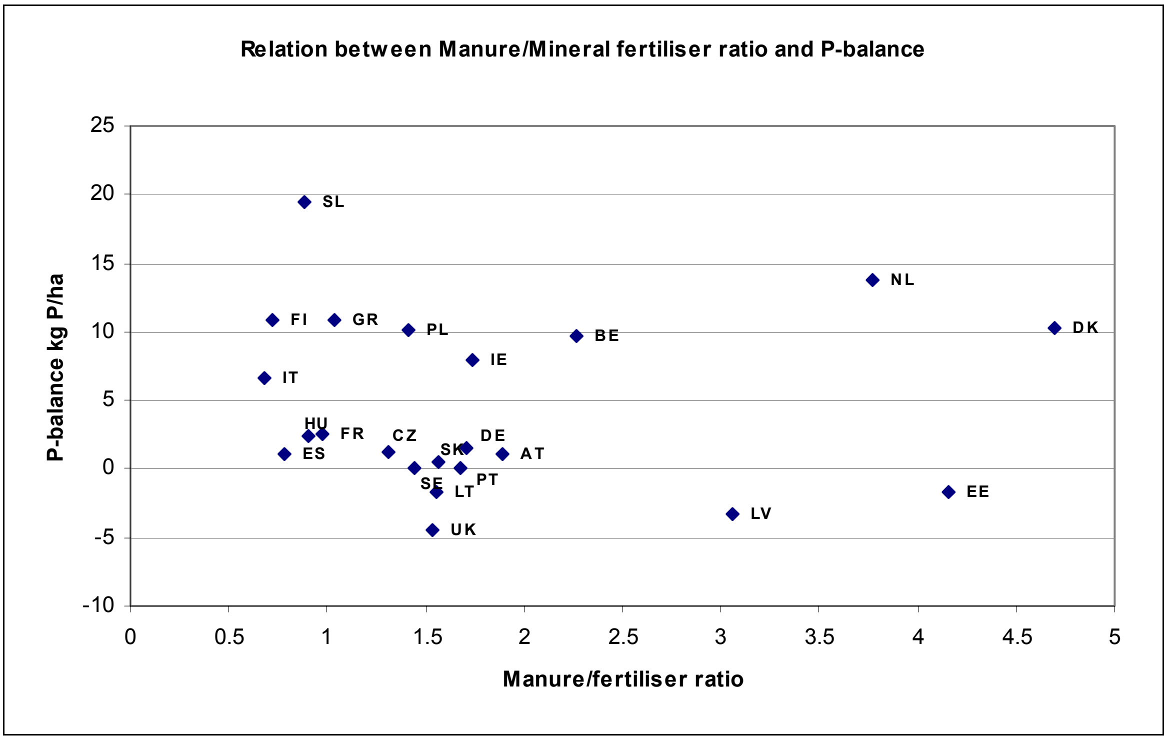


Figure 22: Relation between Manure/Fertiliser ratio and balance surplus at MS-level

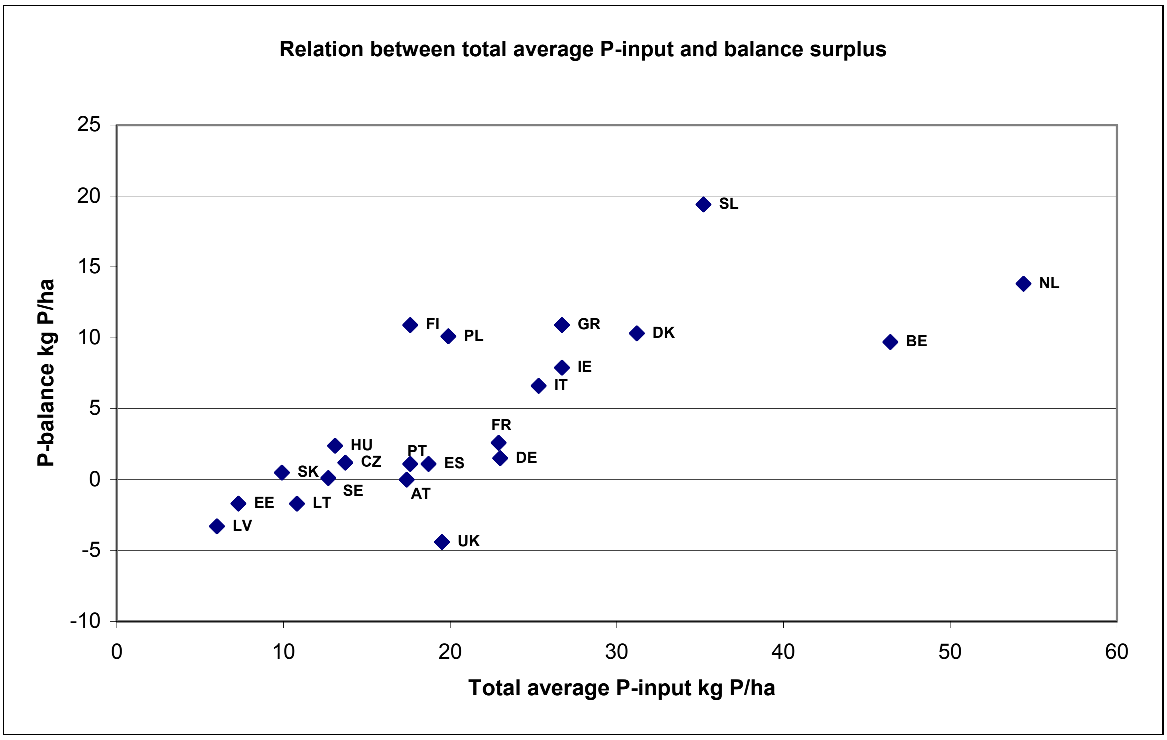


Figure 23: Relation between average P-input and balance surplus at MS-level

From the figures it appears that balance surpluses are explained better (though not exclusively) by total average load than by the form in which P is applied to the land. This also means that manure and mineral are rather interchangeable as source of manure.

The efficiency of P-use and P-uptake seems to be very important too. For instance Belgium and Poland have a similar balance surplus, while the average P-load in Belgium is twice as high as in Poland. In other words; P-uptake per hectare is much higher in Belgium than in Poland. This phenomenon can be explained by soil type, climate and level of intensification.

Similar relationships could be calculated at lower aggregation levels, but this will make sense only if detailed and reliable figures can be found on actual mineral P-fertiliser use and on import/export of manure. As will be seen hereafter, these figures can indeed have a very strong influence on the balance result.

4.5.2 *Missing, doubtful or incorrect data*

Data on mineral fertilisers use for the year 2003 were available for all but a few member states. IFA does not publish separate figures for Luxemburg, nor were such data available for Malta. Therefore no balance was calculated for these Member States. For the Baltic States Latvia and Estonia, only 1996 figures were available, and these were used in the calculations.

Separate figures for member state Cyprus were not found.

Balance calculations are diverging unexpectedly for one state: Slovenia has a very high balance surplus possibly due to inefficient P-uptake and excessive P-losses caused by erosion.

4.5.3 *Effect on the balance of other inputs than manure and fertiliser*

Few reliable and consistent figures are available on the use of P- sources other than manure or commercial mineral fertiliser such as sludge from sewage or water treatment plants, secondary products from the food industry or locally produced ground phosphate rock.

Even when such figures are available, there may by uncertainty about their P-content. In some member states, the use of sludge in agriculture is, if not forbidden, discouraged for fear of contamination.

Data on the recycling of sludge in agriculture were available at member state level for some countries only. The following table illustrates the (limited) effect of this source on the overall P-balance for these countries. Only in the Walloon region, recycling of sludge makes up more than 10 % of the total input.

Table 49: Comparison of balances with or without the use of sludge (2003)

MS	Total input* (tons P)	Sludge (tons P)	Sludge (% of total input*)	Total output** (tons P)	Balance excluding sludge (kg/ha)	Balance including sludge (kg/ha)
AT	59 731	1 335	2.2	56 101	1.1	1.5
BE (Fl)	40 768	1 550	3.8	25 014	24.8	27.2
BE (W)	23 955	2 416	10.1	26 116	- 2.8	0.3
DE	390 516	22 625	5.8	365 271	1.5	2.8
FI	39 437	650	1.6	15 008	10.9	11.2
HU	56 971	528	0.9	46 406	2.4	2.5
NL	109 186	3 676	3.4	81 464	13.8	15.6

* Total input as manure and fertiliser

** Uptake by crops and grassland

4.5.4 *Regional distribution of mineral P use*

The consumption of mineral fertiliser is thought to be linked closely with actual land use, cropping systems, level of intensification, soil type and availability of other sources of P such as manure. Farms in cereal producing regions with low livestock density can be expected to apply larger amounts of mineral P than their counterparts operating in zones with abundant supply of manure. However for lack of detailed figures at the NUTS II/III level, the regional distribution of mineral fertiliser use has been carried out proportionally to the arable land area, assumed to be the best available parameter to split up the national consumption figure.

In some cases this may lead to a certain distortion of the balance. For instance in the case of Belgium, the input figures for mineral P have been split up more or less equally between Flanders and the Walloon region, according to the arable land area of both regions. In Flanders, with its strong intensive livestock sector, the phosphorus needs are covered more and more by manure, and the use of mineral phosphorus has strongly decreased in recent years. In the Walloon region, where agriculture is less intensive, the consumption of mineral phosphorus is relatively more important. Had the calculations been based on the figures[3] put forward (unofficially) by the Flanders government, the ratio of mineral P-consumption would have shown a shift from ± 50/50 to ± 10/90, with a significant impact on the P balance of both regions.

4.5.5 Effect of manure transfer between regions/member states

In the above calculations, transfer of manure or of other sources of P-supply within or between member states was not taken into account. Such transfers are known to occur between regions with high surplus and nutrient deficient areas. Because of the cost of transportations, manure is preferably taken to neighbouring regions, but long distance transport, even beyond the borders of the EU also takes place.

Typical examples of net exporters of manure are the Netherlands and the Flemish region of Belgium. In other member states such as Spain significant quantities of manure are being transferred from surplus regions to nutrient deficient areas (f.i. from central Spain to Andalusia), but precise figures are not available for the moment.

In the following paragraphs, the effect of manure transfers on the P-balance will be highlighted for Flanders and for the Netherlands, for which reliable data on manure transfer are available.

4.5.5.1 Flanders region of Belgium

In 2003, the net export of manure beyond the borders of the Flemish region amounted to the equivalent of 5,9 million kg of P_20_5 or ± 2 600 tons of P, most whereof was exported to the cereal growing regions in Northern France. While the balance total remains rather high, such transfers have a significant impact on the P-balance of the Flanders region as is indicated in the following table.

Table 50: P- balance(s) for Flanders (2003) with and without export of manure

Member state or NUT region	BALANCE excluding export		BALANCE including export	
	Total tons P	kg P/ha	Total tons P	kg P/ha
Flanders region of BELGIUM	15 754	24.8	13 154	20.7

[3] Extrapolation made of figures declared by farmers

4.5.5.2 The Netherlands

Detailed figures on manure transfer are available for the period 1994 to 2002 (CBS, Transport en gebruik van mest en mineralen 1994-2002).

According to the CBS figures, in 2002 over 80% of the fattening pig slurry and three quarters of the dry poultry manure were evacuated from the production location. On a total production of 172 000 tons of P_20_5, 37% was evacuated from the producing farms. Most of the transfers took place between farms situated within the Netherlands. In 2002, net export of 16 500 tons of P_2O_5 took place, while another 2 500 tons were withdrawn from the phosphorus cycle through manure processing, bringing the total to 19 000 tons of P_2O_5 or 8 300 tons of P. Therefore the effective surplus on the national balance is less important than calculated previously (Table 40).

The importance of internal transfer of manure is clearly illustrated by the following table that gives production figures next to import/export figures and actual consumption figures of phosphorus in manure, all expressed in kg of P_20_5 per hectare.

Table 51: Production, transfer and use of P2O5 in manure per province (2002, source CBS)

Province	Kg of P_2O_5 per ha of arable land			% of national average use
	Production	Net transfer	Use	
Groningen	47	+ 20	68	86 %
Friesland	82	0	82	104 %
Drenthe	59	+ 18	77	97 %
Overijssel	110	- 21	89	113 %
Flevoland	27	+ 35	63	80 %
Gelderland	126	- 39	87	110 %
Utrecht	105	- 12	94	119 %
Noord-Holland	45	+ 11	56	71 %
Zuid-Holland	55	+ 12	68	86 %
Zeeland	20	+ 30	51	65 %
Noord-Brabant	159	- 56	103	130 %
Limburg	146	- 67	79	100 %
Netherlands	**90**	**- 10**	**79**	**-**

As can be seen from this table, export of manure to neighbouring provinces may come close to 50% of the total production. In the receiving provinces, import may even exceed the local production.

The figures clearly show that redistribution of manure can effectively help to alleviate part of the pressure in zones with high livestock density, the more as in these areas the consumption of mineral P can be assumed to be below average. In this way for instance the pressure of P from manure per hectare in the Limburg province falls to the national average, while this province is having the second highest livestock density in the country.

On the other hand, large scale transfer of manure can lead to increased risk of P-saturation in areas with vulnerable soils, even when livestock density in these regions is relatively low.

The importance of local differences even within the provinces, and the effect of redistribution of manure become even more pronounced when figures are considered per agricultural region, as illustrated by the following table. Production, net transfer and use of P_2O_5 as manure is given for the 5 agricultural regions within the Netherlands having the highest net export of manure and the 5 regions with the highest net import. All figures are given in kg of P_2O_5 per hectare.

Table 52: Production, transfer and use of P2O5 in manure in selected agricultural regions of the Netherlands (2002, source CBS)

	Kg of P_2O_5 per ha of arable land			**Use as a % of national average use**
Agricultural region (province)	**Production**	**Net transfer**	**Use**	
Westelijke Veluwe (Gld)	284	- 179	105	133 %
Westelijk Peelgebied (NB)	277	- 149	128	162 %
Noord-Limburg (L)	188	- 107	81	103 %
Maaskant en Land van Cuijk (NB)	189	- 75	115	146 %
De Kempen (NB)	174	- 58	116	147 %
Biesbosch (NB)	25	+ 47	72	91 %
Westerwolde en Gr. Veenkoloniën (Gr)	33	+ 41	74	94 %
Drentse Veenkoloniën en Hondsrug (Dr)	37	+ 35	73	92 %
Zuidelijke Ijsselmeerpolders (Fl)	29	+ 38	67	85 %
Voorne-Putten en Hoeksche Waard (ZH)	18	+ 33	51	65 %

While some of the areas with high livestock density export up to 50 % or more of their manure production to other regions, and some importing regions more than double their manure consumption by doing so, the average P-pressure in the exporting areas remains well above the figures for the import regions.

5. Vulnerability of the European soils to excess P

5.1 Introduction

As has been described in previous chapters, excess P applied on agricultural land may be lost to the groundwater and to the surface water mainly by processes of leaching, run-off and erosion.

This chapter describes how the digital European Soil Map is reclassified according to the P sorption capacity of the soil, and how other features such as erodibility, landscape or groundwater characteristics are taken in to account in order to establish a P-vulnerability map.

The combination of the resulting map with the input-output P-balances calculated in the previous chapters will allow pinpointing to areas within the EU25 with increased P saturation risk, and to areas not expected to be associated with major problems of P-loss.

In this chapter "sorption of P" in the soil is defined as a process whereby readily soluble phosphate is changed to less soluble forms by reacting with inorganic or organic compound of the soil so that P becomes immobilized (Kardos, 1964).

'P-retention' refers to the capacity of the soil to retain phosphorus by sorption and by resistance to erosion.

The term 'P-sensitivity' refers to the combined risk of phosphorus loss to the groundwater or to the surface water by the combined action of low sorption capacity, high erosion risk and increased risk of drainage.

5.2 Input data

The Soil Geographical Data Base of Europe (SGDBE) at scale 1:1 000 000 is the most detailed data source on soil covering the whole European territory.

We have used the SGDBEv2 Raster Archive – ETRS_LAEA version (freely available at http://eusoils.jrc.it).

5.2.1 Components of the European Soil Map

The European Soil Map is composed of two components:

1. original soil data of the Soil Geographical Database of Eurasia (SGDBE)

2. data derived from the SGDBE by using pedotransfer rules (PTRBD, PedoTransfer Rules Data Base).]

5.2.2 Generalisation steps carried out by JRC

The soil data provided by JRC had already been submitted to two generalisation steps. Firstly all the soil association groups were generalized to one Soil Mapping

Unit (corresponding to the dominant soil type). Secondly, the polygons were converted into raster files, where each raster received the value of the most dominant polygon.

5.2.2.1 First generalisation step: dominant STU

In most cases the Soil Mapping Units (SMUs) are not pure, i.e. they represent soil associations, also called soil complexes. This is due to the fact that some soil types (i.e. STUs or Soil Typological Units) can be identified (i.e. semantically defined by their name, texture, and all other descriptive characteristics) but cannot be located precisely on the map (i.e. their shape and location cannot be determined with a better precision than their SMU "container"). Examples of complex SMUs are given in Figure 24 for SMUs 1 and 3.

This system is set-up to account for the difference in resolution between the semantic and the geometric information which commonly occurs in soil surveying: soil types are identified and described with a higher level of precision than their geometry.

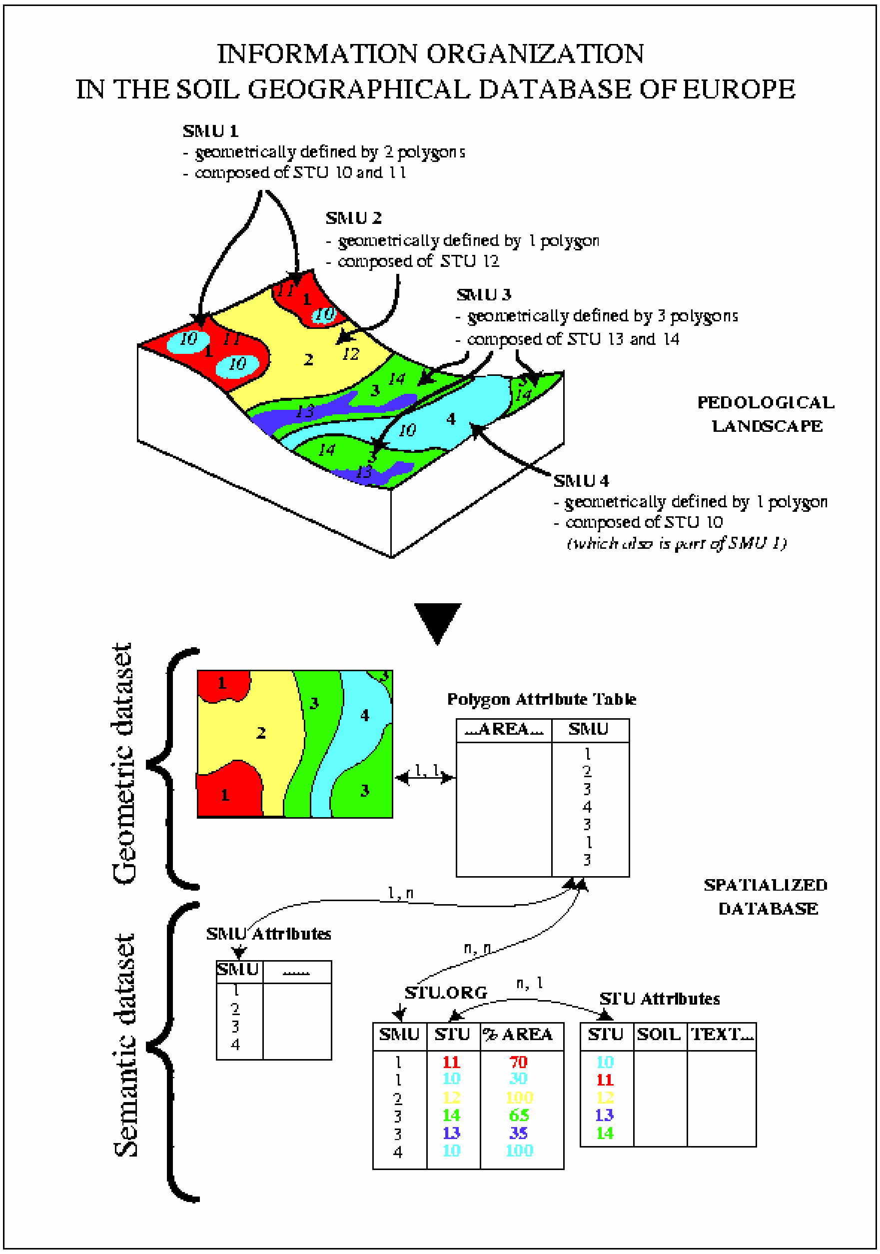


Figure 24: SMU (Soil Mapping Unit) versus STU (Soil Typological Unit).

Generalisation effect: the dominant STU assigns it values to the SMU. E.g. for SMU 1 only the values of STU 11 will be considered, for SMU 3 values are only taken from STU 14.

The characteristics of the most dominant STU is assigned to the Soil Association Group (Soil Mapping Unit). Thus properties of other STU's present in the Soil Association Group are omitted. This generalisation of data should be considered while interpreting the European Soil Map.

5.2.2.2 Second generalisation step: polygon to raster

The geometric polygons have been converted to rasters, where each raster pixel represents a square of 10km x 10 km. The most dominant polygon within the raster pixel assigns its value to it (see Figure 25), whereas the values of the other polygons in the pixel are omitted. This is a second generalisation of data (apart from the generalisation as described in § 2.2.1) that should be considered while interpreting the European Soil Map.

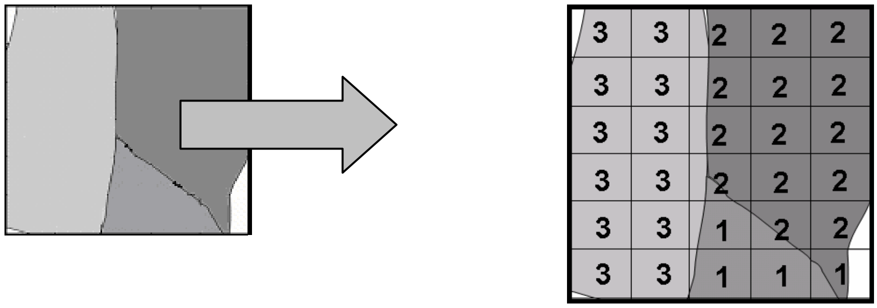


Figure 25: Conversion of geometric polygons to raster pixels

Generalisation effect: only the dominant polygon assigns its value to the raster pixel.

5.2.3 Input layers

For our purpose of this study we have selected the following input layers:

Table 53: Input raster layers

Name of input layer	**Description**
FAO85FU	Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend
SLOPEDO	Dominant slope class of the STU
TXSRFDO	Dominant surface textural class of the STU
WM1	Code for normal presence and purpose of an existing water management system in agricultural land on more than 50% of the STU.
WR	Dominant annual average soil water regime class of the soil profile of the STU.
(ERODI)	Soil erodibility class

5.2.4 Restrictions

5.2.4.1 Low resolution of the data

Since the original scale of the European Soil Map is 1:1 000 000 and furthermore two generalisations have been done (see § 2.2.1 and § 2.2.2) the maps serve as indicator for general patterns at a small scale and should only be interpreted with care at a large scale.

5.2.4.2 Qualitative information

The lack of analytical information on soils complicated the use of this database. The data describing the STU are qualitative, so the concept of pedotransfer functions was extended to the concept of the pedotransfer rules.

More detailed soil information is available at national level, but is not consolidated in one central database. Since our analysis has to be uniform for the whole EU25 territory in terms of input data and methodology we used the European Soil Database (version 2), even if this only consists of qualitative and indicative attributes.

5.2.4.3 Lack of harmonisation

In all thematic layers we can clearly recognize that information in Sweden is very rudimentary, with little differentiation between regions, compared to other countries. Therefore the results for Sweden should be interpreted with care, or not interpreted at all.

Specifically in the texture layer we have also detected a “shift” of texture classes for Hungary. The texture classes in Hungary are consequently finer than those in the neighboring countries. This could be explained by the two generalisation processes as described above, but could also points to a lack of uniformity in the data assessment methodology for this parameter within the European Soil Map.

The texture layer is shown in Figure 26. Sweden and Hungary can be clearly recognized.

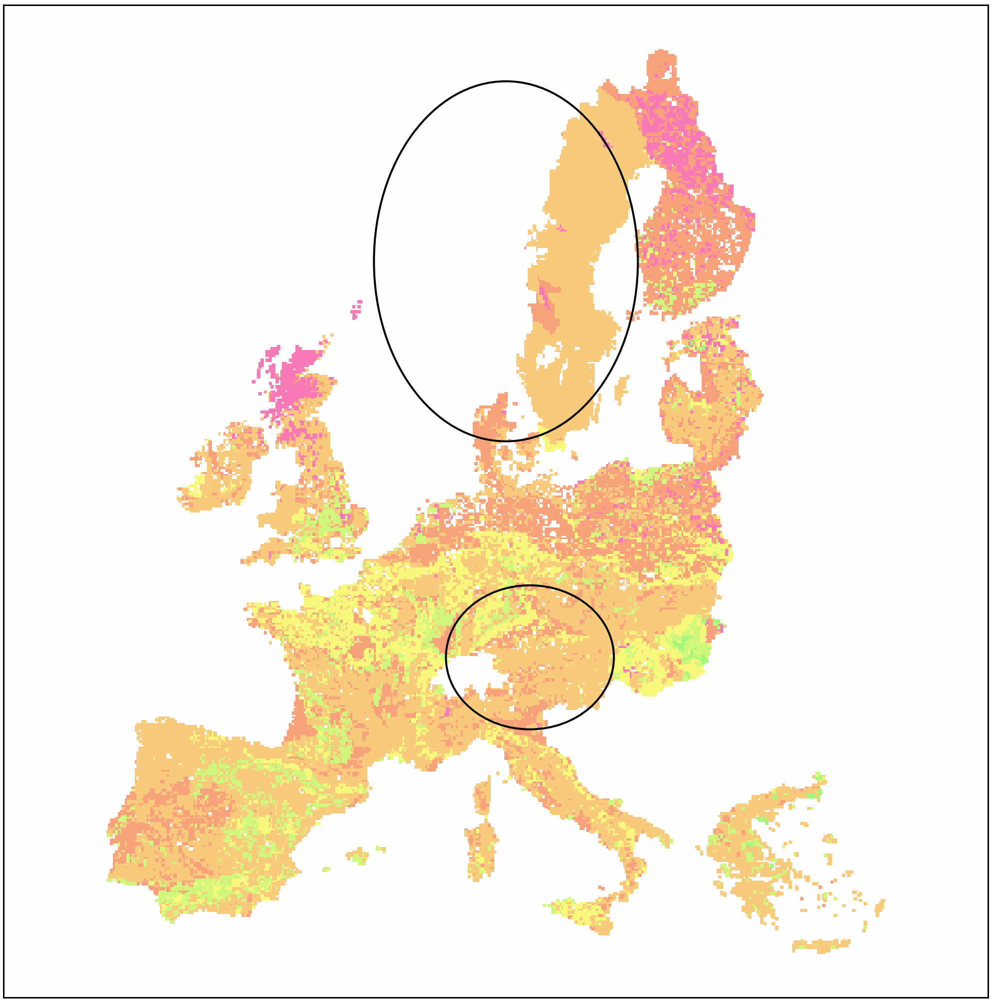


Figure 26: Texture layer of the European Soil Map showing inconsistent patterns for Sweden and Hungary.

Lack of harmonisation is also detected for the water management input layer (presence of artificial drainage). No data information is available for Sweden, France, Spain and Greece. Finland shows surprisingly, a wide use of artificial drainage (Figure 27).

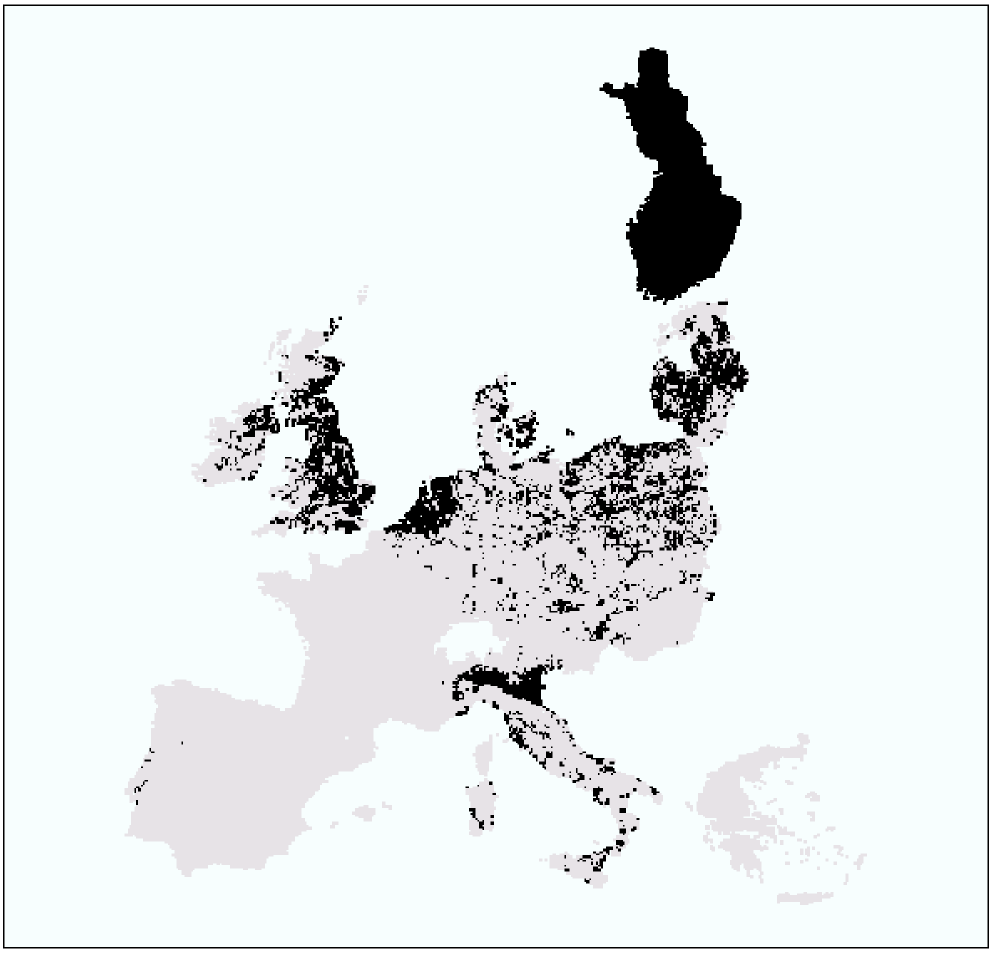


Figure 27: Artificial drainage in EU25 (black corresponds to presence of artificial drainage, light grey corresponds to absence of artificial drainage)

5.2.4.4 Inconsistencies among the attributes of the European Soil Map

When interpreting the FAO-UNESCO attributes, we have found inconsistencies concerning the water regime in the soil. Soils that are described as gleysols, gleyic or stagnic are sometimes occurring in the driest water regime class.

5.2.4.5 Erodibility map

In the erodibility map provided by JRC we have also detected anomalies. In the map below (Figure 28) the anomaly for Belgium is illustrated. The region marked by the ellipse is the loess/loam belt of Belgium, which because of its loamy texture, is very susceptible to erosion. However the Erodibility Map (Figure 28), shows the region to have a weaker erodibily class then north of the loam belt, where the region is characterized by a sandy texture, meaning that the erodibility there should be low, and not very strong.

We have therefore decided to create our own erodibility map, based on the texture layer. The methodology is described in paragraph 5.3.1.2 Erodibility based on texture classes.

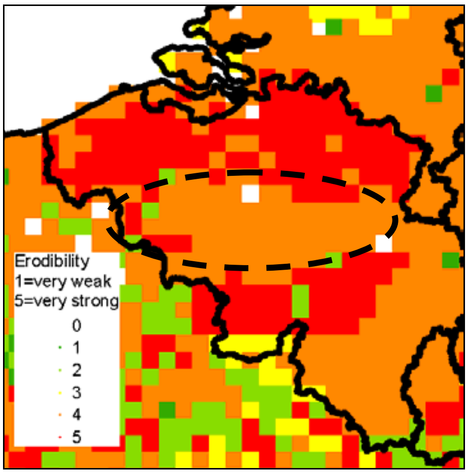


Figure 28: Erodibily according to the erodibility layer of the European Soil Map

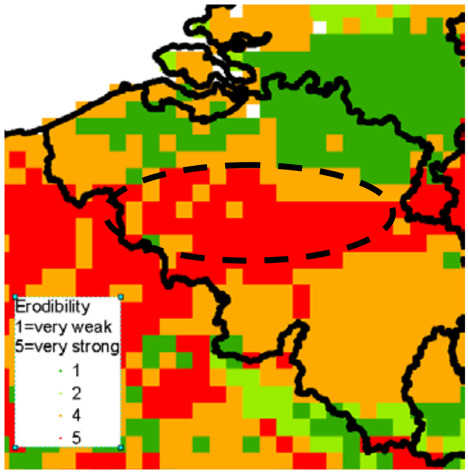


Figure 29: Erodibility derived from the texture layer of the European Soil Map

5.2.4.6 Malta and Cyprus

In the European Soil Map data are missing for Malta and Cyprus

5.3 Methodology

5.3.1 Construction of pedotransfer rule for P retention

5.3.1.1 Parameters influencing the P-retention capacity of the soil

In the pedotransfer rule for P-retention capacities we have included the parameters as listed in the following table.

For each parameter the assumptions on P-sorption or P-movement characteristics based on literature are given together with the corresponding field in the Soil Geographic Database of Eurasia (SGDBE) or the Pedotransfer Rule Database (PTRDB). The six assumptions are as follows:

A1	Finer texture means better P sorption capacities
A2	Higher watertable means less P sorption capacities
A3	More erosion and runoff: more P is removed from the soil
A4	Drainage increases P-losses through leaching
A5	Low or high pH: higher P sorption, neutral pH: lower P sorption Higher content of Al, more P sorption Higher content of Al, more P sorption
A6	More soluble salts: higher P sorption
A7	Shallow soils: lower P sorption

Table 54: Parameters included in the pedotransfer rule

Parameter	P Sorption or movement
Texture	**A1: Finer texture means better P sorption capacities** - Chaudry and Qureshi (1981) reported that P fixation increased with the increase in clay content. - The total phosphorus content of the top soil may be as little as 200 pounds (11 kg) per acre on very sandy soils to over 2500 pounds (1134 kg) per acre on fine textured soils (Withney, 1998).

	Field in SGDBE:
	`TEXT-SRF-DOM (Dominant surface textural class)`
	`----------------`
	`0   No information`
	`9   No mineral texture (Peat soils)`
	`1   Coarse (18% < clay and > 65% sand)`
	`2   Medium (18% < clay < 35% and >= 15% sand, or 18% < clay and 15% < sand < 65%)`
	`3   Medium fine (< 35% clay and < 15% sand)`
	`4   Fine (35% < clay < 60%)`
	`5   Very fine (clay > 60 %)`

Watertable	**A2: Higher watertable means less P sorption capacities** - The extent to which groundwater (and via the groundwater also the surface water) is enriched with phosphate depends in the first place on the characteristics of the water table. Only in soils with a shallow water table will the groundwater be in contact with soil layers saturated with phosphorus. In that case phosphorus will be dissolved in the ground water, and high phosphate concentrations will be measured (Vanongeval and Bomans, 1997).

	Field in SGDBE:
	`WR (Dominant annual average soil water regime class of the soil profile of the STU)`
	`----------------`
	`0   No information`
	`1   Not wet within 80 cm for over 3 months, nor wet within 40 cm for over 1 month`
	`2   Wet within 80 cm for 3 to 6 months, but not wet within 40 cm for over 1 month`
	`3   Wet within 80 cm for over 6 months, but not wet within 40 cm for over 11 months`
	`4   Wet within 40 cm depth for over 11 months`

Runoff and erosion

A3: More erosion and runoff: more P is removed from the soil

- Erosion and crop removal are the major ways soils lose phosphorus (Withney, 1998)
- Phosphate losses can also occur through runoff and erosion processes (Vanongeval and Bomans, 1997).

Combination of field in SGDBE:

SLOPE-DOM (Dominant slope of the STU)
----
0 No information
1 Level (dominant slope ranging from 0 to 8 %)
2 Sloping (dominant slope ranging from 8 to 15 %)
3 Moderately steep (dominant slope ranging from 15 to 25 %)
4 Steep (dominant slope over 25 %)

and of field in PTRDB:

ERODIBILITY = Soil erodibility class.
1 Very weak
2 Weak
3 Moderate
4 Strong
5 Very strong

In the table below the combination of the slope class and erodibility class is shown.
Soils characterized by a very high erosion risk (e.g. slope class 4 together with erodibility class 4) will be ranked 2 classes lower than similar soils without erosion risk. Soils characterized by a normal erosion risk (e.g. slope class 4 together with erodibility class 5) will be ranked 1 class lower than similar soils without erosion risk.

	Slope classes				
Erodibility classes		**1**	**2**	**3**	**4**
	1	0	0	0	0
	2	0	0	0	1
	3	0	0	1	1
	4	0	1	1	2
	5	1	1	2	2

Artificial drainage	**A4: Drainage increases P-losses through leaching** - In case where the field has an artificial drainage system, the phosphate will also rapidly reach the surface water. (Vanongeval and Bomans, 1997). - It should be noted that in some cases, the effect is the opposite if the top soil is better drained allowing to fix more P sorption. For this project A4 is used.
	Field in SGDBE: WM1 (Code for normal presence and purpose of an existing water management system in agricultural land on more than 50% of the STU) ---------------- 0 No information 1 Not applicable (no agriculture) 2 No water management system 3 A water management system exists to alleviate waterlogging (drainage) 4 A water management system exists to alleviate drought stress (irrigation) 5 A water management system exists to alleviate salinity (drainage) 6 A water management system exists to alleviate both waterlogging and drought stress 7 A water management system exists to alleviate both waterlogging and salinity
pH **content of Al** **content of Fe** **content of Ca**	**A5:** **Low or high pH: higher P sorption, neutral pH: lower P sorption** **Higher content of Al, more P sorption** **Higher content of Al, more P sorption** - A low soil pH reflects the likely presence of soluble iron and aluminum which readily react with phosphates to cause fixation as iron and aluminum phosphates. A high soil pH reflects abundance of calcium for fixation as calcium phosphates. The least fixation occurs in the pH range of 6 or 7. (Withney, 1998)
	Field in SGDBE: FAO85-FULL (Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend ---------------- The interpretation of the FAO-UNESCO classes to pH, content of Al, Fe and Ca is described in annex 3.

<table>
<tr><td rowspan="2">Amount of soluble salts</td><td>A6: More soluble salts: higher P sorption

- Precipation of readily soluble salts (chlorides, nitrates,...) occurs where evaporation exceeds rainfall and there is a seasonal or permanent water table close to the soil surface. Such soils are found in hot and arid or semi-arid regions. As there is precipitation or readily soluble salts, all less readily soluble salts (among which sulphates and also phosphates) have been precipitated before. The pH in these soils is commonly high (>7.5). As such, these soils contain little phosphate in solution; all phosphate is precipitated. Although salts may be leached downward by rain or irrigation, the pattern of salt precipitation is re-established during the dry season or when irrigation ceases. This risk of leaching of phosphate salts is comparatively small compared to soluble salts.</td></tr>
<tr><td>Field in SGDBE:
FAO85-FULL (Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend
----
(only corresponding values are listed below)
Z Solonchak
Zg Gleyic Solonchak
Zgf Fluvi-Gleyic Solonchak
Zo Orthic Solonchak
Zt Takyric Solonchak</td></tr>
<tr><td rowspan="2">Depth of the soil</td><td>A7: Shallow soils: lower P sorption

- Because of the lower soil volume, we assume that shallow soils are not capable of fixing the same amount of phosphorus than soils with a normal depth.</td></tr>
<tr><td>Field in SGDBE:
FAO85-FULL (Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend
----
(only corresponding values are listed below)
I Lithosol
Ic Calcaric Lithosol
Ich Humo-Calcaric Lithosol
Id Dystric Lithosol
Ie Eutric Lithosol
U Ranker
Ud Dystric Ranker
Ul Luvic Ranker
E Rendzina
Ec Cambic Rendzina
Eh Histic Rendzina
Eo Orthic Rendzina</td></tr>
</table>

5.3.1.2 Erodibility based on texture classes

As mentioned before the original erodibility layer was not suitable for use. Therefore a new erodibility map was derived in the framework of the current study, based on the texture layer.

The erodibility has been based on the K factor value of the gravitation point of the texture class of the topsoil (Van Rompaey 2001) whereby low K-factor values point to low susceptibility to erosion, high K factor values point to high susceptibility to erosion.

In Figure 30 an overlay is shown of the Belgian texture classification (marked by solid graduated grey areas) with the European texture classification (delineated by thick black line). The K factor values of the Belgian texture classes are known and have been interpolated to European texture classes. This interpolation has been weighted by area values.

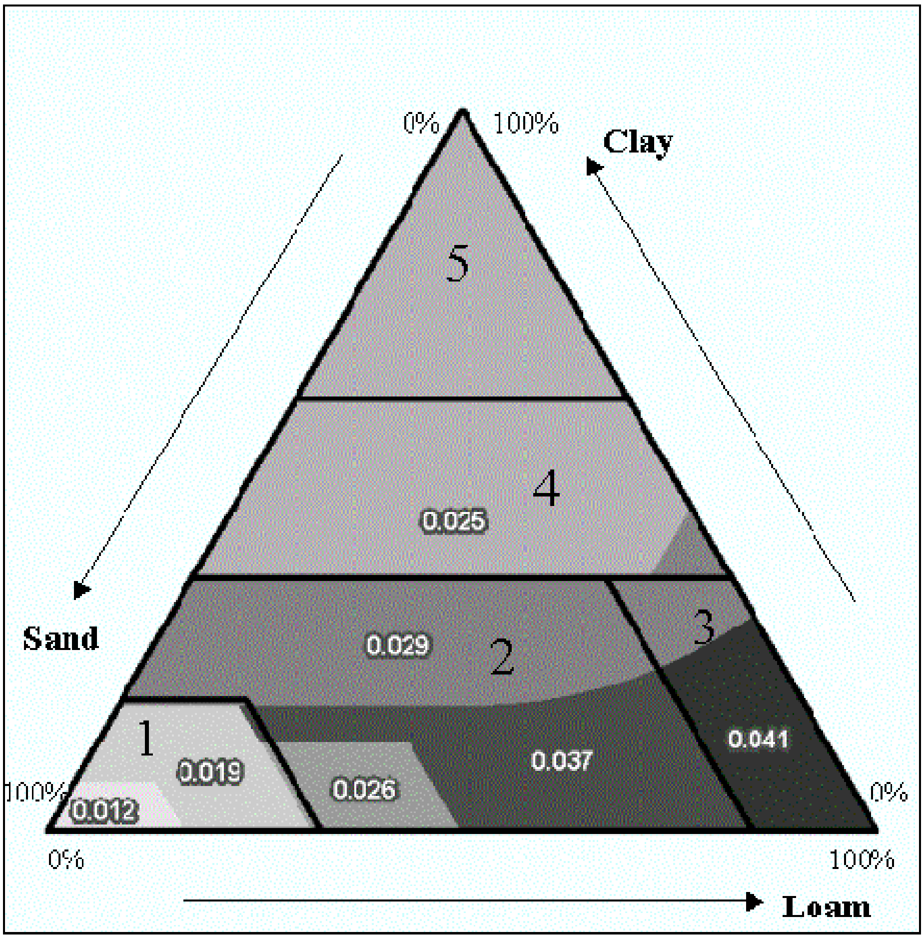


Figure 30: Overlay of Belgian Texture Triangle and corresponding K factor values (erodibility indicators) with texture classes of the TEXT-SRF-DOM input layer

5.3.1.3 Interpretation of the FAO-UNESCO Soil Reference Groups

Not all parameters that influence the P Sorption capacities are present as such in the European Soil Map. However some of the FAO-UNESCO Soil Reference Groups and Soil Qualifiers are characterized by those parameters and can provide us extra information about the P sorption capacities of the soil.

The FAO85FU attribute is the Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend. Therefore an expert-based interpretation of the FAO-UNESCO soil classes has been made in terms of the P-sorption properties, mainly considering pH, content of Al, content of Fe and content of Ca.

A detailed description of this interpretation along with frequency maps of the FAO-UNESCO Soil Reference Groups and Soil Qualifiers are provided in the annex.

The characteristics of the FAO-UNESCO Soil Reference Groups and Soil Qualifiers are summarized in the following tables. A parameter coded '1' means that this parameter is influencing the P sorption capacity of the soil class positively. No value means that the parameter is not determinatively influencing the P sorption capacities.

The parameter pH is coded ‘L’ (low) or ‘H’ (high). In both cases the P sorption capacities are increased.

Table 55: Interpretation of the FAO-UNESCO soil groups according to P sorption parameters

Soil Group	Content of Al	Content of Fe	Content of Ca	pH	Belongs to P sorption class
Acrisol	1	1			3, 4 or 5
Andosol	1	1			4 or 5
Arenosol					1 or 2
Cambisol					
Chernozem			1		
Fluvisol					
Gleysol					
Greyzem					
Histosol					1
Lithisol					1 or (-1, see annex 3)
Luvisol			1		
Phaeozem			1		
Planosol					
Podzol	1	1		L	
Podzoluvisol		1		L	
Ranker				L	1 or (-1, see annex 3)
Regosol					
Rendzina			1		1 or (-1, see annex 3)
Solonchak					(+1, see annex 3)
Solonetz				H	
Vertisol					5
Xerosol			1		

Table 56: Interpretation of the FAO-UNESCO soil qualifiers according to P sorption parameters

Qualifier	Content of Al	Content of Fe	Content of Ca	pH	Belongs to P sorption class
Albic					
Andic / Ando	1	1			4 or 5
Calcaric / Calcaro			1	H	
Calcic			1	H	
Cambic					
Chromic / Chromo					
Dystric / Dystri				L	
Eutric				H	
Ferric / Ferro		1			
Fluvic / Fluvi					
Gleyic / Gleyo					
Gypsic			1	H	
Haplic					
Humic / Humo					
Leptic					
Luvic			1		
Mollic / Molli				H	
Ochric					
Orthic					
Pellic					
Placic		1			
Stagnic					
Vertic					5
Histic					
Planic					
Rhodic					
Spodic	1	1		L	

5.3.2 Pedotransfer rule Scheme

In paragraph 5.3.1 Construction of pedotransfer rule for P , we have summarized the parameters that influence the behavior of phosphorus in the soil. In accordance to these parameters, a pedotransfer rule was developed to map the European soils into the 5 P sorption classes listed in the following table.

Table 57: Qualitative P sorption soil classes

Class	Description
1	Soils with low P sorption capacities
2	Soils with moderate sorption capacities
3	Soils with good sorption capacities
4	Soils with strong P sorption capacities
5	Soils with very strong sorption capacities

This section explains the construction of pedotransfer rules that combine all those parameters and weights them according to their influence on P sorption capacities.The figure below represents schematically how the pedotransfer rule is put together to evaluate European soil on their P Sorption capacities.

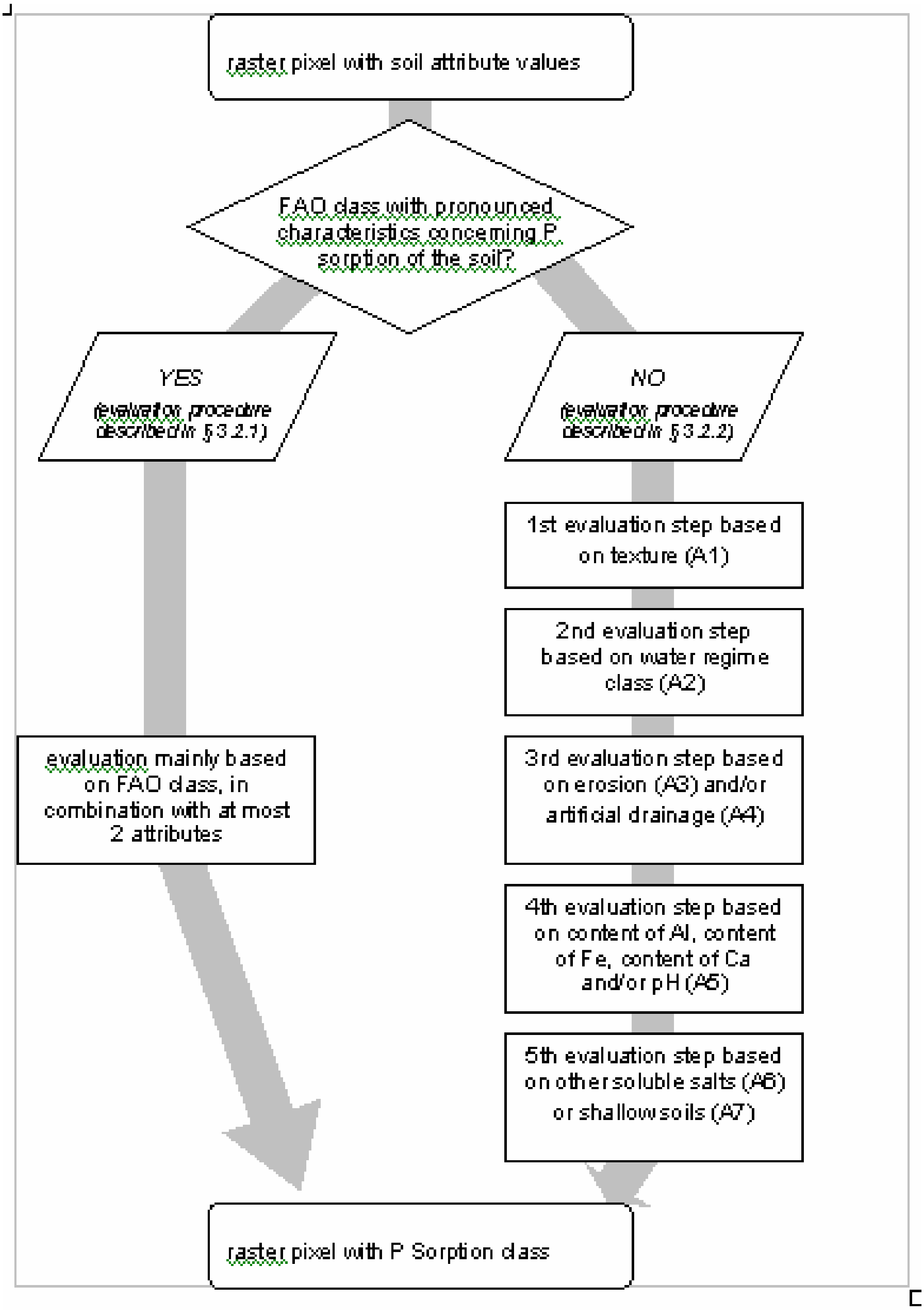


Figure 31: Pedotransfer rule schema for evaluation of P Sorption capacities of the soil

The successive evaluation steps refer to the assumptions as listed in Table 55.

5.3.2.1 *Evaluation of FAO-UNESCO attributes*

Some FAO-UNESCO Soil Reference Groups or Soil qualifiers have such pronounced characteristics concerning P retention that no further evaluation of all other attributes of those soils are needed. This is schematically represented in the previous figure.

These soils with pronounced characteristics because of their FAO-UNESCO attributes are listed in the table below. The column "P Sorption Class" refers to the classification of these soils into the 5 possible P Sorption classes as described in Table 54.

Table 58: Evaluation of FAO-UNESCO attributes with pronounced characteristics with respect to P-sorption capacities

Soil description	**FAO-UNESCO attributes**	**P Sorption Class**
Peat soils	Histosols	1
Shallow soils	Lithisols, Rendzinas or Rankers that occur together with a wet water regime (WR=4, see Table 56) and erosion	1
Sandy soils	Arenosols	
	with qualifier calcic, calcaric, gypsic or luvic or with a dry water regime (WR=1, see Table 56)	2
	else	1
Soils with very active clay	Vertisols or vertic soils	5
Volcanic soils	Andosols or andic soils	
	on steep slopes (slope-dom=4, see Table 56)	5
	on moderate slopes (slope-dom=2 or 3, see Table 56))	4
	on leveled land (slope-dom=1, see Table 56)	3

5.3.2.2 *Evaluation of attributes of the European Soil Map*

For FAO-UNESCO soils with less pronounced characteristics considering P-retention, a different evaluation procedure is developed. In this case the evaluation is a concatenation of the following steps:

- texture,
- height of water table,

- runoff and erosion (optional) and/or presence of artificial drainage (optional),
- content of Al, content of Fe, content of Ca, pH,
- other properties resulting from FAO-UNESCO interpretation.

Erosion and artificial drainage are parameters that influence the physical properties of the soil, whereas the other parameters mentioned above affect the chemical processes within the soil. Therefore the evaluation will also be executed without considering erosion and/or artificial drainage (see results, 5.4).

Some FAO-UNESCO attributes imply relevant properties considering P sorption, may it be not so pronounced as those mentioned in paragraph 5.3.2.1.

5.3.2.2.1 1st evaluation step: Influence of texture (A1)

Texture is the first parameter to be considered in this evaluation procedure. In this stage the soils will be assigned to a P sorption class for the first time. In all further steps (as described in the paragraphs below) this initial P sorption class assignment can shift one class higher or lower, depending on the values of the parameter attributes. In the table below the first division based on the texture parameter is shown.

Table 59: Evaluation of texture (text-srf-dom attribute)

Class code	Class description	P Sorption Class
9	No mineral texture (Peat soils)	1
1	Coarse (18% < clay and > 65% sand)	2
2	Medium (18% < clay < 35% and >= 15% sand, or 18% < clay and 15% < sand < 65%)	3
3	Medium fine (< 35% clay and < 15% sand)	5
4	Fine (35% < clay < 60%)	5
5	Very fine (clay > 60 %)	5

5.3.2.2.2 2nd evaluation step: Influence of watertable (A2)

The P sorption class, determined by texture alone (paragraph 5.3.2.2.1) is adjusted according to the watertable attribute. Very wet soils are ranked one class lower whereas there is no change in P sorption class for soils that are not very wet.

The first rough division as described above will now be adjusted according to the watertable attribute. Very wet soils will be ranked in a lower class, whereas for soils that do not suffer from water abundance there will be no shift in P sorption class.

Table 60: Evaluation of height of water table (input layer WR)

Class code	Class description	P Sorption Class shift
1	Not wet within 80 cm for over 3 months, nor wet within 40 cm for over 1 month	No shift
2	Wet within 80 cm for 3 to 6 months, but not wet within 40 cm for over 1 month	No shift
3	Wet within 80 cm for over 6 months, but not wet within 40 cm for over 11 months	No shift
4	Wet within 40 cm depth for over 11 months	1 class lower

In addition where FAO-UNESCO soil classes also refer to water abundance, the P sorption class is lowered by one. The effects are not accumulative, meaning that in this evaluation step a shift can be at most one class.

Table 61: FAO-UNESCO attributes that refer to water abundance (input layer FAO85FU)

Class code	Class description	P Sorption Class shift
Gleysol	See annex 3	1 class lower
gleyic	See annex 3	1 class lower
stagnic	See annex 3	1 class lower

5.3.2.2.3 3rd evaluation step: Influence of erosion and runoff (A3) and/or presence of artificial drainage (A4)

A further adjustment of the P sorption class will be done based on the risk for erosion and/or artificial drainage. These two parameters are evaluated in the same step, since those two parameters influence the physical properties of the soil.

The effects of both parameters are not accumulative, meaning that the combination of erosion risk and the presence of artificial drainage does not result in two separate shifts. An overview of the combination of the two parameters and the resulting shift in the P sorption classes is given below.

Table 62: Evaluation of erosion (see Table 56) and artificial drainage (WM1 attribute)

Class code erosion	**Class code artificial drainage**	**Description** **(see also table 4)**	**P Sorption Class shift**
0	1, 2, 4	No erosion risk an no artificial drainage	No shift
0	3, 5, 6, 7	No erosion risk but artificial drainage present	1 class lower
1	1, 2, 4	Normal erosion risk but no artificial drainage	1 class lower
1	3, 5, 6, 7	Normal erosion risk and artificial drainage present	1 class lower
2	1, 2, 4	High erosion risk but no artificial drainage present	2 classes lower
2	3, 5, 6, 7	High erosion risk and artificial drainage present	2 classes lower

5.3.2.2.4 4th evaluation step: Influence of the content of Al, Fe or Ca and/or the pH (A5)

Some FAO-UNESCO soil types point to a high content of Al, Fe or Ca and/or a low or high pH result. If any condition is fulfilled, the soil will be shifted to a higher class, indicating more P sorption capacities. There is no cumulative effect if more conditions are fulfilled, meaning that in this step the shift will never be larger than 1 class. An overview is given below.

Table 63: Evaluation of content of Al, Fe or Ca and/or pH

<table>
<tr><th>Parameter</th><th>Corresponding FAO-UNESCO attribute values</th><th>P Sorption Class shift</th></tr>
<tr><td>High content of Al</td><td>Podzol, Podzoluvisol, placic or spodic</td><td rowspan="4">1 class higher</td></tr>
<tr><td>High content of Fe</td><td>Podzol, Podzoluvisol, ferric, placic or spodic</td></tr>
<tr><td>High content of Ca</td><td>Chernozem, Luvisol, Phaeozem, Rendzina, Xerosol, calcaric, calcic, gypsic or luvic</td></tr>
<tr><td>Not neutral pH</td><td>Podzol, Solonetz, calcaric, calcic, dystric, eutric or gypsic</td></tr>
</table>

5.3.2.2.5 5th evaluation step: Influence of other properties resulting from FAO-UNESCO interpretation (A6, A7)

The final adjustment of the P sorption class is done based on some FAO-UNESCO attributes that imply relevant properties considering P sorption, but are not so pronounced as those mentioned in § 3.2.1. It concerns very shallow soils that do not suffer from erosion and water abundance or soils with a large amount of soluble salts. An overview is given in the table below.

Table 64: Evaluation of other properties resulting from FAO-UNESCO interpretation (see table 4 and annex 3)

Parameter	**Corresponding FAO-UNESCO attribute values**	**P Sorption Class shift**
Shallow soils	Lithisol, ranker, rendzina	1 class lower
Soils with soluble salts	Solonchak	1 class lower

5.3.2.2.6 Example procedure for assigning P sorption classes

In order to illustrate the principles we have evaluated a soil unit (dystric cambisol) located in Italy (see map below).

Because of the relatively coarse texture (only texture class 1 is coarser) this soil has initially been divided into P sorption class 3. It's a dry soil (water table class 1) meaning that there is no negative influence because of water abundance. No artificial drainage system is present, but since there is a risk for erosion, the soil example will be ranked one class lower and is at this stage in P sorption class 2. However the "dystric" soil qualifier (generally) refers to a low pH, resulting in a higher P sorption capacity and therefore a shift to a higher P sorption class.

After going through all steps this unit comes out as a soil with good P sorption capacities (P sorption class 3).

Figure 32: Location of the soil unit example

Table 65: Evaluation of example in this stage

Parameter values	**Evaluation steps**	**Shift**	**resulting P sorption class**
Texture class = 2	1st evaluation	/	3
Water table class = 1	2nd evaluation	0	3
Artificial drainage class = 2	3rd evaluation	-1	2
Erosion class = 1			
FAO = Dystric Cambisol	4th evaluation	+1	3
FAO = Dystric Cambisol	5th evaluation	0	3
	Final evaluation		**3**

The evalution has been done without considering the erosion risk. Including erosion would mean a shift of P retention from class 3 to class 4.

5.3.3 Technical specifications

5.3.3.1 Preparation for analysis

5.3.3.1.1 Input layers

FAO85FU	FAO-UNESCO classification
SLOPEDO	Slope
TXSRFDO	Texture
WM1	Presence of artificial drainage
WR	Height of water table
(ERODI)	Erodibility

For a full description of the input data see 5.2..

5.3.3.1.2 Masking

Since the original raster layers cover a much larger region than our study area, we have masked our input layers. The masking was done by the Spatial Analyst extension of ArcGIS, the analysis mask was a raster layer of the 25 Member States of the European Union.

Extent of the original raster data layers	**Original raster layer overlayed with the mask of the EU25**	**Resulting masked raster data layer**

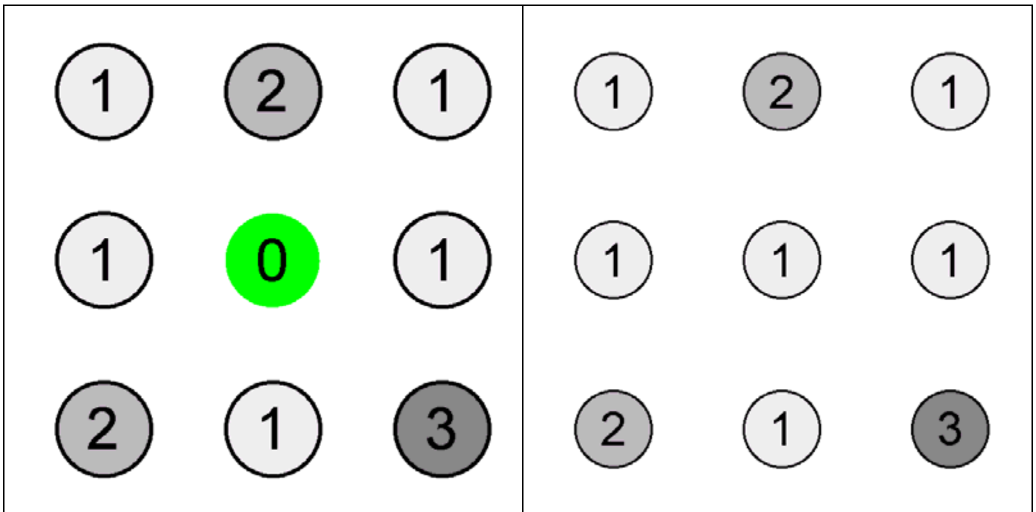
Figure 33: Masking

5.3.3.1.3 Raster to feature point conversion

All rasters have been converted to point feature classes using the conversion toolset of ArcGIS. Each point is located in the center of the original raster pixel. This was done because point feature classes have some advantages for processing.

5.3.3.1.4 Interpolation of points without attribute values ("NoData")

In case an attribute value was missing for a point an interpolation has been done based on the majority of the neighboring cells as illustrated in the figure below.



A point with no data	**After interpolation based on the majority of the neighbouring cells**

Figure 34: Interpolation of missing value

The frequency of missing attribute values is about 2,25%. In the table below the percentage of raster pixels without attribute values (thus the percentage of interpolated values) in the input layers is given.

Table 66: Frequency of raster pixels in the original layers with missing attribute values

Input layer	Description	% of missing attribute values
TXSRFDO	Texture	2.71
WR	Water table	2.01
SLOPEDO	Slope	2.34
WM1	Artificial drainage	No data for Sweden, no interpolation possible
FAO85FU	FAO-UNESCO classification	1.97

For Sweden no data were available concerning the presence of artificial drainage. We could not interpolate this attribute for Sweden. Because of this lack of data we do not consider this parameter for Sweden. This should be taken into consideration while interpreting the results.

5.3.3.2 *Spatial join*

In order to facilitate the processing we have integrated the attributes of all input layers into one central layer by using the Spatial Join tool of ArcGIS.

5.3.4 ***Analysis***

5.3.4.1 *Evaluation of P Sorption capacities*

The pedotransfer rule has been coded in VBA. The entire code is attached in the annex.

5.3.4.2 *Frequency analysis - NUTS II/III regions*

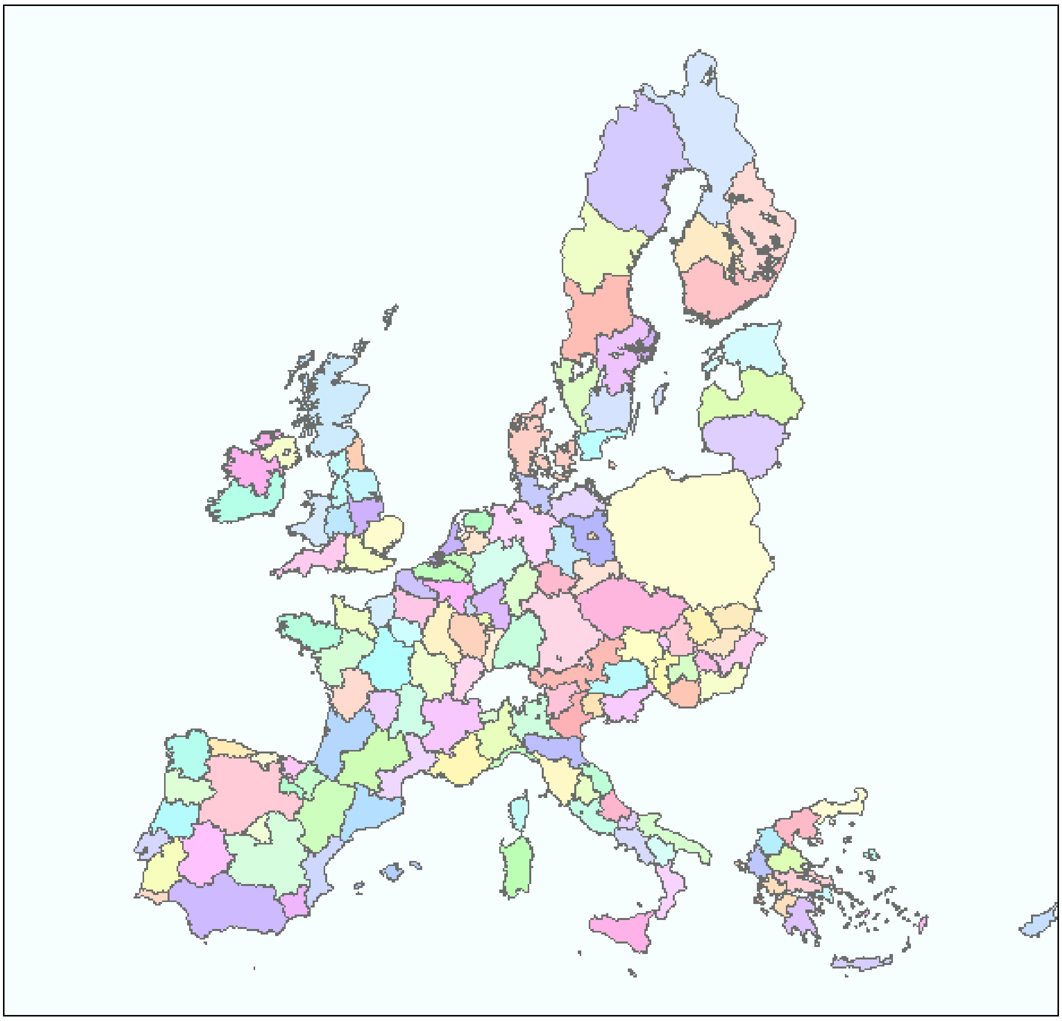


Figure 35: NUTS II/III Regions for frequency analysis

By using the Identify tool of ArtGIS9 we added the NUTS II/III region to the soil pixels. A complete list of the NUTS II/III regions was given in Table 22. Frequency analyses have been carried out at the EU level, national level and NUTS II/III level.

5.4 RESULTS

5.4.1 Mapping the overall P-sensitivity

Erosion and artificial drainage are parameters that influence the physical properties of the soil, whereas the other parameters mentioned above affect the chemical processes within the soil. Therefore the evaluation will also be executed without considering erosion and/or artificial drainage.

In Figure 36, P-retention classes have been mapped, taking into account the potential effects of erosion or artificial drainage.

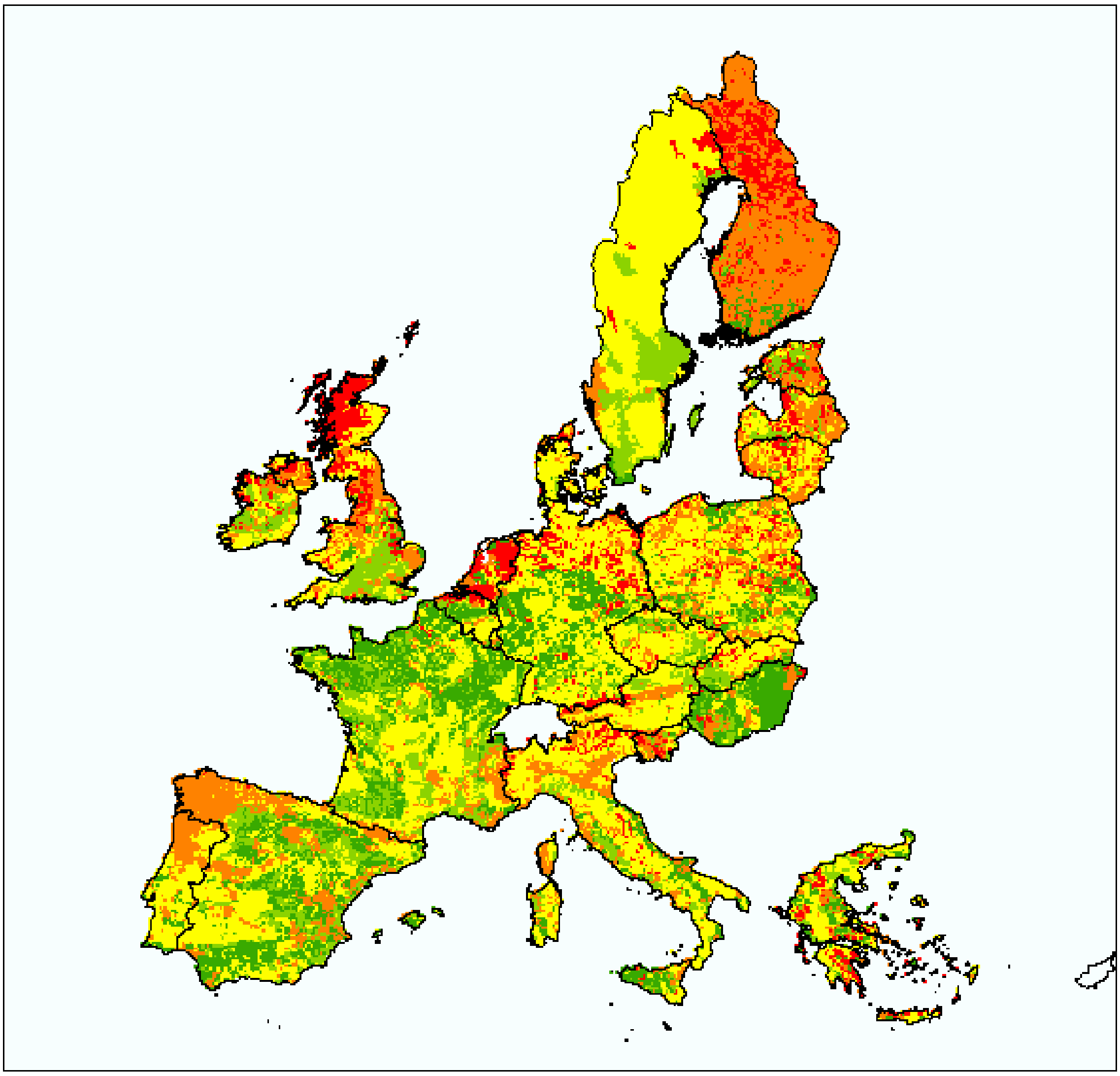


Figure 36: P retention classes in EU25 (including influence of erosion and artificial drainage)

Red colour corresponds to class 1, very weak P retention capacities, dark green corresponds to class 5, very strong P retention capacities, transitional colours correspond to transitional classes

As can be seen from this map, very dense clusters of soils with very low P retention capacities (class 1) can be found in Finland, Scotland, North England, North Ireland, the Netherlands, the North of Belgium and the Baltic states.

Scattered clusters of soils with very low P-retention capacities (class 1) can be found in the North of Germany, Poland and Greece.

An overview of these regions and the typical soils with very low P sorption capacities is given below. For each soil type is indicated whether its P retention capacities are influenced by the presence of artificial drainage and/or erosion.

Table 67: Regions with clusters of soils with very low P retention capacities (class 1)

Member state	**NUTS**	**Soils with very low P sorption capacities**	**Infl. of art. drain**	**Infl. of ero-sion**	**Area (100 km²)**
Finland	FI	• Histosols • Lithisols characterized by a very coarse texture and artificially drained	/ yes	/ /	904 53
Scotland	UKM	• Histosols or soils with peat texture	/	/	460
North England	UKC UKD UKE	• Gleysols characterized by a medium coarse texture that are artificially drained and suffer from erosion • Histosols or soils with peat texture • Gleysols with a very coarse texture that are artificially drained	yes / yes	yes / /	65 28 14
North Ireland	UKN	• Gleysols characterized by a very to medium coarse texture of which some are artificially drained and some suffer from erosion • Histosols or soils with peat texture	yes /	yes /	28 16

The Netherlands and the North of Belgium	NL BE1 BE2	• Very wet and artificially drained podzols • Histosols	yes /	/ /	173 45
Baltic states	EE LV LT	• Histosols or soils with peat texture • Gleysols characterized by a very coarse texture and artificially drained • Very wet and artificially drained cambisols characterized by a medium coarse texture • Very wet and artificially drained podzols	/ yes yes yes	/ / / /	142 71 61 37
North of Germany (less dense cluster)	DE4 DE8 DE9 DEE	• Histosols • Gleysols characterized by a very coarse texture • Very wet cambisols with a very coarse texture	/ / /	/ / /	137 74 72
Poland (less dense cluster)	PL	• Histosols • Very wet and artificially drained luvisols with a very coarse texture	/ yes	/ /	166 86
Greece (less dense cluster)	GR	• Lithisols that are at great risk for erosion	/	yes	231

Also clusters of soils with low P retention capacities (class 2, orange colour) are detected. These clusters are found in the Northwest of Spain and in the Alps.

Table 68: Regions with clusters of soils with low P retention capacities (class 2)

Region		**Soils with very low P sorption capacities**	**Infl. of art. drain**	**Infl. of ero-sion**	**Area (100 km²)**
North-west of Spain and North of Portugal	ES11 ES12 ES13 PT11 PT12	Cambisols characterized by a very to medium coarse texture of which some are artificially drained and some suffer from erosion	/	yes	468
		Rankers with a medium coarse texture that suffer from erosion	/	yes	164
Alps		Rendzinas with medium coarse texture that are at great erosion risk	/	yes	60
		Lithisols with a very to medium coarse texture that suffer from erosion	/	yes	16

In the table below an overview of the distribution of the different FAO-UNESCO Soil Groups over the 5 P retention classes is given.

Most soils of P retention class 1 are histosols, along with some gleysols, podzols and rendzinas. Soil in the highest class are mainly cambisols. These cambisols are usually rich in calcium or have very active clay (vertic properties).

Table 69: Distribution of the different FAO-UNESCO Soil Reference Groups over the 5 P retention classes

	1	**2**	**3**	**4**	**5**	**Total**
Acrisol	0.00	0.00	0.00	0.02	0.22	0.24
Andosol	0.00	0.00	0.00	0.18	0.00	0.18
Arenosol	0.03	1.92	0.00	0.00	0.00	1.95
Cambisol	0.40	3.55	**14.39**	**4.60**	**7.90**	30.84
Chernozem	0.00	0.00	0.05	0.28	0.40	0.73
Fluvisol	0.08	0.48	0.97	2.33	0.79	4.64
Gleysol	1.11	1.34	0.46	0.67	0.04	3.62
Greyzem	0.00	0.00	0.01	0.00	0.00	0.01
Histosol	**4.99**	0.00	0.00	0.00	0.00	4.99
Lithisol	0.79	2.84	0.13	0.00	0.24	3.99
Luvisol	0.24	2.54	4.97	2.31	3.28	13.34
Phaeozem	0.00	0.02	0.01	0.08	0.92	1.02
Planosol	0.00	0.02	0.20	0.02	0.01	0.25
Podzol	0.81	**5.97**	13.90	0.92	0.00	21.59
Podzoluvi	0.00	0.32	1.02	0.44	0.37	2.15
Ranker	0.14	0.95	0.01	0.00	0.00	1.10
Regosol	0.00	0.00	3.47	0.55	0.04	4.06
Rendzina	0.74	0.62	2.04	0.59	0.19	4.17
Solonchak	0.00	0.00	0.03	0.08	0.06	0.17
Solonetz	0.00	0.00	0.00	0.00	0.10	0.11
Vertisol	0.00	0.00	0.00	0.00	0.42	0.42
Xerosol	0.00	0.00	0.18	0.17	0.08	0.43

5.4.2 Taking out the effect of drainage

Because of the lack of harmonization of the water management input layer (indication presence of artificial drainage, issue discussed in 5.2.4.3) a map of P sorption classes that do not include the effect of artificial drainage is more appropriate for assessment of the P-risk. The differences (compare Figure 36 and Figure 37) are very pronounced in Finland, but are also detected in the Netherlands, the Baltic States and the North of England.

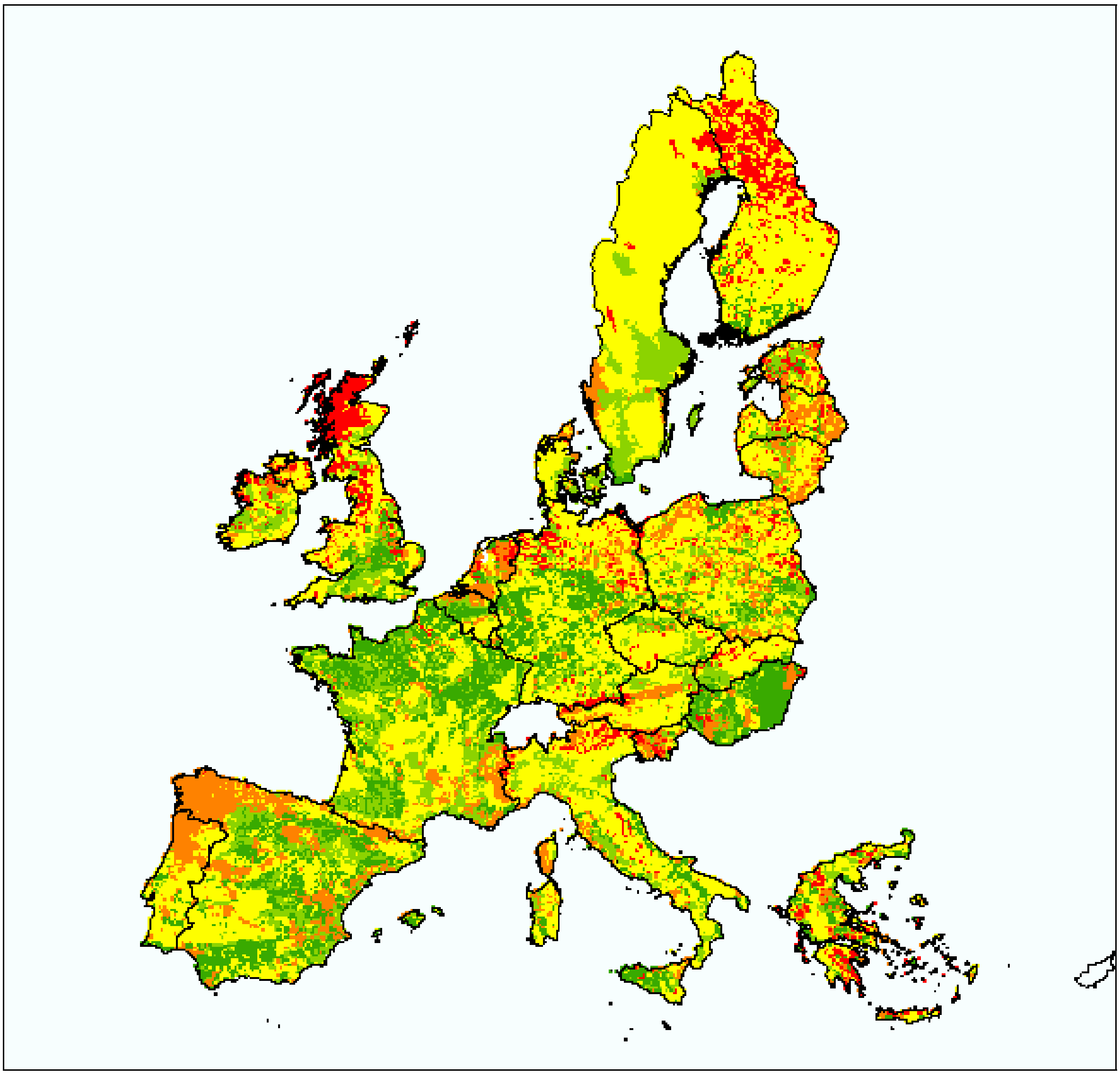


Figure 37: P retention classes in EU25 (including the influence of erosion, but not the influence of artificial drainage)

Red colour corresponds to class 1, very weak P retention capacities, dark green corresponds to class 5, very strong P retention capacities, transitional colours correspond to transitional classes

5.4.3 Taking out the erosion effect

Similarly if we can take out the effect of erosion, this effect is clearly observed in Central Europe, Sweden, Portugal, the West of Spain, Greece and mountain ranges (Pyrenees, Alps, Appenines and Carpathian).

Because of the doubts concerning the data on drainage map and the known importance of the erosion factor, this map seems less relevant for the assessment of the sensitivity of the soils to P-surplus.

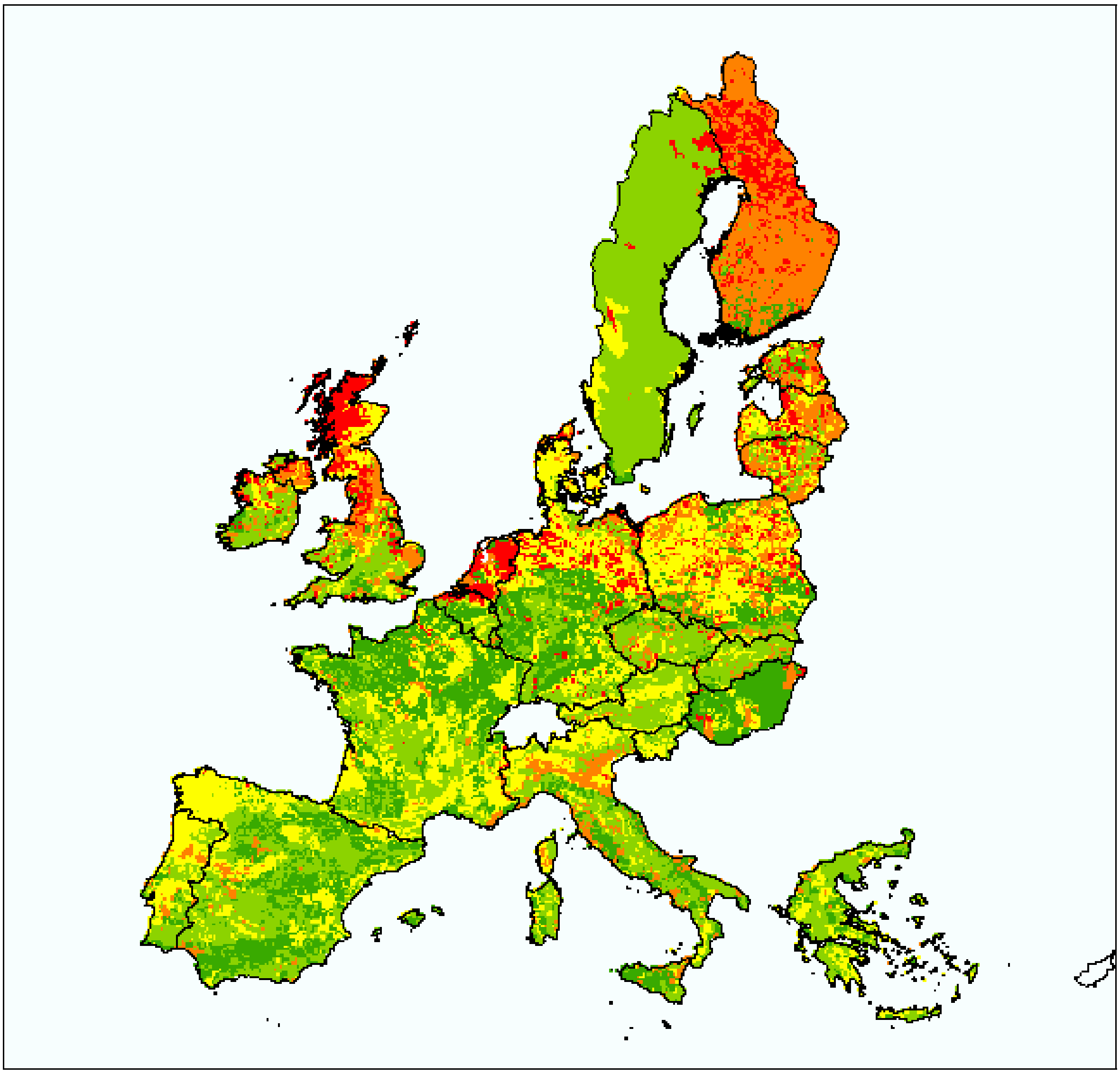


Figure 38: P Sorption classes in EU25 (including the influence of artificial drainage, but not the influence of erosion)

Red colour corresponds to class 1, very weak P sorption capacities, dark green corresponds to class 5, very strong P sorption capacities, transitional colours correspond to transitional classes

5.4.4 Intrinsic sensitivity due to sorption capacity

Finally in the map below, the P sorption mapping was done, not considering erosion nor artificial drainage. This means that the retention capacity of the soil is entirely due to physico-chemical sorption. In other words, this maps reflects the intrinsic property of the soil to chemically fix phosphorus.

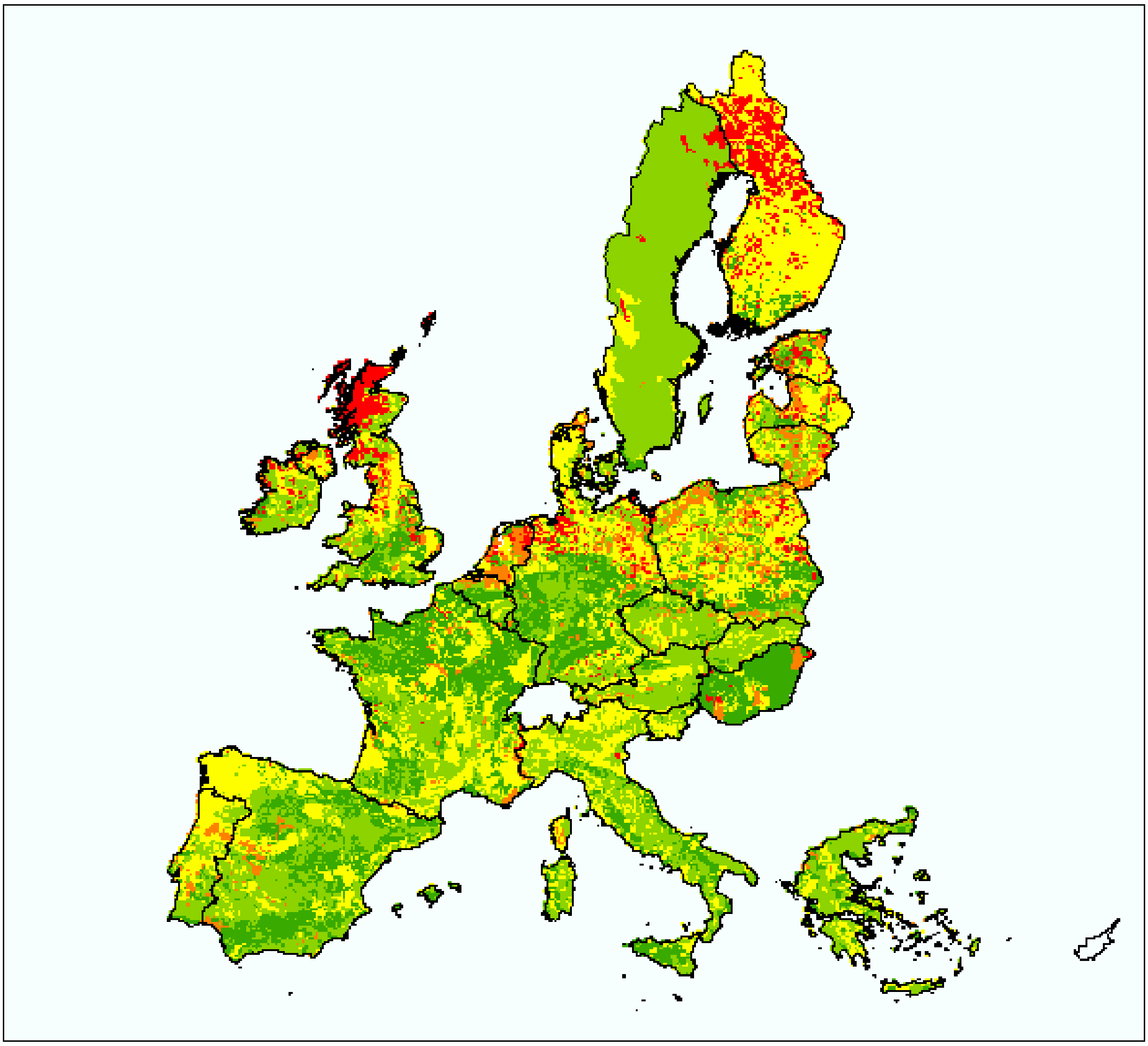


Figure 39: P Sorption classes in EU25 (not including the influence of artificial drainage or erosion)

Red colour corresponds to class 1, very weak P sorption capacities, dark green corresponds to class 5, very strong P sorption capacities, transitional colours correspond to transitional classes

5.4.5 *Importance of the erosion factor*

Since erosion and runoff is of major importance for losses of phosphor to the surface waters, it is also worth considering which regions are mostly at risk for erosion. In the map below it is clear that erosion mostly corresponds to the mountain ranges and the central European loess belt.

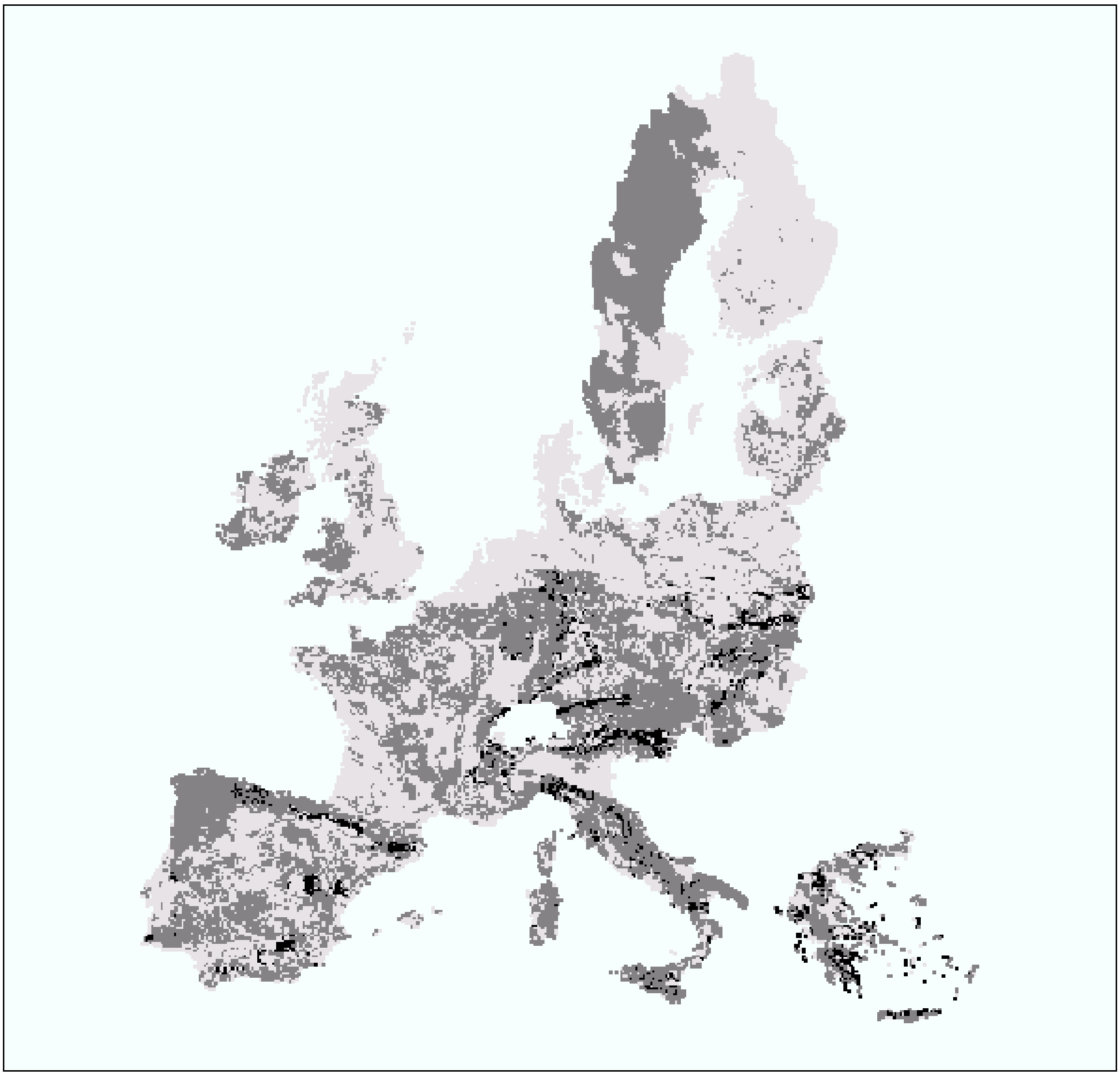


Figure 40: Erosion risk assessment in EU25

Black corresponds to very strong erosion risk, middle grey correspond to normal erosion risk and light grey corresponds to low erosion risk

5.4.6 Frequency analysis at European level

In following figure provides an overview is given of the distribution of the European soil over the 5 different P retention classes. In correspondence with the previous maps this was done including or taking out the effect of artificial drainage and/or erosion.

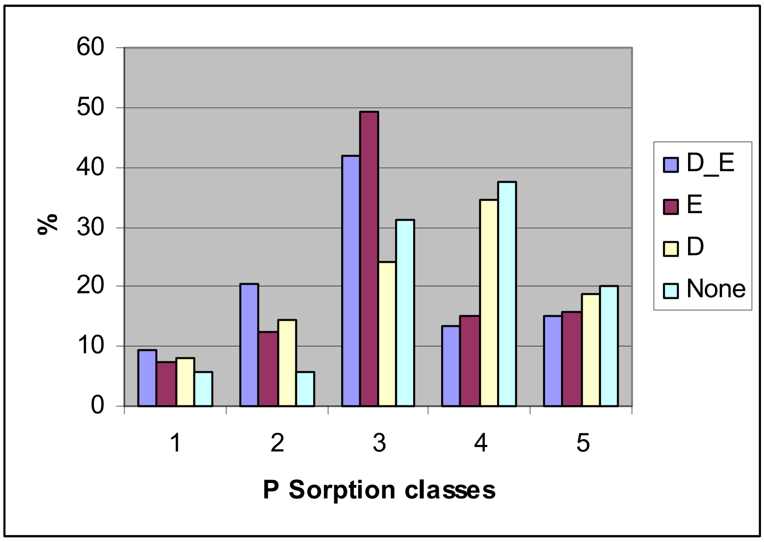


Figure 41: Frequency diagram of the different P retention classes of the European Soil Map

D_E= P retention classes including the effect of drainage and erosion
E= P retention classes including the effect of erosion
D= P retention classes including the effect of drainage
None = P retention classes not including the effects of drainage or erosion

5.4.7 Frequency analysis at national level

Because of the lack of harmonization of the water management input layer (indicator for presence of artificial drainage) as described above, we have based the following frequency analysis of the P Sorption classes without considering artificial drainage, but including the erosion risk, thus corresponding to the map in Figure 37.

In the following diagram (Figure 42) and the table (Table 70) the share of the 5 P retention classes for each Member State (except for Malta and Cyprus) are given. Notably for Hungary is the very high frequency of class 5 (very strong P retention capacities).

Other countries with rather high frequencies (> 20%) for class 5 are Belgium, Germany, Spain, France and Luxemburg.

For class 1 we find high frequencies for Finland, Slovenia and the United Kingdom.

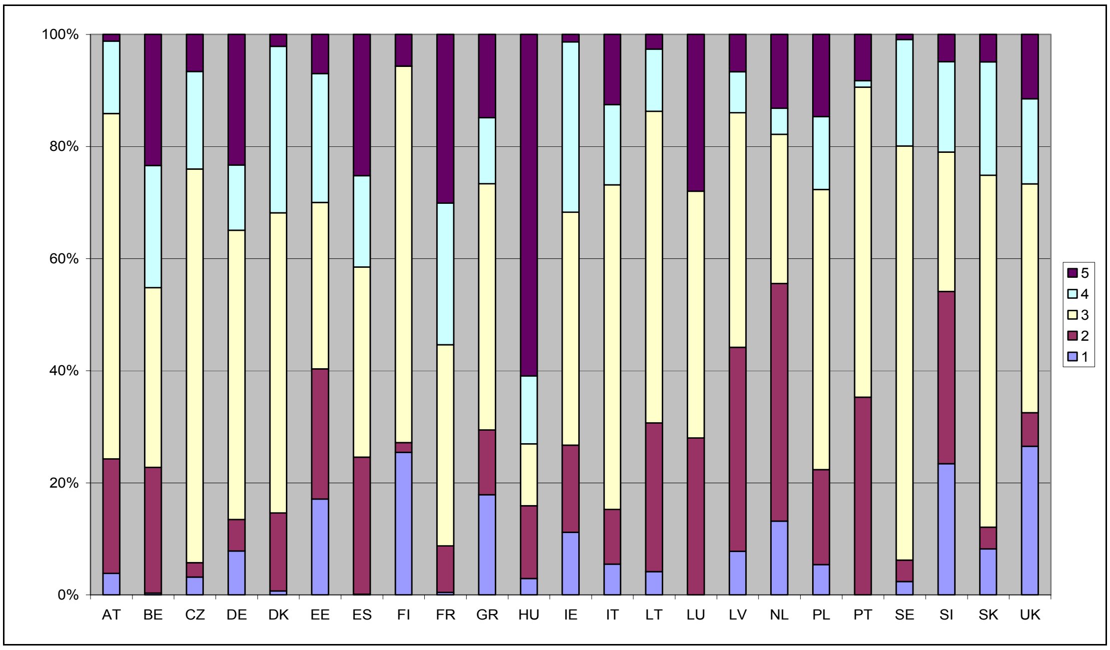


Figure 42: Proportional distribution of the 5 P classes for each Member State (class 1 = very low P retention capacities)

Table 70: Proportional distribution of the 5 P classes for each Member State (class 1 = very low P retention capacities)

	1	**2**	**3**	**4**	**5**
AT	4	20	62	13	1
BE	0	22	32	22	23
CZ	3	3	70	17	7
DE	8	6	52	12	23
DK	1	14	54	30	2
EE	17	23	30	23	7
ES	0	24	34	16	25
FI	25	2	67	0	6
FR	0	8	36	25	30
GR	18	12	44	12	15
HU	3	13	11	12	61
IE	11	16	42	30	1
IT	5	10	58	14	13
LT	4	27	56	11	3
LU	0	28	44	0	28
LV	8	36	42	7	7
NL	13	42	27	5	13
PL	5	17	50	13	15
PT	0	35	55	1	8
SE	2	4	74	19	1
SL	23	31	25	16	5
SK	8	4	63	20	5
UK	27	6	41	15	11

When combining class 1 and 2 (very low and low P retention capacities), we notice that the Netherlands (56%), Slovenia (54%), Latvia (44%) and Estonia (40%) show the highest occurrence of sensitive soils.

Table 71: Proportion (%) of P sorption classes 1 and 2 per MS

MS	% in 1 and 2	MS	% in 1 and 2
NL	56	AT	24
SL	54	BE	23
LV	44	PL	22
EE	40	HU	16
PT	35	IT	15
UK	33	DK	15
LT	31	DE	13
GR	29	SK	12
LU	28	FR	9
FI	27	SE	6
IE	27	CZ	6
ES	25		

When combining class 4 and 5 (very high and high P sorption capacities), we notice that Hungary (73%), France (55%), Belgium (45%) and Spain (41%) show the highest frequencies.

Table 72: Proportion (%) of P sorption classes 4 and 5 per MS

MS	% in 4 and 5	MS	% in 4 and 5
HU	73	GR	27
FR	55	SK	25
BE	45	CZ	24
ES	41	SI	21
DE	35	SE	20
DK	32	NL	18
IE	32	AT	14
EE	30	LV	14
LU	28	LT	14
PL	28	PT	9
IT	27	FI	6
UK	27		

5.4.8 *Frequency analysis at NUTS II/III level*

The NUTS II/III regions as listed in the following show the highest share of soils in P retention class 1.

These regions correspond to the clusters of soils with very low P retention capacities as described in Table 67.

Table 73: 10 NUTS II/III regions with the highest share of P sensitivity class 1

Order	NUTS	P sensitivity class 1 (% of NUTS Area)
1	GR22	70
2	UKM	60
3	FI15	41
4	GR25	40
5	UKD	31
6	IT33	29
7	NL1	29
8	GR43	28
9	DE9	27
10	UKE	26

Similarly we investigated which NUTS II/III regions have a high proportion of soils with very strong P retention capacities. These regions are listed in the following table.

Table 74: 10 NUTS II/III regions with the highest share of P sensitivity class 5

Order	NUTS	P sensitivity class 5 (% of NUTS area)
1	HU05	86
2	HU06	73
3	FR25	69
4	HU07	65
5	FR3	64
6	FR23	62
7	FR41	61
8	HU02	59
9	HU03	58
10	DEB	56

A map of these regions is represented in the following figure.

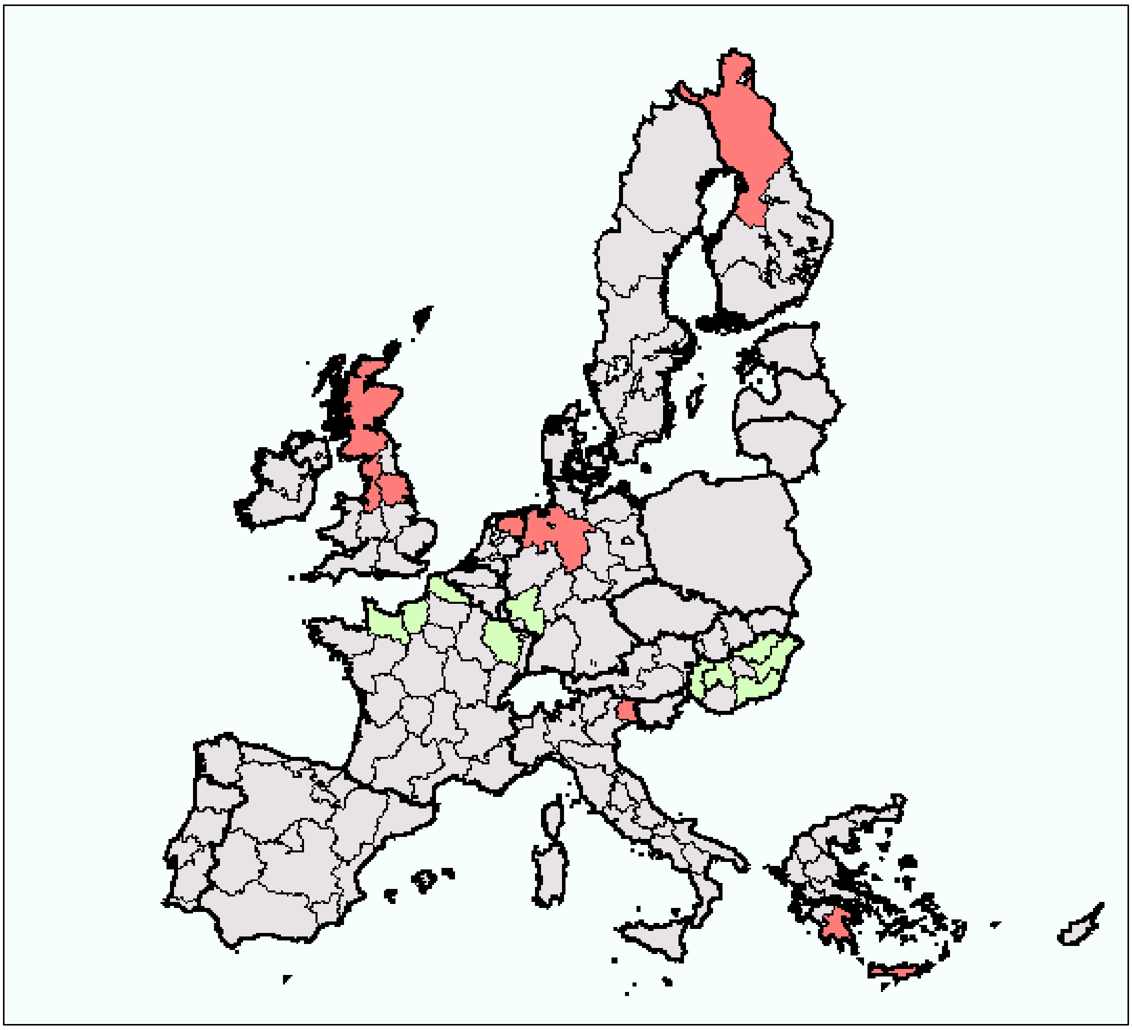


Figure 43: 10 NUTS II/III regions with the highest/lowest share of P-sensitive soils

Green colour: NUTS II/III regions with the highest share of P retention class 5 (very high P retention capacities)

Red colour: NUTS II/III regions with the highest share of P retention class 1 (very low P retention capacities)

5.5 Conclusions

Major parameters in evaluating P retention capacities of the soil are texture, height of the water table, erosion and runoff risk, presence of artificial drainage, content of Al, content of Fe, content of Ca and pH.

Information about these parameters in the European Soil Map provided by JRC is available, but the quality of the thematic layers in this map is poor.

Until now detailed and analytical soil information is only available at member state level. There is a need of a centralized, detailed and analytical European Soil Database at a more detailed scale then 1:1 000 000.

The results of the spatial assessment of soils with low or very low P retention capacity show that at a national level the Netherlands (56%), Slovenia (54%), Latvia (44%) and Estonia (40%) show high frequencies.

There are also distinct regional differences in P sorption capacity – most notably in southern Greece (GR22 70% class 1) and Scotland (60% class 1).

6. Identification of areas at risk of P-loss

6.1 Monitoring the P-status of agricultural soils

In most of the intensive livestock areas, decennia of manure application of manure in quantities far beyond the uptake by the plants gave rise to a sometimes massive build-up of P-reserves in the soil (contrary to nitrogen, washed out by leaching). In other areas, repeated application of high rates or cheap mineral fertiliser caused a similar effect, be it at a lesser scale. Historic data available in several countries clearly illustrate the accumulation effect of phosphorus.

To give an example: Sources in the Netherlands (Stichting Natuur en Milieu, 19 May 2005) estimate that in the period from 1970 to 1995, the P surplus on agricultural land (including mineral P fertiliser) was in the order of 80 to 100 kg of P_2O_5 (35 to 44 kg of P) per hectare and per year. According to the same source, between 1950 and 1970 the yearly surplus was in the range of 75 kg of P_2O_5. In the years after 1995 it dropped to around 60 kg of P_2O_5 per hectare and per year. For 2003, the figure was set at 44 kg P_2O_5 per hectare. These are all national averages, which means that locally the surpluses have been, or are, even higher.

As phosphorus is not very mobile in the soil, considerable reserves of this element were gradually built up, and remain available (to a certain extent) for uptake by the plants. This implicates that yearly phosphorus gifts can logically be lowered without a negative effect on crop production. According to the same source, from a mere production point of view, and based on the current P-status of the soil, phosphorus fertilisation beyond the uptake by the plants would not be beneficial on most of the agricultural land of the Netherlands. About a quarter of the soils wouldn't even need any additional phosphate supply at all. Only 4% of the soils are considered to be P-deficient.

In Belgium, the P-content o the soil is assessed depending on soil type in terms of classes: very low, low, rather low, normal (target zone), rather high, high and very high. Maps published by the Soil Service of Belgium (Figure 44) on the evolution of the P-status of the arable land in Flanders between 1982 and 2003 indicate a clear shift towards higher P-content. Soils low or very low in phosphorus have become the exception. At present, about three quarters of the soils have P-levels beyond the so-called 'target' zone. Locally, very high levels of P can be found in up to a quarter of the soils. High P-levels are clearly linked with high livestock density (pigs and poultry).

On another map by the Soil Service of Belgium (Figure 45), a marked difference is seen between the northern part of Belgium (Flanders) and the southern part (Walloon region). The soils of Flanders, especially the sandy ones, have in general a high P-status, while soils in the south, generally more loamy or clayey, are less well provided with phosphorus, or are even P-deficient. This is explained by the much lower livestock density, but also in part to the nature of the soils.

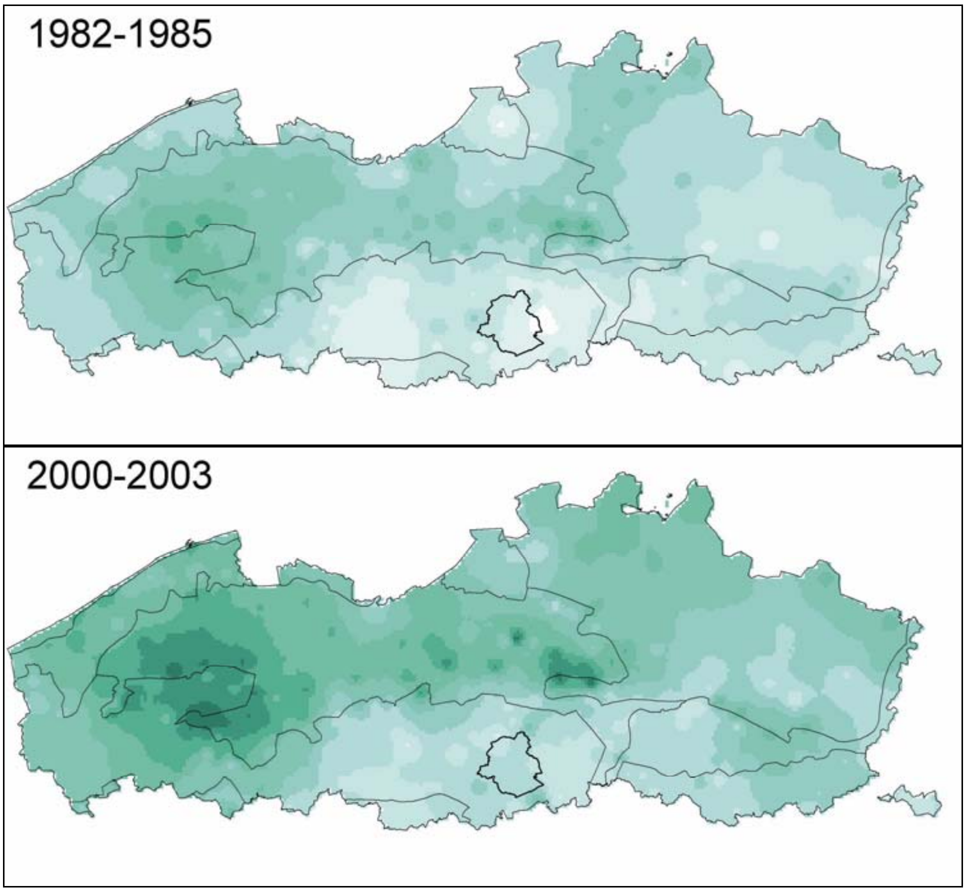


Figure 44: Evolution of the P-status of the soils in Flanders between 1982/85 and 2000/03 (the darker the color the higher the P-status)

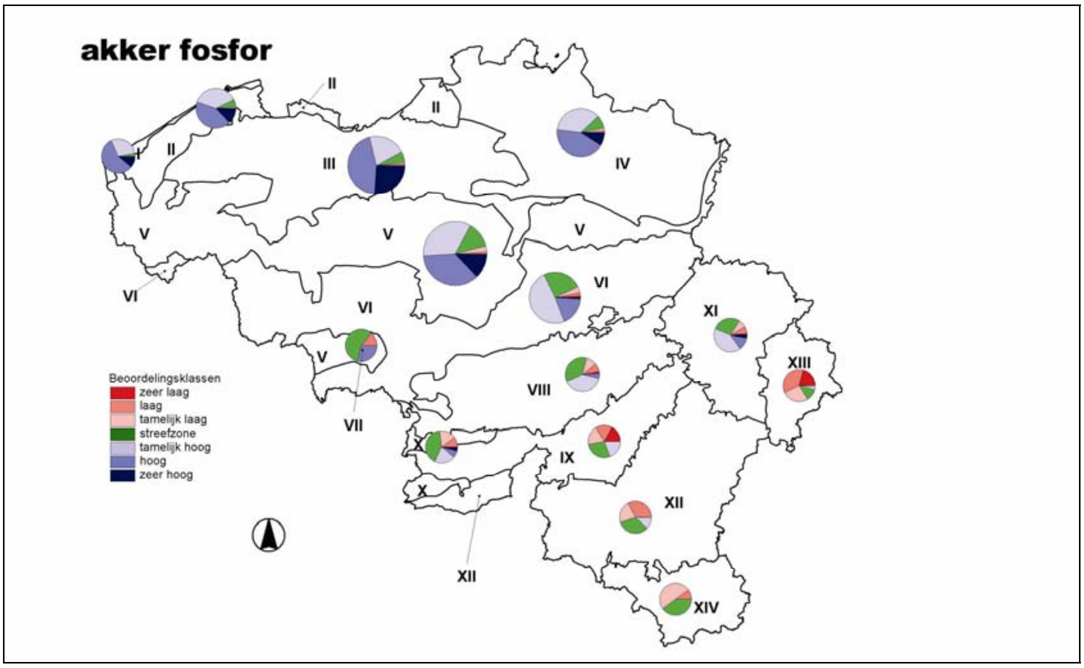


Figure 45: P-status of the arable land in Belgium (per agr region, 2003)

In the framework of this study, the member states were interrogated through a questionnaire on the availability of maps of the P-status of the soils. Replies were received from the Czech Republic, Latvia, Sweden, Hungary, Slovakia, Poland, Austria, Belgium (Flanders), Denmark, Spain, the Netherlands, Malta, Belgium (Walloon region) and Ireland. Most respondents report that figures on the P-status of the soil are available,, either as databases or maps. Similar data are known to be available in member states that did not reply to the questionnaire (f.i. Italy, France).

Providing that the available data can be centralized, it is not unlikely that similar exercises as the examples explained above could be carried out in all member states, be it not at the same scale or with the same precision.

Table 75: Availability of maps on P-status or P-saturation in MS

Member state	**Availability of P status - P-saturation maps**
Czech republic	No maps available but database exists on yearly agrochemical testing
Latvia	No reply to this item
Sweden	Maps on available P (AL method) are available
Hungary	Map of P-concentration published in 1984. Plant available P content is monitored every 3 years
Slovak republic	Database exists on regular agrochemical testing. Average results of period 1995-99 have been published
Poland	Maps available on available P-content
Austria	No maps on P-fixing capacity or P saturation
BE Flanders region	Detailed reporting on the nutrient status (including P) of arable land and grassland ever three years (including maps). Maps of P-saturated areas are available
BE Walloon region	Detailed reporting on the nutrient status (including P) of arable land and grassland (including maps)
Denmark	Maps on P-fixing capacity and P-saturation under preparation
Spain	Soil map including data on P-status to be published was finished in 2004
Netherlands	Detailed mapping on P-status and P-saturation
Malta	No maps available
Ireland	Database exists. No maps on P-saturation or P-fixing capacity

6.2 P-saturation

The subject of phosphorus saturation of soils was mainly studied in the Netherlands (Breeuwsma, Schoumans and others) and, to a lesser extent, in the Flemish region of Belgium. In these countries, the phenomenon of P-saturation has received considerable attention from the policy makers, and has been integrated in the nutrient legislation.

The methodology to define P-saturation was developed in the Netherlands in the late eighties for those soils considered to be more vulnerable, the non-calcareous sandy soils. In these soils, phosphorus is mainly if not exclusively retained by fixation to Fe and Al.

It was found that on this soil type, the accumulation of phosphorus should not exceed 25% of the binding capacity of the soil, calculated for an average maximum level of the water table. Once this level exceeded there is a risk of irreversible loss of phosphate to the groundwater. The idea behind these criteria is that significant increases of phosphorus are found in the groundwater long before complete saturation of the soil has been achieved. **In this respect, the term 'P-saturation' does not refer to a 100% filling up of the available binding capacity.**

Later on, similar criteria were established for other soil types, but so far no general extrapolation to all soil types has taken place. For clayey soils, Schoumans (2004) puts forward the same critical level as for sandy soils (25%). For peat soils and for calcareous sandy soils, the levels are much lower: respectively 10% and 5%.

6.3 Areas identified as P-saturated

6.3.1 Netherlands

According to Schoumans (2004) between 1.1 and 1.3 million hectares or 47 to 56% of the Dutch agricultural land should be considered to be-saturated.

Most of the saturated soils are sandy soils (750 000 ha) but surprisingly enough, also clayey soils figure on the map: about 114 000 ha of non-calcareous clay and 263 000 ha of calcareous clay.

In the same report Schoumans remarks that the degree of P-saturation remains a derived parameter that gives a mere indication of the risk of loss of P- to the (surface) water. The actual contribution strongly depends on other factors: location of the field, fertilising practices, phosphate binding capacity of the soil, hydrological characteristics of the area.

It should be noted that although the P-saturated areas have been identified, this has no direct implication as yet with respect to the manure regulation.

6.3.2 Flanders

As was explained in the previous paragraphs, agricultural soils in Flanders have accumulated considerable quantities of phosphorus over the past decades. This phenomenon is attributed to several factors:

- Massive use up tot the 1980's of by products from the steel industry (Thomas scories) as a cheap source of phosphate
- Use of high rates of mineral phosphate fertilisers (with a drastic decline since the mid '70's)
- Explosive development of the livestock sectors after the second world war, in particular in the sandy regions

Moreover the unfavourable N/P rate in many types of animal manure combined with fertiliser strategies based on N rather than P and the absence of negative effects of P-surpluses on crop production or on crop quality have aggravated the situation. In areas with extremely high livestock density, leaching of phosphorus from agricultural land to the water system was effectively noticed in the 80's.

In December 1995, the Flemish government adopted a **decree on phosphate saturated soils**. Only sandy soils with a pH below 6 are concerned. The decree defines the criteria of phosphate saturation. The method to define the P-saturation degree (FVG) is similar to the one applied in the Netherlands. As in the Netherlands, P-saturation does not refer to full saturation of the binding capacity of the soil, but in Flanders the critical level is set at 40%. Soils are considered to be at risk when the saturation level reaches 30%. The 40% and 30% levels reflect the conditions whereby the phosphorus content of the groundwater (in sandy acid soils) is expected to reach 0.1 mg o-P/l (norm for surface water) or 0.2 mg o-P/l (the norm drinking water). The apparently less stringent norms in the Flemish legislation as compared with the Dutch, may be explained by two factors: the generally deeper water tables in Flanders giving a corresponding higher abs soil volume and the nature of the Flemish subsoil, often rich in iron or aluminium (tertiary glauconite sands) and therefore having a higher sorption capacity.

The decree also defines the methodology to delimitate areas considered to be P-saturated. The latter correspond with the zones where, based on surveys, the statistical probability for the soils of having a saturation degree of over 40% is 95% or more.

Within P-saturated areas, stricter rules apply on P-use. Phosphorus application is limited to a maximum rate of 40 kg of P_2O_5/ha

The regional inventory was made from the 1990's onwards. According to the report by the Flemish Land Authority VLM (1997) a total land area of 7 475 km² of land were investigated using a spatial interpolation method and kriging, resulting in a raster map with a resolution of 500 m x 500 m. Phosphate binding capacity and phosphate levels were established per layer of 30 cm up to a depth of 90 cm .The areas that were identified as being P-saturated or at risk of P-saturation are presented in the following table.

Due to the resolution of the map, no statements can be made on the P-status of individual plots, in Flanders in general not larger than a few hectares at most. Therefore farmers having fields within the perimeter have the right to carry out a countercheck to have their land being withdrawn from the map, if the saturation level is proven to fall below the maximum limits.

Table 76: Land area with P-saturation and areas at risk in Flanders

Province	**Area of P-saturation (km^2)**	**Area at risk (km^2)**
West-Vlaanderen	17	141
Oost-Vlaanderen	40	380
Antwerpen	6	42
Limburg	10	46
Vlaams-Brabant	0	1
Flanders	**73**	**610**

The areas identified in Flanders as P-saturated (73 km^2 or 7 300 ha) or at risk of P-saturation (610 km^2 or 61 000 ha) are much smaller than in the Netherlands. This has to do with the difference in criteria used to define P-saturation, but also with the generally lower sensitivity of the soils in Flanders, due to deeper groundwater tables and to intrinsic soil characteristics.

6.3.3 Other countries

Investigation on P-saturation on a systematic base, as has been carried out in the Netherlands or in Flanders, is not known to have taken place in other member states as yet.

However the subject appears to be receiving particular attention in several other member states, among them Denmark, the Brittany region of France, Ireland and Italy.

6.4 Areas at risk of high P-levels/P-saturation

The current approach does not allow a true quantitative assessment of the potential risk of P saturation, nor is it clear at present what level of P-balance should be considered to be critical.

However, confronting P-balances (pressure) and the proportion of soils sensitive provides a relative idea of the probability to encounter P-excess problems. This exercise has been carried out in the following graphs. The X-axis indicates, per NUTS II/III region or per member state, the area-wise percentage of soils situated in the vulnerability classes 1 and 2 (highest vulnerability). P-sorption capacity and erosion risk have been taken into account (not drainage). The average P-balance, expressed in kg of P per ha of agricultural land, is given in the Y-axis.

In practice this means that the farther a region or state is situated to the upper right corner, the higher the pressure of excess P, and the higher the proportion of vulnerable soils. The areas currently least at risk are those situated close to the bottom left corner, where pressure is low and relatively few sensitive soils are present.

It should be emphasized that in this approach:

- **The figures do not take into account manure transfers to or from other regions,**
- **For lack of detailed local data, mineral P input for the NUTS II/III regions was obtained by splitting up the national consumption figure over the regions proportionally with their share in the national arable land area.**

Moreover, the sensitivity of the soils to P excess was calculated for the entire land area. This may cause a certain distortion as soils with an low sorption capacity (f.i. peat soils) or highly erodible soils are often found on natural land or in areas with extensive forms of agriculture or livestock keeping.

The first graph provides the situation for all the NUTS II/III regions for which a balance was calculated and the sensitivity was assessed.

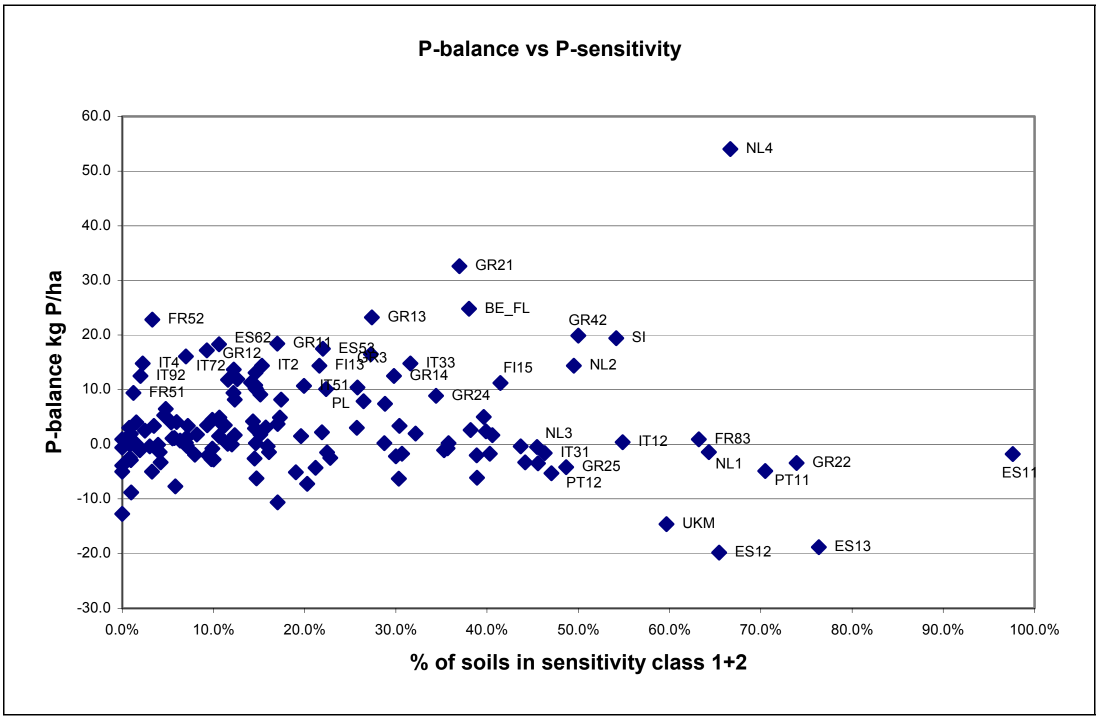


Figure 46: Comparison of pressure and vulnerability at NUT level

It appears from this graph that the bulk of the NUTS II/III regions is situated in the zone delimited by a P-balance between minus 10 and plus 10 kg P per hectare, and with less than 50 % of sensitive soils. NL4 (Zuid-Nederland) has the highest theoretical P balance and has a high proportion of vulnerable soils. The highest proportion of soils in classes 1 + 2 is found in the Galicia region of Spain, but here the pressure from excess P is low. In the former case, the sensitivity is due to the low P-sorption capacity of the soils, in the latter case the sensitivity is linked with erosion risk.

The next graph is focusing on those regions with a balance surplus of at least 10 kg of P per ha, as listed in the following table. Regions with important P-surplus are found in the Netherlands, Greece, Belgium, Spain, Slovenia, France and Finland. Only five of them have a balance surplus of more than 20 kg of P, two whereof are situated in Greece, but the proportion of sensitive soils varies widely. Care should be taken when considering these figures.

Table 77: NUTS II/III regions with a balance surplus > 10 kg P/ha

CODE	NUTS region or MS	Balance surplus	Percentage of soils in class 1+2
PL	POLAND	10.1	22.4%
DK	DENMARK	10.3	14.6%
GR3	Attiki	10.4	25.8%
IT51	Toscana	10.7	19.9%
IT53	Marche	10.8	14.6%
FI15	Länsi-Suomi	11.2	41.5%
IT52	Umbria	11.3	14.1%
GR23	Dytiki Ellada	11.8	11.6%
PT13	Lisboa e Vale do Tejo	11.9	12.6%
GR14	Thessalia	12.5	29.8%
IT92	Basilicata	12.5	2.0%
IT32	Veneto	13.1	14.6%
FI16_1	Pohjois-Suomi	13.7	12.2%
IT2	Lombardia	14.4	15.3%
FI13	Itä-Suomi	14.4	21.6%
NL2	Oost-Nederland	14.4	49.5%
IT33	Friuli-Venezia-Giulia	14.8	31.6%
IT4	Emilia-Romagna	14.8	2.3%
IT72	Molise	16.1	7.0%
ES51	Cataluña	16.5	27.3%
GR12	Kentriki Makedonia	17.2	9.3%
ES53	Illes Balears	17.5	22.0%
ES62	Región de Murcia	18.3	10.6%
GR11	Anatoliki, Makedonia, Thraki	18.4	17.0%
SI	SLOVENIA	19.4	54.1%
GR42	Notio Aigaio	19.9	50.0%
FR52	Bretagne	22.8	3.3%
GR13	Dytiki Makedonia	23.2	27.4%
BE_FL	Flanders	24.8	38.0%
GR21	Ipeiros	32.6	37.0%
NL4	Zuid-Nederland	54.0	66.7%

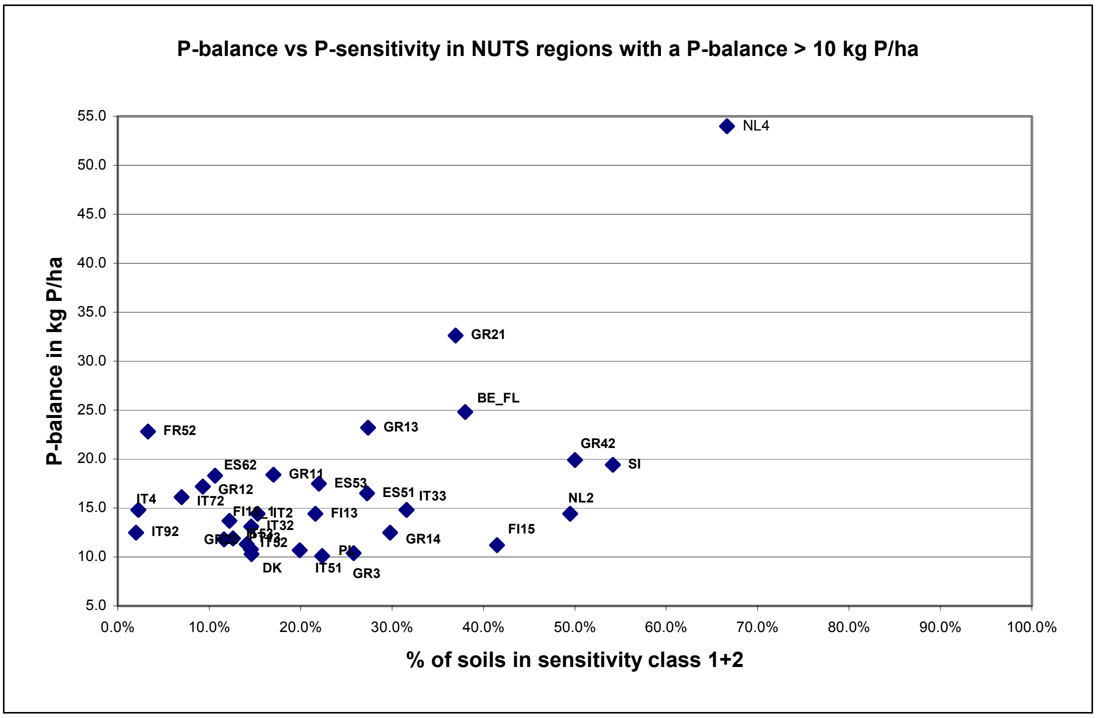


Figure 47: Comparison of pressure and vulnerability in NUT regions with a balance of over 10 kg/ha

The third graph is focusing on the NUTS II/III regions with over 30 % of soils in the sensitivity classes 1+2, irrespective of the P-balance. Twelve regions have over 50 % of their land area situated in either one of those sensitivity classes.

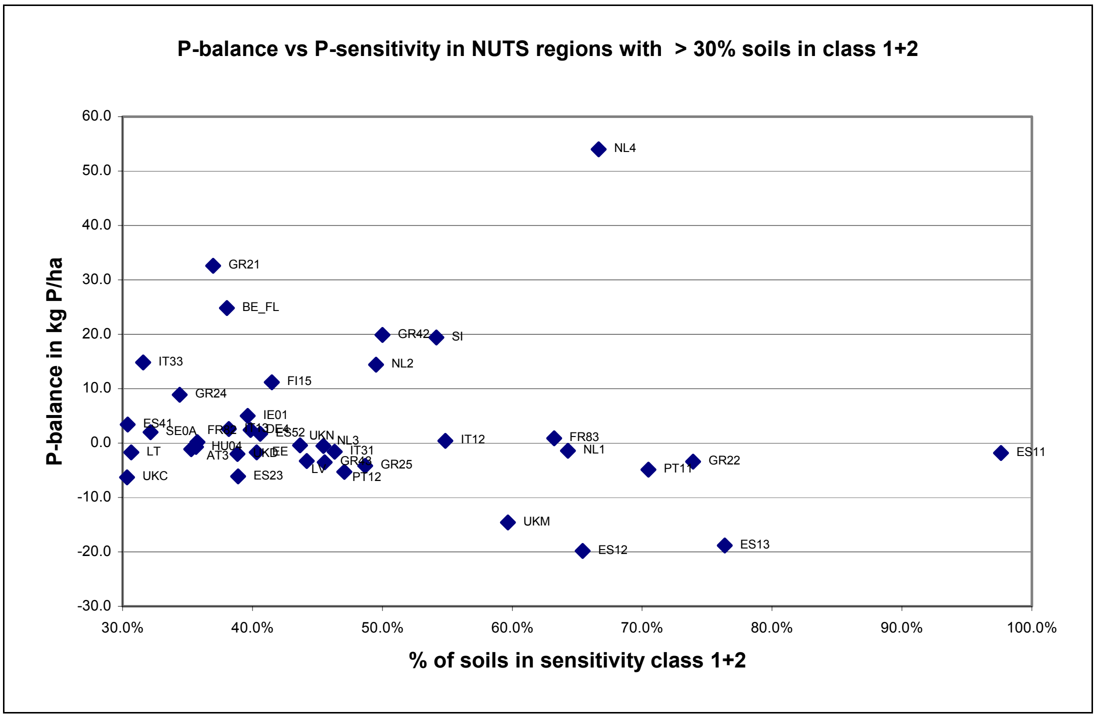


Figure 48 Pressure vs vulnerability in NUTS II/III regions with a high proportion of vulnerable soils

The last figure presents the situation per member state. The Netherlands and Slovenia come out with the highest rate of vulnerable soils and the highest balance surplus. In the case of the Netherlands, the vulnerability is due to the sorption capacity of the soils, while in Slovenia the risk is rather linked with erosion risk.

While for most member states these average figures conceal the local variations, the figure for the Netherlands is probably providing a more realistic picture than the previous graphs per NUTS II/III region. Indeed, as has been seen in previous chapters, redistribution of manure between regions is very important in the Netherlands, making the pressure more even than the previous graphs would suggest. This is not the case for other member states with important local differences in manure production such as Spain, Greece, Italy or Belgium, where internal transfers from high surplus to non or low surplus areas are less systematic or less massive.

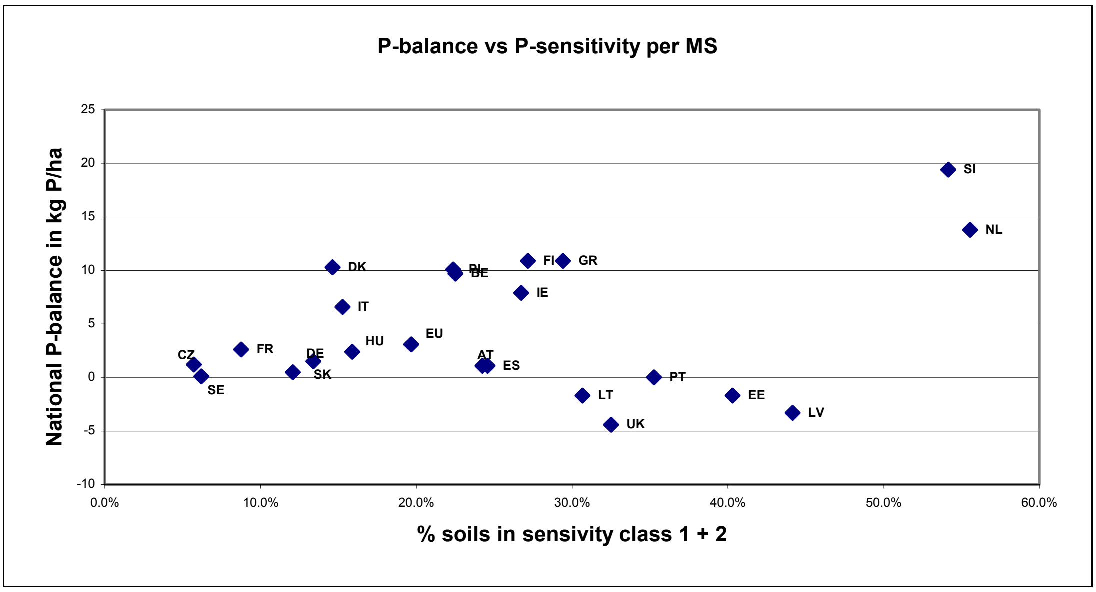


Figure 49: Comparison of pressure and vulnerability at MS level

Remark:
For the sake of clarity and brevity, the exercise was carried out taking into consideration the vulnerability classes 1 + 2. It would of course be possible to do the same per sensitivity class or per grouping of several classes.

Part 2: The legal situation regulating P and approaches limiting P problems at EU and Member States level

7. International legislation affecting P use in agriculture

7.1 Introduction

European Community legislation and policies on environmental protection have had more prominence during the last two decades. In this respect, Regulations are binding in their entirety and directly applicable in all Member States, whereas Directives may be implemented using different methods and forms in each of the Member States they are directed to. In addition, several Member States are also signatories of international treaties that aim to protect natural resources. International conventions of importance to phosphorus use in agriculture include *inter alia* MAP (Mediterranean Action Plan), CBD (Convention on Biological Diversity) and OSPAR (Oslo & Paris Convention to prevent pollution). Such international treaties often give an impetus to harmonise standards amongst all Member States of the European Union. Despite the significant off-site impact that diffuse contamination of phosphorus from agricultural land poses, there is no specific legislation that is directly concerned with the use of phosphorus in agriculture at the European level. However, aspects of the phosphorus problem are integrated in several policy areas and related legal instruments at the European level.

This section provides an overview of existing regulations and directives dealing with farm-level nutrients (and phosphorus) use and production at the international and European level. Specific international legislation concerning manure treatment and transport is dealt with in chapter 9.

7.2 European directives and regulations

7.2.1 Environmental Policy

The following sections will review several environmental policy areas such as water, waste, biodiversity conservation and chemicals/air in order to provide an overview of how the use of phosphorus in agriculture is addressed in several directives. The directives discussed are listed in Table 78.

Table 78: Directives relevant to nutrient management

Environmental Policy	Directives and Regulations	Number	Official Journal
Water	Water Framework Directive	2000/60/EC	*L 327 , 22/12/2000 P. 0001 - 0073*
	Nitrates Directive	91/676/EEC	*L 375 , 31/12/1991 P. 0001 - 0008*
Biodiversity	Birds Directive	79/409/EEC	*L 103 , 25/04/1979 P. 0001 - 0018*
	Habitats Directive	92/43/EEC	*L 206 , 22/07/1992 P. 0007 - 0050*
Waste	Framework Directive on waste	75/442/EEC, amended by 91/156/EEC; 91/689/EEC	*L 194 , 25/07/1975 P. 0039 - 0041; L 078 , 26/03/1991 P. 0032 - 0037; L 377 , 31/12/1991 P. 0020 - 0027*
	Sewage Sludge Directive	86/278/EEC	*L 181 , 04/07/1986 P. 0006 - 0012*
	Waste Shipment Regulation	EEC 259/93	*L 030, 06/02/1993 P. 0001 - 0028*
Chemicals/air	Directive on Integrated Pollution Prevention and Control	96/61/EC	*L 257 , 10/10/1996 P. 0026 - 0040*

7.2.1.1 *Water Framework Directive*

The environmental systems of soil and water are intrinsically linked. Negative impacts on the soil frequently have effects on the water environment and vice versa. As a consequence, legislation on water issues in most cases indirectly affects soil protection and adversely the quality of water bodies is also dependent on consistent and sustainable soil protection policies. Until the conception of the Water Framework Directive, policy was often addressed at single pollutants (e.g. nitrate) or single issues (e.g. groundwater).

The Water Framework Directive (2000/60/EC) aims to establish the goal of a ‘good status’ for all waters by the year 2015. A good status is defined through three factors: biology, chemistry as well as morphology. For achieving this goal, an integrative approach is suggested. The directive changes the focus to whole ecosystems through its orientation on water catchments. It provides for the establishment of ‘a Community framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, in order to prevent and reduce pollution, promote sustainable water use, protect the aquatic environment, improve the status of aquatic ecosystems and mitigate the effects of flooding and drought’. The integrative approach considers water bodies no longer as autonomous environmental compartments, but extends the responsibility of water managers beyond the water body itself to the surrounding environmental systems including soil. The directive rationalises and updates the current water legislation, embodies the concept of integrated river basin management and mandates programmes of measures for river basin districts aiming to reduce the influx of e.g. nutrients and pesticides.

The Water Framework Directive is set to overhaul the management of the water environment in the EU with repeals and transitional provisions being outlined for earlier directives concerned with protection of water and ecosystems. Some of these directives are mentioned in this section. The Surface Water Directive (75/440/EEC), together with the Drinking Water Directive (80/778/EEC) replaced by Directive 98/83/EEC, sets the standard for the quality of water for human consumption, with Maximum Allowable Concentrations set for nitrate and for pesticides. The Directive on pollution by dangerous substances (76/464/EEC) had the ambitious objective of regulating potential aquatic pollution by thousands of chemicals already produced in Europe at that time. In 1980 the protection of groundwater was taken out of 76/464/EEC regulated under the separate Council Directive 80/68/EEC on the protection of groundwater against pollution caused by certain dangerous substances. The Groundwater Directive states that Member States shall take the necessary steps to prevent the introduction into groundwater of substances in list I; and limit the introduction into groundwater of substances in list II so as to avoid pollution of the water by these substances. Inorganic compounds of phosphorus and elemental phosphorus are part of List II which comprises the families and groups of substances that could have a harmful effect on groundwater. Under the Freshwater Fish Directive (78/659/EEC), water companies were urged to reduce ammonia pollution affecting fish. However, some action may also be needed to reduce pollution originating from agricultural sources such as run-off of manure and slurry. The Shellfish Waters Directive (79/923/EEC) concerned the quality of shellfish waters and applies to those coastal and brackish waters requiring protection or improvement in order to support shellfish life and growth. The Bathing Water Directive (76/160/EEC) was concerned with protecting human health and the environment from pollution, listing 19 physical, chemical and microbiological parameters. The register of protected areas listed in the Water Framework Directive includes bodies used for abstraction of drinking water, nutrient sensitive areas as specified by the nitrates and urban wastewater treatment directives, bathing waters and all areas listed in the Birds and Habitats Directives.

The Water Framework Directive sets out environmental objectives for water status based on ecological and chemical parameters, common monitoring and assessment strategies, arrangements for River Basin administration and planning and a Programme of Measures for each River Basin District to achieve the environmental objectives for the individual water bodies. Basic measures include those required to implement Community legislation for the protection of water and ecosystems (enforced under the earlier directives); other measures include controls over water abstraction and regulations relating to point or diffuse sources liable to cause pollution. Supplementary measures may be diverse, including statutory implements and demonstration experiments on farms.

For these programs of measures Member States are furthermore obliged to take a combined approach for addressing point sources and diffuse sources, the latter mostly caused by agricultural activities. Contamination from agriculture is being increasingly identified as a critical remaining source of pollution now that improved sewage treatment is in place. Environmental quality standards are defined as the concentration of a particular pollutant or group of pollutants, sediment or biota, which should not be exceeded in order to protect the environment. In the legislative text of the Water Framework Directive, an indicative list of pollutants includes organophosphorous compounds and substances that contribute to eutrophication (in particular nitrates and phosphates). Member States are required to identify pressures on surface water bodies. Among the information that needs to be reported on is the estimation and identification of significant diffuse source pollution from *inter alia* agricultural activities and as such includes diffuse contamination of phosphorus from agricultural activities. The directive explicitly mentions that this could be based on information gathered under the Nitrates Directive (91/676/EEC). Requested information under the identification of pressures also includes the estimation of land use patterns and identification of urban, industrial and agricultural areas. Measures applied under the Water Framework Directive affecting the use of phosphorus in agriculture relate to best environmental practices and include the reduction of nutrient application, the modification of cultivation techniques, the proper handling of pesticides and fertilisers, and the prevention of soil erosion through erosion-minimising soil cultivation. Most measures suggested in this context are aimed at reducing the influx of nutrients, such as nitrogen, phosphorus as well as pesticides to the groundwater as well as surface waters.

The links between farming practice, the amount of phosphorus that enters rivers and the effect of such pollution on the health of watercourses are complex and often depend on the character of the landscape. This makes it difficult to predict what the precise effect of land management changes would be on water quality and on ecological impacts. The Water Framework Directive emphasises the need to link chemical, material and pollutant flows in a comprehensive material flow analysis. In the case of phosphorus, this encompasses on-farm or field nutrient balances, sediment-phosphorus-water interactions, sediment budgets and classic mass balances for river systems. Major challenges will include the understanding of variability in fluxes, storages and connectivity.

7.2.1.2 Nitrates Directive

The Nitrates Directive (91/676/EEC), established in 1991 and referred to in the Water Framework Directive, aims to reduce water pollution caused or induced by nitrates from agricultural sources and prevent further such pollution. The directive requires the Member States to monitor nitrate concentrations in surface water and groundwater, identify waters affected by pollution and waters which could be affected by pollution if no measures are taken and designate vulnerable zones, defined as all known areas of land which drain into the waters identified. For these vulnerable zones, action programmes containing measures to reduce and prevent nitrate pollution must be developed, implemented and revised every four years. MS must also establish codes of good agricultural practices and set up information campaigns where necessary to implement them.

Measures for designated vulnerable zones aim to reduce the influx of nutrients to groundwater and surface water; at the same time over-saturation and a possible ensuing degradation is avoided. The identification of waters shall be based on following criteria (Annex I):

- Surface waters: Whether they contain or could contain, if no measures are taken, more than the concentration laid down in accordance with Directive 75/440/EEC;
- Ground waters: whether they contain or could contain if no measures are taken more than 50 mg/l nitrates/l;
- Natural freshwater lakes, freshwater bodies, estuaries, coastal waters and marine waters: whether they are found to eutrophic or may become eutrophic when no measures are taken.

It is important to point out that all Code(s) of Good Agricultural Practice (Annex II) and measures to be included in action programmes (Annex III) are mandatory for Nitrate Vulnerable Zones. CGAPs are voluntary in non vulnerable areas. A Code or Codes of Good Agricultural Practice with the objective of reducing pollution by nitrates and taking account of conditions in the different regions of the Community should contain provisions covering at least the items mentioned in Annex II A, in so far as they are relevant. These items include the land application of fertiliser in terms of period, land characteristics (steeply sloping ground; water-saturated, flooded, frozen or snow-covered ground; near water courses) and procedures (rate and uniformity of spreading); and, the capacity and construction of storage vessels for livestock manures. Member States may also include in their code(s) of good agricultural practices additional items, listed in Annex II B. Listed are: land use management (e.g. crop rotation, proportion of permanent crops to annual tillage crops); minimum vegetation cover during certain periods; farm fertiliser plans and fertiliser record keeping; and, the prevention of water pollution from run-off and leaching.

The Action Programmes should contain measures amongst other the establishment of periods when the land application of certain types of fertiliser is prohibited; the establishment of limits on the quantities of fertilisers applied based on a balance system; minimum storage capacity requirements; and, a maximum application standard for livestock manure per hectare to an amount containing no more than 210 kg N during the first four year basis of the action programme or 170 kg N organic/hectare/year during the second four year action programme. Member States are required to report on the designation of vulnerable zones, the results of the water quality monitoring, and the action programmes and the codes of good agricultural practice to the Commission on a four year basis. The Water Framework Directive explicitly refers to the Nitrates Directive for information on diffuse pollution of nitrates from agricultural activities and extends this to phosphates. The measures established within the Action Programmes aim to control diffuse and direct water pollution and also influence the use of phosphorus in farm practice. For instance, by limiting the annual application of nitrogen fertiliser and livestock manure, defining legally binding maximum concentrations of nitrates in drinking water and designating periods when the application is prohibited, the directive clearly aims at establishing and maintaining the natural balance of fertilisers in soils. Through these measures a massive influx of nutrients to ground- and surface water and thus potential eutrophication is prevented, while excess nutrients, over-saturation and a possible ensuing degradation is avoided at the same time.

7.2.1.3 The Birds and Habitats Directive

Under the Birds Directive (79/409/EEC) Member States are required to take special measures to conserve the habitats of certain rare species of birds and regularly-occurring migratory birds. The Habitats Directive (92/43/EEC) further obligates Member states to protect areas that support certain natural habitats or species of plants or animals (other than birds).

Sites that are in accordance with the Birds Directive are known as “Special Protected Areas” (SPAs). The most suitable territories, including land and sea, are to be designated as protected areas for the conservation of birds species. Special attention is given to the protection of wetlands. Measures to preserve, maintain and re-establish biotopes and habitats include the creation of protected areas, the management of habitats both inside and outside protected areas and the reestablishment of destroyed habitats. Diffuse contamination from agriculture and more specifically eutrophication as a result from phosphorus emission is described.

The main purpose of this Directive is to ensure biological diversity through the conservation of natural habitats and of wild flora and fauna within the European territory, while taking into account economic, social, cultural and regional requirements. Farmers who have agricultural land in Natura 2000 sites and face restrictions due to the requirements of the Habitat-Directive are eligible to receive payments for the management of these sites by the Rural Development Regulation, which helps promote environmental-friendly farming. Depending on the specific conditions of a certain area, these include measures to reduce the use of pesticides and fertilisers, measures to mitigate the effects of soil compaction, e.g. limitations on the use of machinery or the setting of stocking limits, or measures aiming to regulate the irrigation of agricultural land.

7.2.1.4 Framework Directive on Waste

The overall structure for an effective waste management regime is set out in the Council Directives on waste (75/442/EEC, as amended by Council Directive 91/156/EEC), often referred to as the Framework Directive on Waste, and on hazardous waste (91/689/EEC), the Hazardous Waste Directive. The ethos of the Framework Directive on Waste was indicated as the protection of human health and the environment against harmful effects caused by the collection, transport, treatment, storage and tipping of waste. Two categories of daughter directives exist within the EU waste management regime: those setting requirements for the permission and operation of waste disposal facilities, and those dealing with processing and disposal options for specific types of waste. The action proposed on biowaste is the development of compost product standards in the context of the Thematic Strategy on waste prevention and recycling to be adopted in 2005.

Excluded from the scope of the Waste Framework Directive were wastes which were covered by other legislation including waste water and gaseous effluents, and agricultural wastes such as faecal matter and other natural, non-dangerous substances used in farming. These are covered by ‘other legislation’. In the context of Case C-114/01 *AvestaPolarit*, the ECJ has clarified that the ‘other legislation’ referred to in the Waste Framework Directive can be either Community or national legislation (para. 49). However, to be regarded as ‘other legislation’, national legislation must not merely relate to the substances or objects in question, but must contain precise provisions organising their management as waste within the meaning of the Waste Framework Directive (para. 52). ‘Other legislation’ is considered where it pursues the same objectives as those of Directive 75/442/EEC (which are very broad) and achieves an equivalent level of environmental protection (covering all environmental media, including soil). Storage of organic waste and/or its landspreading was addressed in a separate case against Ireland (Case C-494/01); the judgment of the court was that Ireland failed to fulfil the obligations and take all the measures necessary to ensure a correct implementation of Directive 75/442/EEC. Although the Spanish authorities claim that agricultural waste is excluded from the scope of Directive 75/442/EEC in two recent cases involving pig farms in Spain (Cases C-416/02 and C-121/03), the handling of waste from pig farms (particularly animal carcasses and slurry) is subject to that directive since there is no specific Community legislation to cover all aspects relating to the handling of such waste. Pollution of waters caused by the increasing volume of slurry generated by the pig farms in the areas concerned constitutes a result contrary to the requirements of Article 4 of Directive 75/442/EEC and is thus a clear infringement of that provision.

The Waste Shipment Regulation (Council Regulation (EEC) N° 259/93 and amendment acts) on the supervision and control of shipments within, into and out of the European Community draws a distinction between waste for disposal (as listed in Annex IIA to the Waste Framework Directive, such as for example landfill or certain types of incineration) and waste for recovery (as listed in Annex IIB to the Waste Framework Directive, such as for example recycling). Spreading on land resulting in benefit to agriculture or ecological improvement is listed amongst the recovery operations. In the case of waste for recycling, the Regulation draws a further distinction between a "green list" of wastes (Annex II to the Regulation), for example wastes arising from agro-food industries, an "amber list" including liquid pig manure and sewage sludge (Annex III), a "red list" (Annex IV) and, finally, wastes not yet on any of these lists. Animal faeces, urine, manure (including spoiled straw) and effluents are included under the category “wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing” in the Annex to Commission Decision 2000/532/EC, as amended.

7.2.1.5 Sewage Sludge Directive

The 1986 Sewage Sludge Directive (86/278/EEC), as part of the EU waste legislation regulated by the Waste Framework Directive, deals with the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. The Directive lays down limit values for concentrations of heavy metals in the soil (Annex IA), in sludge (Annex IB) and for the maximum annual quantities of heavy metals which may be introduced into the soil (Annex IC). The use of sewage sludge is prohibited if the concentration of one or more heavy metals in the soil exceeds the limit values laid down in accordance with Annex IA.

The Sewage Sludge Directive takes into account the nutrient needs of plants, the protection of surface and groundwater and the pH of the soil (Article 8). The use of sludge is prohibited on grassland or forage crops if the grassland is to be grazed or the forage crop is to be harvested before at least three weeks; on soil in which fruit and vegetable crops are growing, with the exception of fruit trees; on ground intended for the cultivation of fruit and vegetable crops which are normally in direct contact with the soil and normally eaten raw, for a period of 10 months preceding the harvest of the crops and during the harvest itself (Article 7).

Sludge and the soil on which it is used must be analysed according to the procedures set out in the annexes of the Directive (Article 9). One of the parameters subject to the provisions of the Directive includes total phosphorus in percentage of dry solids. The Commission notes that on average in the EU a tonne of sludge (dry matter) contains 30-40 kg N and 20-30 kg P.

7.2.1.6 *Directive on Integrated Pollution Prevention and Control*

The Directive on Integrated Pollution Prevention and Control (96/61/EC) introduces an integrated cross-media approach, aiming to prevent or minimise emissions to air, water and land, as well as to avoid waste production with a view to achieve a high level of environmental protection as a whole. The IPPC Directive concerns highly polluting industries, e.g. energy, production and processing of metals, minerals, chemicals, waste management and others, including intensive pig and poultry farms.

A single permit based on the concept of Best Available Techniques (BAT including limit values) must include all arrangements made, including emission limit values for pollutants, for water, air and land, and may, if necessary, contain requirements for the protection of the soil and the groundwater as well as measures for waste management (Art. 9(3)) in order to continuously prevent and reduce pollution.

The purpose of the IPPC Directive is to achieve integrated prevention and control of pollution arising from several categories of industrial activities. Among these are installations for the intensive rearing of poultry or pigs with more than 40 000 places for poultry, 2 000 places for production pigs (over 30 kg), or 750 places for sows. Installations for the disposal or recycling of animal carcases and animal waste with a treatment capacity exceeding 10 tonnes per day are also included. The indicative list of main polluting substances to be taken into account if they are relevant for fixing emission limit values includes oxides of nitrogen and substances which contribute to eutrophication (phosphates and nitrogen).

7.2.2 Agricultural Policy

The legal instruments of the **Common Agricultural Policy** (CAP) have formed the crucial driving force behind agricultural development and through land use changes have influenced nature and environment. The Regulations mentioned are listed in the following table.

Table 79: Regulations relevant for nutrient management

Regulation Name	Number	Official Journal
Support system for producers of certain arable crops (Mac Sharry reform)	Council Regulation (EEC) No 1765/92	*L 181 , 01/07/1992 P. 12 - 20*
Rural Development Regulation	Council Regulation (EC) No 1257/1999 Commission Regulation (EC) No 817/2004	*L 160, 26/06/1999 P. 80 - 102 (CONSLEG - 92R1600 - 26/06/1999 - 44 P. CONSLEG - 92R1601 - 26/06/1999 - 43 P); L 153,30/04/2004 P. 30 -83*
Common Rules for direct support schemes under CAP (also called Horizontal Regulation)	Council Regulation (EC) No 1259/1999 Commission Regulation (EC) No 963/2001	*L 160 , 26/06/1999 P. 113 – 118; L 136 , 18/05/2001 P. 04 - 05*
CAP 2003 reform including compulsory Cross-Compliance	Council Regulation No 1782/2003 and Commission Regulation No 796/2004	*L 270 , 21/10/2003 P. 01 – 69; L 141 , 30/04/2004 P. 18 - 58*
Organic production of agricultural products	Council Regulation (EEC) 2092/1991	*L 198 , 22/07/1991 P. 01 - 15*

7.2.2.1 Set-aside

Under the 1992 reform of the common agricultural policy (Council Regulation (EEC) No 1765/92 - the Mac Sharry reform), price support for the production of cereals, oilseed and protein crops (COP) was reduced and offset by subsidy payments for areas under the COP crops. Compulsory set-aside was introduced. Set-aside, rotational and above all recently fixed and long-term, is very beneficial for soil protection. The effect of plant cover in limiting erosion and leaching is critical as it cuts nitrate and phosphate concentrations in soil in some cases to a tenth or a twentieth of what they were. If land is set-aside along rivers and streams, in some circumstances the transport into rivers of phosphates can be considerably reduced. The sowing of certain plants can considerably enrich the soil with organic material. It has been shown that crop yields are generally higher following set-aside than after another crop, thereby reducing the input of fertilisers (EC, 2002).

7.2.2.2 Agri-environmental Programmes and Measures

The **Agri-Environmental Measures** were introduced in 1992 under the Mac Sharry reform of the CAP, integrated as an obligatory measure within the Rural Development Regulation in 1999 (pillar two) in order to promote environmental friendly farm practices. The key objectives of these measures are promote agricultural methods to protect the environment, maintain the countryside or improve animal welfare. The Member States develop their own agri-environment measures according to their environmental needs. Farmers receive financial compensations covering the income foregone, costs incurred and as an incentive for their participation in agri-environmental schemes that go beyond the application of good agricultural practices. The measures lead to quantified reductions in use of inputs, conservation of valuable farmed habitats, and changes in land use for environmental purposes. These identified positive impacts contribute to biodiversity, landscape, water and soil resources. Various agri-environment measures throughout the European Union have been established directly or indirectly addressing diffuse contamination by phosphorus. Some of these measures are directed at mitigating soil erosion such as crop rotations, mulch seeding retaining stubble after harvest and ploughing restrictions. Other measures tackle the problem of excess nutrients through reduced fertiliser use. All measures that impact soil erosion and nutrient balances ultimately result in a reduction of diffuse contamination by phosphates from agricultural land.

Organic farming is controlled by Regulation (EC) 2092/1991 and may benefit from support of agri-environmental measures. Organic farming contributes significantly to healthy nutrient balances through increasing soil biological activity, on-farm nutrient cycling and sustainable use of soil resources. Organic farming helps decrease soil erosion and reduce fertiliser input, leading to reduced contamination by phosphates.

7.2.2.3 Code of usual Good Farming Practice

Codes of usual Good Farming Practice represent minimum standards for farmers to get, in the framework of the Rural Development Regulation, compensatory allowances/payments in the Least Favoured Areas and support for voluntary agri-environmental measures on the basis of income foregone, additional costs and the need to provide an incentive. Usual Good Farming Practices are defined as “the standard of farming which a reasonable farmer would follow in the region concerned”. Codes are set up by the Member States as verifiable standards in their rural development plans (see chapter 8 on national legislation). These standards entail at least, compliance with general mandatory environmental requirements. Table 82 Table 83 in the section on national/regional legislation are based on information extracted from Rural Development Plans, with a focus on verifiable standards.

7.2.2.4 Cross-compliance Scheme

The **Cross-Compliance Scheme** was initially introduced as a voluntary scheme in 1999 as part of the Agenda 2000 CAP reform. However, only few Member States implemented the voluntary cross-compliance scheme (France, Ireland, UK and Denmark) mainly addressing over- and under grazing, indirectly contributing to diffuse contamination by phosphates by preventing further soil erosion. Since the 2003 CAP reform, a compulsory cross-compliance scheme (Council Regulation No 1782/2003 and Commission Regulation No 796/2004) for all direct payments was introduced. From 2005 onwards, all direct payments will be conditional upon 19 statutory requirements in the field of environment, food safety, animal and plant health, and animal welfare. All farmers receiving direct payments have to comply with these requirements, as in the case of non compliance, the amount of direct payments will be reduced or cancelled. From the 19 statutory requirements listed in Annex III of the 2003 Regulation, only one directly addresses diffuse contamination by phosphates from agricultural land, i.e. the Sewage Sludge Directive. Furthermore, the Member States are required to keep all agricultural land in good agricultural and environmental conditions (GAEC) which will be conditional from 2005 onwards. For this purpose, Member States have to define, at national or regional level, minimum requirements for GAEC taking into consideration the specific characteristics of the areas concerned, including soil and climatic condition, farming systems and farming practices. The GAEC of the Member States have to be in accordance with the framework set out in Annex IV of the Regulation. Soil protection is addressed in a direct and coherent manner within the European framework for GAEC through qualitative standards set for soil organic matter, soil structure and soil erosion. Standards that are relevant for phosphorus use are found among those to mitigate soil erosion (minimum soil cover, minimum land management reflecting site-specific conditions and retention of terraces); those to ensure minimum levels of maintenance to avoid the deterioration of habitats (minimum livestock stocking rates or/and appropriate regimes, protection of permanent pasture, retention of landscape features and avoiding the encroachment of unwanted vegetation on agricultural land); and, those to maintain soil organic matter levels (crop rotations, arable stubble management). Member States have to ensure that land which was under permanent pasture is to be maintained under permanent pasture (based on the area surfaces of 2003).

7.3 International initiatives

Several Member States are signatories to multi-national environmental agreements and initiatives, the majority of which aim at the protection of marine resources and include nutrient management in the marine environment. More background information on these international treaties and initiatives can be found according to Table 80.

Table 80: International initiatives in relation to nutrient management

International Initiative	**Website**
HELCOM (Helsinki Commission – Baltic Sea)	http://www.helcom.fi/
OSPAR (Oslo Paris Convention - North-East Atlantic)	http://www.ospar.org/
North Sea Commission	http://www.northsea.org
Baltic 21	http://www.baltic21.org/
MAP (Mediterranean Action Plan)	http://www.unepmap.gr/
The Global Environment Facility (GEF) Strategic Partnership on the Black Sea and Danube Basin	http://www.iwlearn.net/region/europe.php
OECD	http://www.oecd.org/

7.3.1 Helsinki Commission

The Helsinki Commission, HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention.

The Helsinki Commission has been assessing the effects of nutrients and hazardous substances on the Baltic Sea ecosystem for the past 25 years as well as compiling data on pollution loads to the Baltic Sea since the late 1980's. Every five years the overall pollution load of nutrients, organic matter and heavy metals entering the Baltic Sea via rivers or via direct discharges from pollution sources located on the coastline is assessed. The resulting assessment reports are unique compilations of data and analysis based on the scientific research carried out around the Baltic Sea.

The major portions of losses and discharges of total nitrogen and total phosphorous originate from diffuse sources. Natural background losses of nitrogen and phosphorus amount to a little less than one third of the total losses and discharges entering inland surface waters within the Baltic Sea catchment area. The load from point sources amounts to roughly 10 % for nitrogen and 20 % for phosphorus.

Diffuse pollution from agriculture is estimated to account for more than half of the nitrogen input and about one third of the phosphorus input to the Baltic Sea. Reducing nutrient loads from agriculture is more complicated than cutting loads from point sources. The implementation of agri-environmental measures promotes reductions in nutrient loads from agriculture, but there is evidently a considerable time lag between the implementation of agricultural water protection measures and any visible effects in water bodies.

Annex III, part II of the Helsinki Convention contains the most important criteria and measures concerning the prevention of pollution from Agriculture decided by HELCOM. In general the Contracting Parties shall apply Best Environment Practice (BEP) and Best Available Technology (BAT) to reduce the pollution from agricultural activities. The Contracting Parties shall elaborate Guidelines specified in the Annex on e.g. fertilising recommendations taking reference to soil conditions, soil nutrient content, soil type and slope as well as climatic conditions and irrigation, land use and agricultural practices, including crop rotation systems. Application rates for nutrients should not exceed the crops nutrient requirements. Appropriate measures such as reduced fertilization rates, zones where manure spreading is prohibited and permanent grass land areas should be established.

The two major weak points are the lack of knowledge of what is really happening at farm level and what the real effects on the aquatic environment are.

7.3.2 OSPAR conventions

The Convention for the Protection of the Marine Environment of the North-East Atlantic (known as the "OSPAR Convention") is the basis for national laws governing the discharge of pollutants in the waters of the OSPAR signatory states: Belgium, Denmark (including, for these purposes, the self-governing province of the Faroe Islands), Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland. OSPAR regulations thus cover all the coastal states of Western Europe. The European Community is also a signatory, as are Luxembourg and Switzerland. The work under the convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community.

The OSPAR Convention combined and up-dated the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution. According to the convention all contracting parties should take all possible steps to eliminate pollution. They must take the necessary measures to protect, or where practicable, to restore the maritime area from adverse effects of human activities. The work under the Convention is guided by the Ministerial Declarations and Statements made at the adoption of the Convention and at the Ministerial Meetings of the OSPAR Commission. The work applies the ecosystem approach to the management of human activities, and is organised under six strategies: Protection and Conservation of Marine Biodiversity and Ecosystems; Eutrophication; Hazardous Substances; Offshore Oil and Gas Industry; Radioactive Substances; and, Monitoring and Assessment. Organic compounds of phosphorous and elemental phosphorus are listed as requiring strict control but they are considered less noxious than dangerous substances and more readily rendered harmless by natural processes.

As part of OSPAR, commitments have been made to reduce the input of nutrients in the sea by 50% as of the reference year of 1985 (PARCOM 88/2 & 89/4 recommendations). Measures to achieve this aim are set out in a co-ordinated programme for the reduction of nutrients. The nitrogen input fell by only 20% between 1985 and the year 2000, while the target for phosphorus reductions was met in full (a fall of almost 60%). In both cases, it is mainly industrial sources that have fallen. Remarkable reductions in domestic input were also achieved, mainly as regards phosphorus. In response to the significant contribution from agriculture to diffuse contamination, recommendation 92/7 deals with the reduction of nutrient inputs from agriculture into areas where these inputs are likely, directly or indirectly, to cause pollution. More specifically leaching, run-off and erosion losses of P and farm waste discharges should be reduced.

A Harmonised Reporting Procedure on Nutrients (HARP) exists in order to monitor and assess progress of implementation in the national legislation on the signatory countries. The lack of appropriate direct measurements and the timelag between the application of measures and their effects on the reduction of emissions from agriculture to the maritime area necessitates the use of nutrient balances. Nutrient balances on nitrogen and phosphorus are identified as useful tools for assessing the effectiveness of the nutrient reduction measures taken within the agricultural sector. The frequent calculation of a national (or where appropriate regional) agricultural nutrient balance provides an estimate of overall surplus from agricultural production. The changes over the years of the surplus provide an overall estimate of the effects obtained by the measures taken.

In 1998 OSPAR defined its strategy for the fight against eutrophication, the aim of which is to achieve and maintain a healthy marine environment where the phenomena of eutrophication no longer occur. Application of this strategy is linked to the "Common Procedure" used to determine the eutrophication status of the maritime zone. Eutrophication of the marine environment is caused by excessive inputs of nitrogen and phosphorous from multiple sources including agriculture, industry and domestic, as well as from atmospheric deposition of NOx from ships, which may give rise to algal blooms and problems of algal toxins and oxygen depletion in benthic waters due to decomposing algae. A Joint Assessment and Monitoring Programme aims at monitoring and assessing the health of the marine environment through repeated measurements of water, sediments and biota; the human activities affecting it; and, the effectiveness of measures and actions undertaken for its protection.

7.3.3 North Sea Commission and Conferences

The First International Conference on the Protection of the North Sea was held in Bremen 1984 with participation from Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, United Kingdom and the European Commission. The aim was to provide political impetus for the intensification of the work within relevant international bodies, and to ensure more efficient implementation of the existing international rules related to the marine environment in all North Sea States. The Bremen Conference in 1984 was followed by the London Conference in 1987, the Hague Conference in 1990, the Esbjerg Conference in 1995 and the Bergen Conference in 2002. A brief overview is given of decisions addressing agricultural emission of nutrients and phosphorus in particular.

The Bremen Declaration underlined the importance of the North Sea as an important and irreplaceable ecosystem. The purpose was to make a political declaration which, from a North Sea perspective, would stimulate and further ongoing work within the existing international conventions and regulations. A comprehensive quality status report (QSR) of the North Sea environment was prepared in preparation of the next conference.

In London, the North Sea Task Force (NSTF) was instituted to organise a coordinated scientific programme leading, in a reasonable timescale, to a dependable and comprehensive statement of circulation patterns, inputs and dispersion of contaminants, ecological conditions and effects of human activities in the North Sea. The specific goal was established of a reduction by 50% in inputs of phosphorus and nitrogen to those areas of the North Sea where such inputs are likely to cause pollution. Specific measures on how these goals could be met by agriculture were formulated.

The Conference at The Hague aimed at reviewing the implementation of the previous conferences and the clarification of political decisions in measurable terms. Further concrete steps were taken to alleviate eutrophication, notably by measures in agriculture which targeted an environmentally acceptable relationship between crop uptake and the amount of nutrients applied.

The Esbjerg Conference underlined the importance of the commitment to reducing phosphorus inputs. The deadline of a 50% reduction was achieved by all states except France. The ambitious target set for phosphorus has almost been met, while the reduction target for nitrogen has been more difficult to fulfil because of the particular difficulties of achieving reductions in nutrients from agricultural production. For the EC Member States, national action plans resulting from the Nitrates Directive, the agri-environmental measures and set-aside schemes need optimisation in order to reach the projected targets.

At the Bergen Conference, the Ministers committed themselves to achieve full implementation of the nitrates, urban waste water directives, and the water framework directive or equivalent national measures and to meet the target of the OSPAR Strategy to combat Eutrophication, i.e. to achieve by 2010 a healthy marine environment where eutrophication does not occur.

7.3.4 Baltic 21

The Mission of Baltic 21 is to pursue sustainable development in the Baltic Sea Region by regional multi-stakeholder co-operation. Accordingly, Baltic 21 provides a regional network to implement the globally agreed Agenda 21 and World Summit on Sustainable Development activities, while focusing on the regional context of sustainable development. The process was initiated in 1996 by the Prime Ministers of the Baltic Sea Region and involves the eleven countries from the Baltic Sea Region (the members of the Council of the Baltic Sea States, CBSS), the European Commission and a number of intergovernmental organisations, international financial institutions and international non-governmental networks.

The overriding objective of Baltic 21 is to contribute to achieving sustainable development in the Baltic Sea Region in a 30-year perspective. Baltic 21 addresses the three dimensions of sustainable development – environmental, social and economic aspects. The emphasis is on regional co-operation, and the work is focused on seven economic sectors (agriculture, energy, fisheries, forests, industry, tourism and transport) as well as on spatial planning and on education. Among the main objectives of Baltic 21 are that biological and ecosystem diversity and productivity are restored or maintained, that pollution to the atmosphere, land and water does not exceed the carrying capacity of nature; and, that renewable resources are efficiently used and managed within their regeneration capacity.

The agricultural sector is vital for all the countries in the Baltic Sea Region. Especially in the new Member States such as Poland, the population is to a large extent involved in agriculture, living in rural areas. Sustainable agriculture is defined as the production of high-quality food and other agricultural products and services in the long run, with consideration taken to economy and social structure in such a way that the resource base of non-renewable and renewable resources is maintained. Important subgoals for achieving sustainable agriculture are that the farmers in the region should practice production methods which do not threaten human or animal health or degrade the environment, including biodiversity, and a the same time minimise the environmental problems that future generations must assume responsibility for; that non-renewable resources gradually have to be replaced by renewable resources, and that re-circulation of non-renewable resources is maximized; and, that sustainable agriculture will meet the needs of food and recreation, and preserve the landscape, cultural values and historical heritage of rural areas, and contribute to the creation of stable, well-developed and secure rural communities.

One of the most important issues for the state of the Baltic Sea is the high contents of nutrients, such as nitrogen and phosphorus. Algal blooming during the summer, areas with no or low levels of oxygen and negative effects on fish, seals and other species have been reported. On average, agriculture is estimated to account for ca 35 % of the nitrogen input and ca 15 % of the phosphorus input to the Baltic Sea. Measurements showed that the 50% reduction target as of the reference year 1985 was not met in 1995. However, difficulties in assessing the effects of implemented measures exist, due to a significant time lag that affects the soil and sea systems depending on the mineralization of stored phosphorus in the soil, erosion of soil including phosphorus and many other processes in these systems.

Regions and farms with a high livestock density and/or high inputs of fertilisers, as well as inappropriate agricultural management, can often be a serious environmental threat. The main challenges are to reduce the negative effects of agriculture on the Baltic Sea by reducing nutrient pollution which to a large extent originates from animal production and improper use of fertilisers. In the new Member States (e.g. Poland), an immediate problem is nutrient point sources due to insufficient or non-existing manure storages and often large animal holdings. In the old Member States, point sources in connection with manure handling have been the focus of environmental action programmes for a couple of decades. Diffuse sources of pollution remain a problem in all countries.

Modern agriculture in the Baltic also relies on imported feed, non-renewable fossil fuel and finite phosphorus resources. Among the most urgent non-sustainable issues identified are dependence on non-renewable phosphorus deposits; nutrient losses (N and P) to the environment; decrease in soil fertility (acidification, carbon content, nutrient status, structure, compaction, salinisation); and, soil erosion. In the area different countries are involved in many projects of importance for sustainable agriculture. Several countries have programmes to promote organic agriculture, as one way of achieving a more sustainable agriculture.

Based on scenario analysis aiming at a sustainability goal of 50% reduction in all 10 countries involved, the maximum production of food and fodder possible was calculated and measures were identified. The scenario shows that less arable land and fewer animals will be needed in the future to provide the needed amounts of food and feed, due to greater efficiency in production, improved management and more sustainable technology. Opportunities to increase agricultural production of energy- and industrial crops, other types of bio-energy, etc. on excess arable land will be obvious. This will also be of great importance to develop the infrastructure and employment in rural areas. The changes are bound to be larger in the new Member States than in the rest of the Baltic Sea Region. Specific action programmes include the reduction of nutrient losses from agriculture, the protection of ground- and surface water for drinking water purposes in agricultural areas; the development of new production alternatives for arable land; the maintenance and development of rural landscapes; and, the preservation agricultural productivity for production of high quality food and feed.

7.3.5 Mediterranean action plan

The Mediterranean Action Plan (MAP), adopted in an effort, strives to protect the environment in the Mediterranean basin; to control pollution and protect the water quality of the Mediterranean Sea; and to foster sustainable development in the Mediterranean basin. It was ratified in Barcelona, Spain, in 1975 by 16 Mediterranean States and the EC, under the auspices of the United Nations Environment Programme (UNEP). Its legal framework comprises the Barcelona Convention adopted in 1976 and revised in 1995, and six protocols covering specific aspects of environmental protection. A Mediterranean Commission for Sustainable Development was also established by MAP in 1995 to facilitate the participation of all stakeholders in the Mediterranean area. The Mediterranean Commission on Sustainable Development (MCSD) is MAP’s advisory organ and provides a forum for dialogue and proposals where the Contracting Parties define a sustainable development strategy for the Mediterranean. The MCSD is composed of both representatives of the contracting parties and civil society, which includes five NGO’s.

The Mediterranean Action Plan has defined its range as the region bound by whole Mediterranean Sea starting from the Gibraltar and ending at the Dardanelles. This definition excludes the “inland extensions” of the Mediterrenean, the Marmara Sea, which belongs totally to Turkey, and, the Black Sea. Since water pollution is not limited to the specific water body it appears in, pollutants in these two inland extensions, may render a potential threat to the Mediterranean Sea, as the three seas are directly connected and pollutants in one may be transported to anyone of the three if conditions are favourable.

Originally the MAP had three aspects. The first was institutional/legal and dealt with the implementation of the Barcelona Convention on the protection of the Mediterranean Sea and its Protocols, numbering six. The second was scientific and was embodied by the Programme for the Monitoring and Research of Marine Pollution (MED POL). The third was socio-economic and worked on a systemic approach to the prospective and environmental priorities of all of the Mediterranean countries with the setting up in 1977 of regional activity centres for the Blue Plan and for a Priority Actions Programme. The 1980s saw the creation of other specific regional activity centres and the development of MAP's activities on the coastal regions with its "Coastal Area Management Programme". A co-ordination unit in Athens sees to the implementation of the whole. Several countries host programmes and specialised regional activity centres. Important for diffuse contamination from agricultural land are the MED POL programme in Athens for monitoring and research of marine pollution; BP/RAC (The Blue Plan) near Nice with the task of observing, evaluating and exploring the possible developments in the relationships between the environment and development in the Mediterranean Basin; the PAP/RAC (Priority Actions Programme) in Split works for the planning of and integrated coastal management; SPA/RAC for specially protected areas, located in Tunis, contributes to the protection of coastal environments and endangered marine species; the ERS/RAC for environmental remote sensing, implemented in Palermo in 1993; and the CP/RAC for clean production, the founding of which in Barcelona was approved in June of 1995.

The Long-term Programme of Pollution Monitoring and Research in the Mediterranean Sea provides information needed for the development and implementation of preventive and control measures. Complementary to this programme are subregional projects in water resource management, aquaculture, renewable energy, human settlements, tourism, and soil protection, where the state of existing knowledge is sufficient to justify concrete practical action. The shift from traditional agriculture to modern farming with greater productivity and increased use of fertilisers, insecticides, and pesticides, is observed as a major cause for the pollution of the Mediterranean.

The Convention for the Protection of the Mediterranean Sea against Pollution is supported by protocols covering the dumping of wastes at sea, cooperation in pollution emergencies, pollution from land-based sources, and specially-protected areas; other protocols are being prepared. The protocol for the prevention of pollution from land-based sources and activities (signed in 1980 and revised in 1996) is regarded by the countries concerned as one of the most important components of the Plan. In article V of this protocol, the parties commit themselves to eliminate pollution of the protocol area from land-based sources of a number of substances. Among the substances are organic and inorganic phosphorus.

7.3.6 The Global Environment Facility (GEF) Strategic Partnership on the Black Sea and Danube Basin

The watershed of the Danube includes eleven countries; Austria, Bulgaria, Czech Rep., Germany, Hungary, Moldova Rep., Romania, Slovak Rep., Switzerland, Ukraine, and Yugoslavia Fed. Rep.. The Black Sea hosts six riparian countries, Bulgaria, Georgia, Romania, The Russian Federation, Turkey and Ukraine, and is connected to the Mediterranean through the Bosphorus, Marmara Sea and the

Dardanelles. Hence, pollution carried to the Black Sea by the Danube is not only a problem for the riparian countries of the Black Sea itself, but it may also be a potential risk to the Mediterranean Sea, as well.

The environment of the Black Sea/Danube Basin has become degraded over the past four decades. Pollution of the waters of the Black Sea and its tributaries, notably the Danube, has caused significant losses to riparian countries through reduced revenues from tourism and fisheries, loss of biodiversity, and increased waterborne diseases. Extensive studies conducted during the 1990s have shown that over-fertilization of the water bodies by nitrogen and phosphorus discharges from municipal, industrial and agricultural sources ("eutrophication") were the most significant cause of the ecological degradation that the Black Sea and the Danube River have experienced.

The Global Environment Facility (GEF) Strategic Partnership on the Black Sea and Danube Basin has been established with the cooperation of the World Bank (WB), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and other multilateral and bilateral financiers and basin countries. The Partnership aims to promote investments and capacity building to return the Black Sea/Danube Basin environment to its 1960s condition. The two elements of the Partnership are:

- The WB Investment Fund for Nutrient Reduction in the Black Sea/Danube Basin to help finance investment projects in industrial and domestic wastewater treatment, wetland restoration and environmentally friendly agriculture (projects under implementation); and,
- Two UNDP/UNEP Regional Projects designed to enhance the capacity of individual riparian countries and their commissions (Black Sea Commission, Danube Commission) and improve the policy framework to address Black Sea and Danube pollution.

Two regional projects are aimed at addressing transboundary environmental degradation in the Danube/Black Sea basin through policy and legal reform, raising of public awareness, and institutional strengthening. They are (1) control of eutrophication, hazardous substances and related measures for rehabilitating the Black Sea ecosystem and (2) strengthening the implementation capacities for nutrient reduction and transboundary cooperation in the Danube River Basin.

7.3.7 OECD

In the framework of its initiative to develop a series of agri-environmental indicators, the OECD is currently working out a system to calculate phosphorus balances, similar to the one for nitrogen balances which was finalized in the late 90's. Balances will be calculated at the national level only.

8. National/regional legislation concerning P use in agriculture

8.1 National implementation of European Regulations and Directives

Three different groups of standards or requirements are applied with respect to nutrient related problems in farm practices. They are applied in different but sometimes overlapping situations in the Member States and comprise the Good Agricultural Practices of the Nitrates Directive, the Codes of usual Good Farming Practices, and Good Agricultural and Environmental Condition practices cross-compliance requirements. Different regulations and directives refer to definitions, implementation and control of Good agricultural Practices, Codes of usual Good Farming Practices and GAEC Practices (Table 81).

Table 81: Regulations referring to definitions, implementation and control of Good Agricultural Practices, usual Good Farming Practices and GAEC Practices (cross-compliance requirements)

Terminology	Regulation / Directive	Official Journal
Good Agricultural Practices	**Nitrates Directive** 91/676/EEC	*L 375 , 31/12/1991 P. 0001 - 0008*
Codes of usual Good Farming Practices	**Rural Development Regulation** Council Regulation (EC) No 1257/1999 Commission Regulation (EC) No 817/2004	*L 160, 26/06/1999 P. 80 - 102 (CONSLEG - 92R1600 - 26/06/1999 - 44 P. CONSLEG - 92R1601 - 26/06/1999 - 43 P); L 153,30/04/2004 P. 30 -83*
Codes of usual Good Farming Practices	**Horizontal Regulation** Council Regulation (EC) No 1259/1999 Commission Regulation (EC) No 963/2001	*L 160 , 26/06/1999 P. 113 – 118; L 136 , 18/05/2001 P. 04 - 05*
GAEC Practices, Cross-Compliance Requirements	**CAP 2003 reform** Council Regulation No 1782/2003 and Commission Regulation No 796/2004	*L 270 , 21/10/2003 P. 01 – 69; L 141 , 30/04/2004 P. 18 - 58*

8.1.1 Codes of Good Agricultural Practice

Good Agricultural Practices are an important agri-environmental policy tool and are used within the Member States for the correct implementation of Community environmental legislation such as the Nitrates Directive and Water Framework Directive. The Nitrates Directive (Council Directive 91/676/EEC) constitutes the most prominent example where the common legislation requires not only the definition of codes of GAP, but defines detailed GAP criteria to be included in the national implementation (see next box). Good Agricultural Practices are synonymous to Good Farming practice within this context. **Austria, Denmark, Finland, Germany** and **The Netherlands** applied the action programme to their whole territory. In other Member States the extent to which the action programme is applied differs and is often limited to the identified Nitrate Vulnerable Zones.

Codes of Good Agricultural Practice defined within the EU Nitrates Directive

Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources

Article 4

1. (...) Member States shall, within a two-year period following the notification of this Directive:

(a) establish a **code or codes of good agricultural practice**, to be implemented by farmers on a voluntary basis, which should contain provisions covering at least the items mentioned in Annex II A.

ANNEX II **CODE(S) OF GOOD AGRICULTURAL PRACTICE**

A. A **code or codes of good agricultural practice** with the objective of reducing pollution by nitrates and taking account of conditions in the different regions of the Community should certain provisions covering the following items, in so far as they are relevant:

1. periods when the application of fertilizer is inappropriate;
2. the land application of fertilizer to steeply sloping ground;
3. the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground;
4. the conditions for land application of fertilizer near water courses;
5. the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage;
6. procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.

B. Member States may also include in their **code(s) of good agricultural practices** the following items:

7. land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;
8. the maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate pollution of water;
9. the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use;
10. the prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems.

8.1.2 Codes of usual Good Farming Practice

Codes of usual Good Farming Practice represent minimum standards for farmers to get, in the framework of the rural development regulation, compensatory allowances/payments in the Least Favoured Areas and support for voluntary agri-environmental measures on the basis of income foregone, additional costs and the need to provide an incentive. Usual Good Farming Practices are defined as “the standard of farming which a reasonable farmer would follow in the region concerned”. Codes are set up by the Member States as verifiable standards in their rural development plans. These standards entail at least, compliance with general mandatory environmental requirements.

For the implementation of usual Good Farming Practices, operational indicators are needed for farmers and their management decisions and for administrative control. The different control-indicators used by Member States for the control of compliance with Codes of usual Good Farming Practice are listed in Table 70. Other indicators are controlled in a different way at national level but fall outside the European Regulations context. Therefore these indicators have been detailed in the section on national legislation.

In practice, many definitions of GFP are established by MS governments or are based on requirements set by national, regional or local legislation. All legally binding criteria can be subject to control and punishment, whereas the standards beyond legislation are either voluntary (i.e. promoted by advisory services) or mandatory (i.e. in the framework of support programmes). Table 82 is based on information extracted from Rural Development Plans in the different Member States.

Table 82: Control of Good Farming Practices in Member States

Control of Standards for Fertilisation	Countries
1. Manure storage: CZ, IT, EE, NL, PL: Minimum storage capacity of manure containers UK: Notification & control of manure storage with the environment Agency; sheep dip disposal requires authorisation from Environment Agency	CZ, IT, UK, PL
2. Soil conditions for spreading: Organic or chemical fertiliser not to be spread on wet, waterlogged, frozen, snow covered soil or on land sloping towards a watercourse or on steep slopes.	CZ, AT, EI, NL, EE, ES
3. Maximum N input from livestock manure and equivalent livestock density (See also livestock densities to combat overgrazing): DE: 170 kg N/ha on arable crops, 210 kg N/ha on grassland DK: max. 1.4 LU/ha for pigs, 1.7 LU/ha for cattle, goats, ship, poultry and 2.3 LU/ha for pure cattle farms; excess sold to other farms or biogas plants (Harmony rules: between land & animals) AT: < 2.7 LU/ha arable land (in relation to water law) EE : 1.5 LU/ha equivalent for arable land ; 1 LU/ha in NVZ	CZ, DE, AT, DK, ES, EE, EL
4. Fertiliser plans & records/accounts, nutrient balances: DE: fertiliser plans for each crop, farmgate-balances for N (yearly) and P & K (every 3 years) required DK: fertiliser plan includes expected nitrogen demand for farm; N & P demand for single fields; animal units; spreading of manure (incl. maps). Quota allocated to each farm. NL: Registration of supply and abduction of livestock manure on farm level; Mineral loss accounting system EI: Record of date, type and quantity of chemical fertilisers and organic waste brought onto or leaving the farm CZ: Yearly record per field, kept for 7 years IT: Fertilisation plan for N, P, K based on crop uptake, application & timing	CZ, DE, DK, IT, NL, EI
5. Time ban for fertilisation: NL: 1. Sept. - 1. Feb. DE: generally between 15. Nov.-15. Jan. CZ: generally between 15.Sept.-31.March	CZ, DE, IT, NL
6. Low emission application techniques for manure spreading	CZ, NL
7. Laboratory testing DE: yearly for mineral N; every crop rotation (and min. every 6 yrs) for K & P; N, P, K in manure EL: Soil & foliar analysis IT: N, P, K in manure	DE, EL, IT
8. Immediate incorporation of manure and mineral fertilisers	DE, CZ
9. Prohibited direct entry of fertiliser into watercourses	DE, EI, CZ
10. Catch crop requirement: DK: On at least 6 % of the farm area which may not be ploughed before 20.Oct	DK
11. Buffer zones AT: Buffer zones to watercourses EI: No chemical fertiliser being spread within 1.5 m of a watercourse No organic fertiliser being spread 10 m of a watercourse or within 50 m of a domestic well or public water supply source CZ: 1 m wide strip not ploughed; 25 m wide strip not ploughed nor manured on 7° slopes DK: No digging, cultivation, planting, fencing, changing terrain within 2 meters from lakes and water courses EL: No application of fertiliser within 2 m from surface waters and NATURA2000 sites; 6 m for steep (> 8°) slopes	AT, EI, CZ, DK, EL
12. Sewage sludge and waste products: AT: Control of certificates of sewage sludge (with content of pollutants, delivery note, crop, time of application), checks by appearance (suitability of soil and limits for amount and timing of application). DK: Maps in field and fertilisation plans indicating fields of spreading; rules on maximum nutrients to be applied IT: N, P, K in sewage sludge	AT, DK

13. Maximum Application Rates: CZ: 170 kg N/ha DE: Manure: 170 kg N/ha on arable; 210 kg N/ha on grassland; after harvest: 40 kg NH_4-N or 80 kg N/ha EL: 140 kg N/ha for cereals in split applications NL: Grassland, Farmland & Fallow: 20 kg P/ha/yr; Grass on non-sensitive soils: 180 kg N/ha/yr; Grass on sensitive soils: 140 kg N/ha/yr; Farmland and fallow on clay or peat soils: 100 kg N/ha/yr; Farmland and fallow on sensitive sandy and loss soils: 60 kg N/ha/yr; NATURA2000: 10 kg P & 50 kg N/ha/yr	CZ, DE, EL, NL
Control of Standards for Soil Conservation	**Countries**
1. Soil cover requirement: DK: plant cover of 65 % during autumn and winter (up to 20% can be fulfilled by leaving straw from cereals and rapeseed on the field); field plan showing plant cover (catch & cover crops); 6% of farm is catch crop CZ: no row-crops above 7° slope; no grassland removed above 12° slope IT: Inter-row cropping on vineyards and orchards SE: Rules for soil cover in certain areas on farms with > 5ha	DK, CZ, IT, SE
2. Cultivation practices: ES: Contour cultivation on steep slopes EL: Contour cultivation and no deep ploughing on steep slopes; no heavy machinery without permission; no cultivation of 1 m between fields IT: Maximum plough depth; no soil packing on grassland	ES, EL, IT
3. No conversion of grassland	AT
4. General erosion measures IT: Ditch maintenance, distance between water gullies/ditches in sloping areas UK: No supplementary feeding to avoid poaching and erosion	AT, UK, IT
5. Overgrazing UK: farms with a stocking density of 1.4 LU/ha (1.8 in Northern Ireland) or above are subject to inspection at least once every three years; 0.15 LU/ha to avoid under utilisation in hill farms CZ: No grazing on steep slopes EL: Limitations in terms of period, area (not on burned or afforestation areas or long term set-aside); not within 30 m from steep (>40%) lake shores and riverbanks; Grazing loads: 0.5-0.8 LU/ha in (semi-)mountainous land and 0.2-0.5 LU/ha on insular pastures. Further cut by 30% on degraded pasture EI: checks if > 2 LU/ha ES: Maximum livestock densities in forage production lands: • annual rainfall < 400 mm: 0.5 LU/ha • annual rainfall 400 - 600mm: 1 LU/ha • annual rainfall 600 - 800mm: 1.5 LU/ha • annual rainfall > 800mm: 2 LU/ha	UK, CZ, EL, EI, ES
6. Crop rotation requirements EL: Cereals: leguminous crop once in 4 years; Leguminous crops: cereal once in 4 years. Sugar beet: 40% of farm area in rotation, every 4 years in the same field; Cereals, tomato, potatoes, tobacco: 20%; Cotton: 15-20%. AT: Cereal or maize < 85% of arable land ES: Fallow in dryland farming	AT, EL, ES
Control of standards for Landscape (of importance to soil conservation)	**Countries**
Maintenance of landscape elements	AT
Destruction of hedges and stonewalls not permitted except by consent	UK
Control of standards for other categories	**Countries**
Environmental farm management plan	EL
Burning grass, stubble ES: No burning of stubble and pastures unless authorised by the Regional Authorities; protection of areas at fire risk by 3m wide ploughed strip EI: Burning of growing vegetation on non-cultivated land between April 15th and August 31st EL: No straw burning on steep (> 6°) slopes and within 500 m from forests and NATURA2000 sites	ES, EI, EL
Environmental Requirements for set-aside land	
Prohibition of fertilisers, waste waters, sewage sludge and composted waste	AT
Minimum tillage	ES
Maintenance of vegetation cover	ES, NL

(Sources: annual reports according on the implementation of Rural development Plans according to Regulation (EC) 1257/1999, Http://www.bal.fal.de/en/)

8.1.3 Good Agricultural and Environmental Condition (GAEC) Practices

Since the 2003 CAP reform, a compulsory cross-compliance scheme (Council Regulation No 1782/2003 and Commission Regulation No 796/2004) for all direct payments was introduced. From 2005 onwards, all direct payments are conditional upon 19 statutory requirements in the field of environment (e.g. protection of natural resources, landscape, historic and archaeological features); labour safety; plant health and food safety; public health; and, animal health and welfare (Annex III). Additional cross-compliance requirements beyond EU environmental legislation are defined as 'Good Agricultural and Environmental Conditions', regarding soil erosion, organic matter and structure as well as a minimum level of maintenance and avoiding the deterioration of habitats (Annex IV).

Minimum standards for farm management within the frame of cross-compliance serve as a precondition for payments to farmers in the context of market policy as well as rural development policy. Table 83 presents categories of cross-compliance and GAEC Good practices in Member States with a focus on verifiable standards.

Table 83: Categories of Cross-Compliance requirements and GAEC Practices in Member States (Adapted from Bergschmidt et al., 2003)

Categories	AT	DK	UK	DE	IE	NL	SE
Fertiliser Management:							
Storage		VS-leg	VS-leg		VS-leg	VS-leg	VS-leg
Use of Mineral Fert.	VS-leg	VS-leg	Leg		VS-leg	VS-leg	VS-leg
Use of Organic Fert.	VS-leg	VS-leg	Leg	VS-leg	VS-leg	VS-leg	VS-leg
Time-limit for Org.F.		VS-leg	Leg			VS-leg	VS-leg
Time-limit for Min.F.			Leg			VS	VS-leg
Livestock density	VS-leg					(indir)	VS-leg
Soil Testing				VS-leg			
Buffer zones	VS-leg	VS-leg			VS-leg		
Water Use							
Farm Management (Nutrient Mgt Plans)		VS-leg		VS-leg		VS-leg	
Soil Conservation:							
Soil cover	X						VS-leg
Maintenance of Grassland	X						
Sewage Sludge & Compost	VS-leg						
Erosion, Tillage	X						
Crop rotation							
Landscape:							
Field Boundaries			VS-leg		VS		
Hedgerows			VS				
Other:							
Waste handling			VS-leg		VS-leg		
Burning			leg		VS-leg		
Fire protection							
Categories	**EL**	**ES**	**CZ**	**EE**	**LV**	**LT**	**PL**
Fertiliser Management:							
Storage			Leg	VS-leg	XlegR	Xleg	Xleg
Use of Mineral Fert.	X	X	Leg	VS-leg	XlegR	XlegR	Xleg
Use of Organic Fert.	X	X	Leg	VS-leg	VS-leg	XlegR	Xleg
Time-limit for Org.F.			Leg		XlegR		Xleg
Time-limit for Min.F.					XlegR		
Livestock density		VS		VS-leg	Indir		

Categories	AT	DK	UK	DE	IE	NL	SE
Soil Testing					VS		
Buffer zones	X				Xleg	Xleg	Xleg
Water Use	X	X				Xleg	
Farm Management (Nutrient Mgt Plans)	VS		Leg	VS-leg	Xleg		
Soil Conservation:							
Soil cover					XlegR	XlegR	
Maintenance of Grassland			VS-leg			Xleg	Xleg
Sewage Sludge & Compost					Xleg	Xleg	Xleg
Erosion, Tillage	X	VS					
Crop rotation	X						
Others			VS-leg		XlegR	Xleg	Xleg
Landscape:							
Field Boundaries							
Hedgerows							
Other:							
Waste handling	Leg	X		VS-leg		Xleg	Xleg
Burning	Leg	VS					X
Fire protection		X					

X = principle of GFP, leg = legislation, VS = verifiable standard, R = regional.

8.1.4 Analysis per country

All EU Member States have chosen different strategies for the definitions of Good Agricultural Practices, Codes of usual Good Farming Practices and GAEC Practices. In most countries, mandatory standards consist of existing legal obligations, mainly in the field of fertiliser use, laid down in EU, national and regional law, and only few countries defined standards going beyond legislation.

In Austria, Denmark, Germany, Sweden and The Netherlands a lot of emphasis is placed on fertiliser use. Denmark, Germany and The Netherlands require nutrient accounting, and their control relies heavily on records. Sweden controls additional standards for farms in Nitrate Vulnerable Zones. Austria and Denmark have included verifiable standards for animal husbandry, soil cover or use of sewage sludge in their rural development plans.

In Germany, each federal state can present its own selection of criteria and a set of indicators in the areas of fertilisation use is generally used. Livestock density is regulated indirectly through the maximum allowed amounts of manure. The verifiable standards represent a selection of criteria out of the broader national requirements.

In The Netherlands all aspects of fertilisation were until recently covered with very detailed standards for production, storage and application of fertiliser and manure. A mineral accounting system (MINAS) with specific loss standards for N and P was administered and made compulsory for all farmers. However, on 2 October 2003 the Court of Justice decided that part of the Dutch Action Programme was not in line with the Nitrates Directive. On 1 July 2004 the EU Commission and the Netherlands agreed on a Third Action Programme implementing the objectives of the Directive and establishing the basis for a possible derogation. The new Action Programme centres on the introduction of a system of nutrient application standards to replace the previous system based on maximum allowable nutrient losses. The new system will come into force on 1 January 2006. Apart from the replacement of loss standards by application standards, more stringent standards will be set for soils prone to leaching, new rules are laid out regarding manure storage and a number of regulations on the conditions for the use of manure have been modified. It should be noted that the Dutch fertiliser policy is not only based on the Nitrates Directive but also refers to other parts of the Water Framework Directive. Partly on the basis of these regulations, specific standards have been set for phosphorus too.

Austria specifies standards for soil protection, such as compliance with regional and local regulations for soil protection and waste management and avoidance of erosion and soil compaction. In areas at risk, the local administration can order measures that minimise the pressure on soil such as minimal tillage or soil cover. Participation in the agri-environment 'basic support measure' is based on additional principles. Compliance with these principles is financially supported.

England and Ireland emphasise landscape elements such as field boundaries. In addition, three verifiable standards are defined for grazing, as overgrazing is a significant problem in many upland areas of the UK. Other definitions cover waste handling (disposal of sheep dip) and burning of grass and crop residues. The only verifiable standard in the area of fertilising refers to storage of silage and slurry, where a farmer has to notify the environment agency before starting to use a new storage facility.

In Greece and Spain all standards of GFP are considered to be verifiable. In Greece, inspections check the existence of a management plan that includes all relevant rules to comply with and invoices for fertiliser purchase, additionally, laboratory analyses are carried out. Spain developed a general code, which farmers have to comply with in order to receive benefits within agri-environment measures. Three essential and verifiable standards have been pointed out for livestock density, fertiliser use, stubble burning and anti-erosion measures. The regions can define their own standards according to climate and soil conditions. Both countries include standards for fire protection, erosion protection and the limitation of the stocking density. Greece limits also the grazing period.

The Czech Republic combines legislation and, sometimes additional, verifiable standards for soil protection, grassland management and protection of biotopes, defined in the rural development plan. Verifiable standards going beyond legislation are added.

Estonia has defined verifiable standards as a baseline for agri-environment measures, including a maximum livestock density, the requirement to keep a field record book and standards for waste handling. Most categories except soil protection are covered. The use of fertiliser is prohibited on snow and frozen ground.

Latvia has detailed mandatory standards in all categories. Additional standards for fertilising and soil protection in nitrate vulnerable zones are defined. Latvia has selected two indicators for control of fertiliser use. Concerning soil conservation, crop rotation is observed.

Lithuania defined mandatory standards in its Agriculture and Rural Development Plan 2000-2006, resulting in an elaborated catalogue of standards, all covered by legislation. Land owners have to preserve and enhance soil fertility. For karst zones, additional rules apply. Farmers can follow the requirements on a voluntary basis.

In Poland standards are defined in most of the categories as minimum standards for Rural Development measures. Storage facilities for manure and slurry must have a capacity of at least 6 months.

8.2 Specific legislations regulating P-use

Information on specific legislations regulating phosphorus use in the different Member States is difficult to find. Therefore questionnaires with questions on regulations, manure treatment, and national / regional farm practices with respect to phosphorus were administered to the different EU delegations of the Member States and from there sent to the relevant Member State Ministries. Replies were received from the Czech Republic, Latvia, Sweden, Hungary, Slovakia, Poland, Austria, Belgium (Flanders, Walloon Region), Denmark, Spain, The Netherlands, Malta and Ireland. For some Member States that did not reply, information on their national legislative systems with regard to phosphorus use in farm practice was sought on the www.

This section provides a detailed overview of the specific legislation regulating phosphorus use in different Member states based on the responses to the questionnaires augmented with information based on consultation of relevant websites. The aim of the questionnaire was to obtain information from the Member States concerning specific existing or projected legal instruments dealing with phosphorus related problems in farm practice. Other items concerned the use of manure treatment techniques, availability of information on the P-status and P-sensitivity of the soils; use of P-balances; and, incentives to rational P-use. Differences in laboratory analysis (extraction methods), use of phosphorus fertilisers, extension services and fertiliser advisory systems are discussed in chapter 3 (section 3.3.4).

The questionnaires were sent out to the MS delegations at the EU in Brussels, who were requested to forward it to the most appropriate institution within their respective country.

8.2.1 Austria

Austria reported on the existence of “Vorläufige Richtlinie für die Begrenzung von Immissionen in Fließgewässern, 1987”, where target values are more or less orientated at those values of 78/659/EEC Fresh Water Directive for Fish. In line with the implementation of EU Framework Directive 2000/60/EC limit values are being worked out to define the different classes of ‘good status’. At present, the ‘Grundwasserschwellenwertverordnung’ (BGBL. Nr 502/1991) regulates threshold levels and remediation measures for exceedance of values at a defined percentage of sites.

There is no explicit limitation of P-emissions from agriculture since P-balances as well as results of national monitoring of water quality in Austria do not disclose any major problems and since P-emissions are limited sufficiently but indirectly by the limitation of nitrates due to the nation-wide nitrates action programme (implementation of the nitrates directive). Manure has a certain ratio of N and P depending on the individual animal category, and any restrictions on N will have implications for phosphorus. There are no intentions to reduce the P-content in manure through separation and treatment of slurry and solids in farm manure.

P-fertiliser applications are regulated by the Fertiliser Ordinance BGBl. Nr.100/2004; limit values are applied for the heavy metals Cd, Cr and V in mineral P-fertilisers (with > 5% P_2O_5) and lime. In the Austrian province Vorarlberg the application of sewage sludge is forbidden, if P_2O_5 content is more than 25 mg/100g soil (Sewage Sludge Ordinance LGBl. Nr 75/1997 (27/2002)). In the past, P balances were set up periodically at national level. According to "Nährstoffbilanzen der Donauanrainerstaaten, Erhebung von Österreich, Institut für Wassergüte und Abfallwirtschaft der TU Wien 1992" the input of P on agricultural soils declined in Austria between 1988 from a range of 71.8 to 82.2 KT P to a range of 66.0 to 76.4 KT P in 1992. Losses remained within a range of 45.6 to 59.1 KT more or less the same between 1988 and 1992 thus resulting in a considerable decline in the surpluses which were stored in the soils. In 1992 a range of 34.8 to 43.6 KT P had their origin in the spreading of manure; 28.7 KT P were from mineral fertilisers. At the beginning of the 90ies the input per hectare amounted to a range of 19.2 to 22.3 Kg per hectare. Since 1992 a decline in the consumption of fertilizer application from 28.7 KT P to about 18.8 KT as well as a decline of livestock has been observed resulting in a further considerable decline of inputs.

8.2.2 Belgium - Flanders

For Belgium a distinction is made between the Flanders and Walloon region for they have a different legislation concerning phosphorus use and production at farm level. In Flanders, nutrient management legislation focuses on both N and P. Standards, norms and guidance values with respect to phosphorus concentrations in water are set in VLAREM II from 1/7/1995 onwards and monitored by the Flemish Environment Agency. For surface waters the mean of total phosphate should be lower than 0.3 mg P/l; the norm for orthophosphate is 0.3 mg P/l in running waters and 0.05 mg P/l in standing waters (calculated as the 90-percentile with none of the results exceeding 150% of the threshold value). For groundwater, the maximum acceptable concentration is 5 mg P_2O_5/l with a guidance value of 0.4 mg P_2O_5/l. For drinking water, monthly monitoring applies: the 90-percentile should not exceed 0.7 mg P_2O_5/l and none of the results is allowed to exceed 150% of this value. Controls of bathing water are needed in case the water shows a tendency to eutrophication. For fishing water, monthly monitoring should not reveal total phosphate concentrations more than 1 mg P/l. No specific requirements for P exist for shellfish production. Sectoral discharge standards are set at 2 mg P/l for manure treatment installations.

Fertiliser norms are given for both nutrients N and P. From 1991 onwards and with different changes thereafter, application norms in terms of total phosphorus are differentiated according to the type of vulnerable zone and four crop types (Grassland, maize, crops with low nitrogen requirement, other crops). In the period

1993-1997 a regional inventory was conducted on P-saturation degree of sandy acid soils in Flanders (VLM, 1997). On the basis of this study phosphate saturated areas (phosphate saturation degree > 40 %) and phosphate risk areas (30 % < phosphate saturation degree < 40 %) were indicated in Flanders. In phosphate saturated areas, more stringent regulations are applicable. Restrictions for total phosphorus per hectare and for application of animal and organic manure exist with regard to the period of spreading, the state of the soil and the distance to certain watercourses.

On a yearly basis, each farmer has to declare his livestock, the surface of the farm' s cultivated acreage, geographical location and cropping plan, the transport of manure, the stock of manure at the end of the year, the use of chemical and organic fertilisers. All data are registered at the farm level and P-balances are calculated for each farm to budget the use of P/ha. This is done by the Manure Bank for the implementation of the manure policy. Farms with an annual P production over 10,000 kg P_20_5 (7,500 kg in areas with a high P-pressure) are obliged to treat or process a certain percentage of the manure produced. At present these percentages range from 30% to 95% and will further increase in the future, up to a 100% in some cases. In total 8.4 million kilograms manure has to be eliminated every year. The end product has to be exported outside the Flemish territory or to be used for non agricultural purposes (e.g. homegardens, public green areas). Redistribution of manure from areas with an intensive livestock production to areas with a lower manure-pressure is compulsory. Considerable quantities of dry poultry manure are exported to France.

In Flanders' legislation definitions are used for treatment and processing of manure. The treatment of manure is any transformation in order to improve its quality or its handling or transportation qualities, basically without elimination of the nutrients. Processing of manure is any transformation of manure that reduces the amount of nutrients brought onto the agricultural land (via neutralisation or elimination of the nutrients, export outside the geographical borders or use on non - agricultural land).

Depending on the type of manure the export may be preceded by manure treatment. Manure treatment may consist of separation of liquid and solids, biological treatment liquid fraction, drying, composting, ultra filtration, reverse osmoses, ammonium stripping + catalytic oxidation, electro flotation, and digestion. Operational Capacities for 2003-2004 were 400,000 ton/year for poultry, 250,000 ton/year for pigs and 50,000 ton/year for other animals. This amounts to a total of ca. 8500 tons of P_2O_5 per year. Feeding techniques are commonly used at farm-level to limit the phosphorus content in manure. For Pigs and poultry the use of feed with a low P content and of Phytase is common practice. The standard phosphorus amount in low P-feed (kg/ton) is given in Table 84. In practice the average use of P in feed is often still lower, in which case the equations are used to calculate the animal P-excretion. Between 2000 en 2003 the total Flemish P-production from livestock manure decreased with 12.5 million kg P_2O_5 from 75 million kg P_2O_5 to 63 million kg P_2O_5 because of the use of low P-feed.

Table 84: Phosphorus amount in low P-feed (kg/ton) and animal P2O5 Production (kg/animal.year) for some categories of animals as used in farm-level P-balances in Flanders, Belgium.

Animal	P amount in feed (kg/ton)	Animal P_2O_5 Production (kg/animal.year)
Pigs	6	Y = 2,03 X – 1,114
Sows	6	Y = 1,86 X + 0,949
Slaughter pigs 20-40 kg	5.5	Y = 1,92 X – 1,204
Slaughter pigs 40-110 kg	5	Y = 1,86 X + 0,949
Laying hens	5	Y = 2,30 X – 0,115
Broilers (> 2 weeks)	5.5	Y = 2,25 X – 0,221

Whereby X is the use of kg P/animal/year and Y is animal P_2O_5 production (kg/animal.year)

The manure Bank has an inspection and control team of 25 persons; penalties for non-compliance are 1 € per kg P_2O_5 for fertiliser applications and 0.99 € per kg P_2O_5 for livestock densities plus possible additional judicial penalties. Pollution charges and taxes are € 0.0111 /kg P_2O_5 for animal production, € 0.0223 /kg P_2O_5 for the use of mineral and organic manure, € 2,4789/ton manure for manure import, € 0.99 /kg P_2O_5 for not processing manure, € 0.99 /kg P_2O_5 for not respecting the nutrient stop, € 1/kg P_2O_5 for not legally accounting for nutrient placement (export, processed, use on land, storage), and € 1/kg P_2O_5 for not respecting the manure application norms.

At regional level a P-soil balance is made and described in the Environmental and Nature report of Flanders (MIRA-T, 2004) in order to (re)direct nutrient policy. Since 1995, there is a stand-still licensing policy and nutrient stop in order to freeze or reduce manure-based nutrient production at farm level, controlled by means of livestock numbers.

8.2.3 Belgium – Walloon Region

In the Walloon region of Belgium, the norm for total phosphorus concentration in surface water is 1 mg P/l based on the median value (Arrêté royal du 4 novembre 1987). Based on the compulsory yearly control frequency of groundwater (Arrêté du Gouvernement wallon du 15/01/2004), no abnormal changes in P_2O_5 content were observed; no norms are set for P concentrations in groundwater. Guidance values with respect to phosphorus concentrations in drinking water are 0.7 mg P_2O_5/l for category A2 surface waters (Arrêté royal du 25 septembre 1984; Arrêté du Gouvernement wallon du 17 octobre 1996). For fishing water, the total phosphorus concentration should not exceed 0.5 mg P/l (Arrêté du Gouvernement wallon du 15 décembre 1994).

In the Walloon region, there is no regulation concerning P-fertiliser application, nor are there restrictions on P-production at farm-level. No norms are set for total P-surplus (loss rates) based on P balances. There are no taxes or pollution charges linked to phosphorus pollution from agriculture. However, the law concerning pollution from industrial pollution applies for large emissions of phosphorus (0.9 mg P/kg emission).

Several studies exist with regard to nutrient and phosphorus balances for the region (Van Bol et al., 1996; Debouche et Lambin, 2000).

8.2.4 Czech Republic

In the Czech Republic the following water quality norms exist according to Public Notice No. 82/1999 on indicators of water pollution: 0.15 mg P/l in surface waters for water supply purposes, 0.40 mg P/l in surface waters for other (not specified) purposes and 0.05 mg P/l for drinking water. Since the nineties when state subsidies for fertilisation became limited, the doses of fertiliser rates have become one tenth of previous rates. Due to very limited fertiliser use diffuse emission of P from agriculture is perceived as non-existent. However, undertakers have to comply with the fertiliser law (No. 156/1998 Sb.) and subsequent public notices and amendments thereby not introducing contaminants into the soil, avoiding diffuse emission into the waters and ensuring uniform and regular spreading of fertiliser. Further to this, the Central Agricultural Institute for Supervising and Testing ensures fertiliser registration; organises soil testing; and exercises control and supervision for storage and use of fertilisers. Categories of P-content (5 classes from low to very high) are based on yearly soil testing data and available for all individual regions and for the different agricultural land uses in each region. Penalties for non-compliance with the fertiliser law range from 50,000 CzK for not allowing soil testing and for failing to keep records; 100,000 CzK for improper storage of fertilisers, manure and sewage sludge; 500,000 CzK for improper marking and denotation of fertiliser; to 5 mio CzK for setting afloat unregistered fertiliser. Considering the conditions of the present Czech agriculture and an average proportion of only 0.42 cattle units per hectare, there exist no restrictions on phosphorus content in terms of production or manure treatment at farm level. In an attempt to increase P availability in the soil and improve the effectiveness of fertilisation with respect to P, manure or organic fertilisers were incorporated into mineral fertilisers and used for fertilisation.

8.2.5 Denmark

In Denmark water quality norms exist only for surface water where it is used for drinking (0.7 mg P2O5 pr. L jvf. bekendtgørelse nr. 162 af 29. april 1980) and for drinking water (total P: 0.15 mg/l). Analysis of drinking water supply wells is performed from twice a month to once a year depending on produced volume (Miljø- og Energiministeriet: Bekendtgørelse nr. 871 af 21. Sep. 2001).

The Danish normative system (Poulsen et al. 2005) is quite detailed in order to give each farmer or control authority a possibility to “identify” the actual livestock production and obtain standard values that can be used for e.g. fertiliser planning and control. The Danish normative system includes nutrient contents (N, P and K) together with volume and dry matter content. Values are calculated for all species and categories relevant for Danish livestock production and they are furthermore given separately for relevant housing systems and manure types. The standard values are updated annually and are to a large extent based on data from Danish livestock farming (practical farming). The default values are used by the major part of farmers but the Danish normative system also includes possibilities for correction of the default standards if the farmers can document own values.

Guidelines exist for the optimum phosphorus amount for the most important agricultural crops, and tables with P-amounts in manure are available. However, there are until now no controls and no penalties on the amount of P in manure and the P given to crops. A tax exists on P in fertiliser and a tax on P in feedstuff has just been implemented (at 4 Dkr/kg). The application of sewage sludge is regulated by statutory order on application of waste products for agricultural purposes no. 623 of June 30, 2003. Sludge must be analysed for heavy metal and xenobiotic substances before application on farmland. An equivalent application of 30 kg total P/hectare/year is allowed for sewage sludge. After separation of manure in phosphorus rich fractions, redistribution or export is allowed. Eleven installations for manure treatment are registered; they mainly practice separation by centrifugation. The total capacity is around 290.000 ton per year (manure + some sludge). However, environmental issues and taxations limit further expansion. In order to limit P in feed, addition of EEC-approved feed additives such as Phytase is practised. Phytase breaks down the undigesatble phytic acid in grains, thereby releasing digestable phosphorus, which would otherwise first be released in nature. The Danish Institute of Agricultural Sciences is planning to prepare maps on the P-fixing capacity and P-saturation.

8.2.6 Hungary

Hungary provided details on limits for emissions of phosphorus to surface waters: depending on the applied production technology: 1-10 mg/l; depending on the area: 0.7-10 mg/l and for fertiliser production 3 kg/t. The water quality norm for phosphate in is 200 µg/l for drinking water and 500 µg/l for groundwater. For fishing ponds is 2 mg P/l applicable and for fishing waters is 0.1 to 0.4 mg/l applicable depending on the fish species. Concerning P fertiliser applications, no specific rules for P but general provisions are made such as the P application should be based on the local circumstances, soil characteristics and the crop. Soil analysis is required for mineral fertiliser applications, whereby reference is made to the Law of 1994 LV on agricultural land chapter 6 and to the Governmental Decree 49/2001 (IV.2.) on the protection of waters against pollution of nitrate from agricultural sources. Permit from the soil conservation authority is required for the application of sewage sludge according to Gov. Decree 50/2001. (IV. 3.) on the rules of agricultural use of sewage sludge and sewage. No limit value for P exists; the limiting factor is heavy metal content of the sludge and applied heavy metal/N/ha annually. Manure and fertilizer can not be applied within a minimal distance (10 m) from surface waters springs and wells. The priority with manure treatment is not the removal of nutrients but the conserving the quality of the manure and protection the environment during manure treatment. Control mechanisms are the inspection of good agricultural practices by the competent authority and the Hungarian Soil Monitoring System (from 1992). Although P-production at farm level and P losses to the environment are not perceived as a major problem, fines exist for excessive discharges from animal breeding farms and taxes in the case of discharges into the surface water. Farmers applying for subsidies in the frame of the Rural Development Plan are required to have soil analysis done and appropriate cultivation techniques to combat erosion prior to receiving payments. Soil analysis is required every five years for nitrate vulnerable zones. The ‘plant available’ P content of soil is analysed in the Hungarian Soil Monitoring System every 3 years, first in 1992 (Central Service for Plant

Protection and Soil Conservation). P balances are calculated at national level using the OECD methodology.

8.2.7 Ireland

In Ireland, the minimum standard for unpolluted surface water under the Phosphorus Regulations are a median standard of 0.03 mg P /l for orthophosphate in river waters and an average value of 0.02 mg P /l for total P in lake waters (Local Government (Water Pollution) Act, 1977). Different P standards are set for polluted surface waters. Measures are undertaken by Local Authorities that have the objective of meeting prescribed targets by 2007. For groundwater, there are no norms. The maximum admissible concentration for drinking water is 5,000 µg P_2O_5/l. Specified bathing waters are to be sampled where there is a tendency towards eutrophication. Local Authorities take appropriate measures to ensure the standards set are complied with. No standards or norms on phosphorus content apply to fishing waters or waters for shellfish production.

Participants in the Rural Environment Protection Scheme (REPS) use nutrients (including phosphorus) in accordance with a nutrient management plan (http://www.agriculture.gov.ie/index.jsp?file=areasofi/reps3/reps3.xml). Maximum limits are set for P in this scheme. The nutrient management legislation in force is primarily based on phosphorus. Specified soil testing for P levels and prohibition of inorganic P applications to grassland which show excess levels of P are some of the measures that are already implemented (De Clerq et al, 2001). The Rural Environment Protection Scheme is operated and controlled by the Department of Agriculture and Food. Penalties are applicable where the conditions of the scheme are not complied with. Sewage sludge may only be used in agriculture in accordance with a nutrient management plan. Control mechanisms are the Local Authorities for the Sewage sludge Regulations with penalties for breaches (Waste Management Act, 1996).

Regulations will be drawn up shortly for the purpose of the further implementation of the Nitrates Directive (91/676/EEC) in Ireland. The following is one of the provisions proposed: the quantity of chemical fertiliser and organic fertiliser applied to land should not exceed an amount determined by reference to the foreseeable nitrogen and phosphorus requirements of crops. Quantities should be determined according to the procedures set out in Teagasc Nutrient Guidelines and should not exceed the limits in the guidance document (http://www.wfdireland.ie/).

Although there are no regulations concerning phosphorus production at the farm level, every effort is made to minimise the amount of P that is added particularly to pig and poultry diets. Phytase is widely added to pig and poultry diets.

Nationally there is no excess phosphorus from organic sources in Ireland. However, in general the intensive pig and poultry sectors do not have adequate owned land to landspread all of the P produced by these sectors. It should be noted that pig and poultry manure account for only 4% and 3% respectively of the total P from organic sources applied to land in Ireland. Landspreading continues to remain the most practical and economical method of utilising animal manure. However, storage of organic waste and/or its landspreading was addressed in a European court case against Ireland (Case C-494/01); the judgment of the court was that

Ireland failed to fulfil the obligations and take all the measures necessary to ensure a correct implementation of Directive 75/442/EEC.

P-balances are not routinely done; the OECD are presently co-ordinating a P balance exercise for all OECD member countries including Ireland. A discussion document was prepared by the Environmental Protection Agency on a national P-balance for agriculture based on concerns of Water Quality in Ireland 1995-1997 raised in another EPA report (http://www.epa.ie). The report on water quality clearly demonstrates that surface water quality in Ireland is continuing to deteriorate. The Agency attributes the increase in slight and moderate pollution mainly to eutrophication by nutrients (primarily P) from organic manures, slurries, sludges and chemical fertilisers used in agriculture. Despite a decrease in sales of chemical P fertiliser, soil P levels are continuing to increase; approximately 24 percent of soils analysed by Teagasc contain P in excess of that needed to produce suitable crop yields. The EPA report concluded that improvements in surface water quality were unlikely to be achieved without controls on phosphorus losses from agricultural activities. The analyses described herein were undertaken to quantify the current scale of the problem, particularly in relation to diffuse P loss from agricultural land to water.

8.2.8 Italy

Various studies have been conducted in Italy in order to evaluate the phosphorus content of manure (Mordenti A., Martelli, G., 1992; Russo et al., 1991; Russo et al., 1995). However, even in this case there are no tables of standard values which can be used by law to regulate the manure application to the agricultural land. Some regions of South Europe, rather than considering the phosphorus content of manure, have established thresholds for manure application to the land. In some Italian areas, e.g. when the concentrations in the soil exceed 200 mg/kg phosphorus, this area is excluded from the fertilization programmes. In other regions such exclusion is only legally applicable to acid soils because of the high risk of phosphate mobilization.

8.2.9 Latvia

Latvia's water quality norms for surface waters are set at 0.18 mg PO_4/l for A1 and 0.30 mg PO_4/l for A2&3 categories; these categories are waters used for human consumption. In fishing water the norms are set at 0.065 mg P/l for salmonid and 0.1 mg P/l for cyprinid waters. In all other waters norms for the P-content are not determined.

The maximum application of organic phosphorus (from animal manure, sewage sludge or other) is set in relation to the present concentration of available P (mg/kg soil) in the topsoil (25 cm): 40 kg/ha/year if < 43 mg/kg available topsoil and 30 kg/ha/year if > 43 mg/kg available topsoil. Total phosphorus content is regulated in animal feed for intensive rearing of poultry and pig farms. In general, there is no regulation on phosphorus content in manure in terms of acceptable amount, nor on P limits in fertilisers. Latvia is preparing fertiliser plans based on soil agrochemical investigation to be implemented mandatory in nitrate vulnerable zones from 2007 onwards.

8.2.10 Malta

In Malta, water quality norms are regulated by legislation LN342/2001 under the Environment Protection Agency of 2001, in force since 1st March 2002. These include fresh waters supporting fish life regulations and bathing water regulations. Only for groundwater a norm for P concentration exists and is 0.04 mg P/l.

There are no plans for implementing fertiliser application norms with respect to P. Since the first version of the Code of Good Agricultural Practice for the Maltese Islands was aimed at preventing pollution from nitrate from agricultural sources, P was not highlighted as an issue, except in very broad and general terms, e.g. when reference is made to fertilisation planning. It is envisaged that measures related to P application would be introduced in the second version of the Code when the current version is eventually revised. Consequently, there are no norms based on P-balances and there are no plans for implementing regulations related to P-pollution, and no timeframe for introduction of such measures.

At the moment, there are no plans for implementing any kind of restrictions for phosphorus production at farm level. However, a waste management study is currently in progress, and it is possible that restricting P production at source (in farms) could be highlighted as one of the implementation strategies aimed at managing agricultural waste in the Maltese Islands. The first results of this study, which was commissioned by the Ministry for Rural Affairs and the Environment (http://www.mepa.org.mt), are expected to be issued in May 2005.

As mentioned earlier, a study on agricultural waste management is currently in progress. The main constraints for implementing manure treatment are:

- The lack of available data on P-content in manure, soil and crop uptake. Without this data, it is not possible to identify whether there is a need to treat manure.
- Different collection and storage practices on farms for different types of animals, giving rise to manures of different quality, especially with respect to BOD and DM content.

Transportation costs of manure from farms to centralised/localised treatment plants.

8.2.11 The Netherlands

In the Netherlands, the maximum permissible concentration of phosphorus in surface water is 0.15 mg P/l; a non-binding goal is set at 0.05 mg P/l. Other non-binding goals are set for groundwater: 0.4 mg P/l for sand and 3 mg P/l for clay and peat soils. Surface water for drinking water production may contain 200 mg P_2O_5/l at most, whereas the norm for drinking water is 2 mg P_2O_5/l.

In the Fourth National Environmental Policy Plan (NMP-4) it was envisaged that equilibrium phosphate fertilisation would be reached no later than 2030; within the Water Framework Directive this view will be accelerated to 2015. The loss oriented system of the MINAS accounting system will be replaced from 1 January 2006 onwards by an application based system of standards. Between 2006 and

2015 maximum allowable rates will decrease gradually in order to reach equilibrium fertilisation by 2015 (Table 85).

Until 2006 loss standards (MINAS) are in place that limit the loss of phosphate from animal manure up to a certain (legal) amount per hectare per year. The phosphate loss standard of 20 kg phosphate per ha applies both for grassland and for arable land. From 2006 for all land uses standards are set for total phosphate application (animal manure, chemical fertilisers and other organic fertilisers) per hectare per year. These total phosphate standards are gradually tightened to achieve equilibrium fertilisation in 2015 and to combat eutrophication of natural freshwater lakes, other freshwater bodies, coastal waters and marine waters. Equilibrium fertilisation means that the application of phosphates must then be equal to the amount taken up by crops, plus a small allowance for unavoidable loss (< 5 kg phosphate per ha per year). This means a phosphate application standard for grassland of an average of 90 kg of phosphate per ha per year, and 60 kg phosphate for arable land. In order to prevent an increase of manure application, a separate standard of 85 kg phosphate per ha of arable land per year applies in 2006 and 2007.

From 2008, it is no longer necessary to distinguish between manure and chemical fertiliser. The application standards for 2009 and beyond must be considered as indicative. Phosphate application standards from 2009 onwards and the extent of differentiation will be set on the basis of new insights on crop uptake and requirement, phosphate load on soil and phosphate loss to surface water.

Table 85: Phosphate application standards in kg P2O5 per hectare (maximum manure rates between brackets)

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
GL	130 (110)	110	105	100	95	95	95	95	95	95	90
AL	115 (85)	95 (85)	90 (85)	85	80	75	70	70	65	65	60

GL: Grassland
AL: Arable land

Rules and restrictions with respect to P-fertiliser application are derived from the Nitrate Directive and include the use of fertilisers on steeply sloping ground; the use of fertilisers near watercourses; and, methods of applying chemical fertilisers. The application standards for total phosphate fertilisation will form part of one interrelated application standards system, incorporated in a single proposed legislation that includes the accompanying regulations governing implementation. The phosphate application standard applies for each individual year, and it is not possible to offset surpluses against results from another year. The usage of fertilisers on a farm is calculated from the usage of animal manure, chemical fertilisers and other fertilisers. The application standard is calculated as the aggregated product of the application standard per hectare per crop and the acreages of the relevant crops.

In order to limit manure production, an animal quota system in force since 1987, was replaced by a manure contract system from 2002 onwards. However, the evaluation of the Fertiliser Act made it clear that the animal quota system is a better tool for limiting manure production than the manure contract system. Therefore the manure contract system has ceased as of 1 January 2005. The current system imposes a ceiling on the production of manure: manure production rights, poultry rights and pig rights. These rights are expressed in kg phosphate. It is illegal for a farmer to produce more (i.e. to have more animals) than this manure reference amount/manure production rights, expressed in amount of phosphate. These rights are tradable among farmers. A package of measures with a total value of more than EUR 800 million was set up in order to realise the required reduction. The core of the package was an arrangement for buying up manure production rights, mainly for pigs and poultry. Under this arrangement, the production capacity of around 13 million kg of phosphate was bought up in 2000 and 2001: around 7 million kg of phosphate for pigs, around 5.5 million kg of phosphate for poultry and around 0.5 million kg of phosphate for other livestock. Other arrangements and autonomous developments also reduced manure production. As a result, manure production in the Netherlands decreased from 183 million kg of phosphate in 2000 to 172 million kg in 2002.

Under the Fertiliser Act, each farm was ascribed in 1987 a manure reference amount, expressed in kg phosphate, determined by the multiplying the number of animals held on 31 December 1986 by a standard coefficient of manure production per animal species. This system of manure production rights was for the pig and poultry sector replaced by a system of pig and poultry (production) rights. For the other sectors manure production rights are still in place. In 1998, pig production rights were set up and in 2000 poultry production rights, which were based on the average number of pigs/poultry in 1995-1996 for pigs, and in 1995-1996-1997 for poultry. Manure production rights not used in these reference years were withdrawn. Pig and poultry production rights and manure production rights can be traded between farmers. However, farmers in the south and east regions, where pig and poultry farming is concentrated, can not buy pig and poultry production rights from farmers in other regions. Even between the south and east rights are not tradable between farmers. Farmers outside the south and east can only buy pig and poultry production rights and manure production rights if certain environmental conditions are met. The amount of manure (phosphate) produced that can not be applied on own soil within the application standards can or must be transported or redistributed to other (arable) farms or can be exported. When doing so, the rules for weighing, sampling and analysis must be applied. In exporting, farmers must comply with the relevant European legislation. In practice mostly poultry manure, which is rich in phosphate, is exported. Penalties for non-compliance with the fertiliser act fall within a punitive regime.

The calculation of the usage of phosphate in animal manure is derived from the calculation for the application standard for animal manure. The production of phosphate in animal manure is calculated on the basis of the same numbers of animals, but in combination with a forfeit for the phosphate excretion per animal, or on the basis of the farm's excretion level using the stable balance. The volume of manure brought in and taken off the farm is calculated for the same number of tonnes or cubic metres, but in combination with the phosphate content of the manure. Stock differences are calculated from the same stock measures, but in combination with the phosphate content in the manure. For other fertilisers, phosphate usage in chemical fertiliser and in other fertilisers is calculated from the total quantity of each fertiliser brought into the farm, with corrections for stock differences.

Many techniques are available for the treatment of animal manure. However, only separating pig manure, drying, burning and composting poultry manure, and biological treatment of veal manure are in use on a substantial scale. Burning poultry manure will possibly increase in the near future, other techniques are unsure, because they are too expensive. There is a rapidly growing interest for co-digestion as a result of financial incentives and changes in environmental legislation.

Until 2006 the Netherlands apply a system of loss standards (MINAS) to regulate a sensible use of nutrients, as required by the Nitrate Directive. If the loss standards are exceeded, a levy is imposed per kg N/ha and kg P_2O_5/ha exceedance. The rates of the levies are EUR 2.30 per kilogram of nitrogen and EUR 9.00 per kilogram of phosphate. The levies are to prevent to exceedance of the loss standards. From 2006 when the application standards will be enforced, there will also be a change in instruments for sanctioning. The sanctions will take the form of a combination of administrative fines and criminal justice, with the emphasis on the application of administrative fines. Criminal prosecutions will, in principle, be reserved for very serious infringements and fraud. The rate of the administrative fines are: EUR 7 per kg N exceedance of application standard for nitrogen from animal manure, EUR 7 per kg N exceedance of application standard for nitrogen, EUR 11 per kg P2O5 exceedance of application standard for phosphate. In principle, the rate of fines is unlimited. But apart from that, in case of a heavy or repeated violation, another punitive regime can be applied, of which the maximum administrative fine is rated at EUR 45.000 per violation by a natural person and EUR 450.000 per violation of a corporation or corporate body (or even 6 years in prison).

The Netherlands has since 1998 relied on nutrient balancing to set norms for P-surplus. In January 1998 MINAS (minerals accounting system) was implemented to regulate fertiliser use and reduce the amount of nitrogen and phosphate losses from farms to the environment. MINAS is based on farm-level nutrient balances (*www.minlnv.nl)* whereby the input of minerals must not exceed output, plus a permitted loss. Information on P-fixing capacity of agricultural soils exists on the same website. The maximum loss standards in terms of phosphate, expressed in kilograms per hectare per year, are incorporated in the Fertilisers Act. This policy is in place until 2006. The Netherlands will abandon the MINAS system, as well as N and P loss standards, because the European Court has ruled that a system of loss standards is not adequate to implement the Nitrates Directive (Court case C-322/00, OJ C 275, 15/11/2003 p.5).

8.2.12 Poland

Water quality norms in Poland are 0.25 mg P/l for surface water (Dz. U nr 241, poz. 2093: 2002), 5 mg P_2O_5/l for drinking water and bathing water (Dz. U nr 82, poz. 937: 2000). The control is exercised by the Regional Districts for Water Management and the Regional Health Sanitary Stations, respectively. No regulations were reported concerning phosphorus fertiliser application, management of phosphorus in agriculture and P-production at farm-level. Nitrogen pollution from agriculture is addressed but not phosphorus; manure treatment is practised to reduce nitrogen contents. No norms were reported for total P-surplus (loss rates) based on national and farm-scale P balances.

8.2.13 Slovak Republic

Water quality in the Slovak Republic is regulated by attachments No 1-2 of the Governmental Order 491/2002, anchored in Water Act 364/2004; no norms are used for phosphorus concentration in water. For fishing water there is no phosphorus concentration set, but an optional analysis can be done as part of prevention of eutrophication. The control mechanism is provided by the local and regional administrative bodies of environment, Slovak Inspection of Environment. The principles of manure use are detailed in the national Code of Good Farming Practice. To avoid excess phosphorus application rules are based on available phosphorus content in the soil and crop demands. Phosphorus applied through animal manures is taken into account for fertiliser rate application. According to amendment no. 555/2004 of the fertiliser act the farmers must keep records and are obliged to yearly calculate organic matter and N, P, K balance that must be for disposal for control body (e.g. CCTIA, Bratislava). For more than 10 years phosphorus rates are lower than crop demands in Slovak agriculture. Moreover, animal stocks have decreased by 40 to 50% since 1990 minimising phosphorus related problems associated with animal manure. Soil phosphorus balances are reported negative. No plans exist to prepare additional regulations concerning phosphorus pollution from agriculture, management of phosphorus in agriculture or manure treatment.

8.2.14 Spain

The norms for water quality in Spain are 0.4 mg P_2O_5/l for first category surface waters and 0.8 mg P_2O_5/l 2^{nd} to 3^{rd} category surface waters, according to the national implementation of the surface water directive (75/440/CEE). In fishing water the norms are set at 0.065 mg P/l for salmonid and 0.1 mg P/l for cyprinid waters, according to the national implementation of the freshwater fish directive (78/659/CEE).

The fertiliser application norms with respect to P and phosphorus production at farm level will depend on the total P-surplus as calculated from farm-level P-balances. The first balance is being made and will refer to the year 2004. The results of the balance will determine the allowed value of P-surplus. Phosphorus is not perceived as an environmental problem since most soils are calcareous having a pH more than 6.5 when phosphorus is immobilised. A financial regulatory policy concerning phosphorus pollution from agriculture will depend on the outcome of the total P-surplus calculated from the balances. At present, no techniques are being used at farm-level to limit the phosphorus content in manure and no manure treatment is being reported. If necessary, measures (regulation concerning fertiliser application, restrictions on P-production, norms for total P-surplus, manure treatment…) will be taken according to the results of the phosphorus balances of reference year 2004. Current measures and practices focus on N surplus in vulnerable areas. The preparatory works for a soil map have been finalised and its publication is planned in 2005. This map will provide information about the contents of heavy metals, N P K, and pH in the soils of Spain.

8.2.15 Sweden

In addition to the regular water quality norms set in different EU Directives, Sweden pays special attention to the influence of phosphorus in lakes bigger than 1 km² and streams longer than 15 km.

For mineral fertilisers outlines and recommendations from the Swedish Board of Agriculture depend on the crop type and soil status. The Swedish regulation on environmental concerns in agriculture (SJVFS 1999:79) sets a maximum livestock density of 22 kg P per hectare equivalent on farm level; this is converted to different livestock numbers per hectare, e.g. 1.6 dairy cows/ha or 10.5 fattening pigs or 3 horses/ha. In order to limit P content in manure, feeding techniques include phase feeding in pig production; phytase use in pig, poultry and egg production; and, steeping in pig production. Regulations concerning manure spreading relate to the nitrate vulnerable zones but have implications for phosphorus and help decrease P losses to the environment. Manure treatment is in general not practiced due to its high expense although small scale experiments of drying and separation have been carried out. Manure export to neighbouring countries is allowed but limited due to high transport expenses. Sweden encourages the transfer of manure from excess farms to neighbouring farms via a website, and leaves open the possibility of incentives within the implementation of the EU Water Framework Directive. The Swedish regulation about protecting the environment (SNFS 1994:4) restricts the amount of phosphorus from sewage sludge: under conditions with a satisfying phosphorus concentration in the soil, no more than an average of 22 kg phosphorus per hectare per year is allowed. Regular NPK balances are calculated at farm scale using the Program STANK and at national and regional scale by Statistics Sweden.

8.3 Conclusions on national legislation regarding phosphorus

Water quality norms with respect to phosphorus in surface waters exist in almost all the Member States, but not for all uses of water. For groundwater, standards for phosphorus concentrations are sometimes lacking. Within the frame of the Water Framework Directive, water quality standards (e.g. for phosphate to combat eutrophication) will be reviewed in different Member States to achieve a good status of waters in 2015.

A sectoral discharge standard for waste water from manure treatment plants (2 mg P/l) is mentioned only by Belgium (Flanders). The Netherlands aims at reducing diffuse emission of P from agriculture using a gradual evolution to a situation of equilibrium P-fertilisation, but no specific discharge standards are mentioned.

Legislation regarding application of fertilisers exists in several countries, most often as a means to comply with the Good Agricultural Practices as outlined in the Nitrates Directive, with the Codes of usual Good Farming Practices or with the Cross-Reference Requirements (GAEC Practices). Codes of good practices devote chapters to reduce, directly or indirectly, the risk of P-pollution, but are often on a voluntary basis. The application of sewage sludge in agriculture is regulated through the national implementation of the Sewage Sludge Directive; restrictions apply primarily to the heavy metal content and in some countries on P-content too (e.g. Sweden and Latvia). Denmark applies a tax on phosphorus in mineral fertilisers. Some Member States report that regulations on P-use are in preparation (e.g. Poland, Malta and Ireland). Only Flanders (Belgium) and the Netherlands based their nutrient management legislation on phosphorus and have legal restrictions on the use of phosphorus fertilisers.

Legal restriction on P-production at farm level exists in Flanders (Belgium), The Netherlands and Sweden via limitations to the livestock density. In the Netherlands and in Flanders, the size of livestock units is expressed in terms of P-production, and farmers have a P-quota. In Sweden, livestock density is limited to the equivalent of 22 kg of P per hectare. In Denmark there are no limitations to P-production, but a new tax on P in feedstuff should discourage its production. In the Walloon region of Belgium, livestock size (for the purpose of licensing) is expressed in terms of N-production, and therefore only indirectly in terms of P. Most of the new member states do not pay specific attention to P-production at farm level, since livestock densities have decreased significantly compared with the situation before 1990.

Manure treatment (without reduction of nutrients) and manure processing (with reduction of nutrients) is a common practice in Member States with high levels of manure production (Flanders-Belgium, The Netherlands, Denmark). Current methods mainly aim at a reduction of the water content or at its complete elimination, e.g. by incineration, and may be applied on-farm or off-farm.

Methods to reduce the P content of manure at the source are commonly practised in Flanders, the Netherlands, Sweden, Denmark and Austria; and include low P-content animal feed, phase feeding and the use of phytase in pig, poultry and egg production.

The OECD are presently co-ordinating a P-balance exercise at national level for all OECD member countries. For policy reasons, several member states (e.g. Malta, Spain, Austria, Flanders, the Netherlands) calculate P-balances at national or regional level in order to identify any areas with high surplus or to monitor development. Farm level nutrient balances are a compulsory practice in Flanders and the Netherlands, whereby farmers have to declare their annual input and output of P. Fines for non-compliance range from 1 €/kg P in Flanders to 9 €/kg P in the Netherlands. In the future, the Dutch levy will be set at 11€ per kg and legal prosecution will become possible. The Walloon region of Belgium has developed calculation methods to establish nutrient balances at various levels, but with the emphasis on nitrogen.

9. Measures to reduce P-production, consumption and loss at farm level

9.1 Source oriented approaches

The following paragraphs are based largely on work carried out by ADAS (UK), Jondreville and Dourmad, Valk and Flakowski

9.1.1 Dietary manipulation of P intake by livestock

The amount and composition of freshly excreted manure can vary considerably, and is primarily influenced by the original composition of the diet. In addition, feeding management practices can influence the efficiency of nutrient utilization by livestock and poultry, which will influence the composition of the manure produced.

Cereals contain relatively uniform P concentrations (2.7-4.3 g P/kg DM) and vegetable protein sources even more (5-12 g P/kg DM). Most of this (50-80 %) is present as phytate P, which is well utilized by ruminants but less so by non-ruminant animals and poultry. In contrast, the P concentration of forages varies widely, and is primarily influenced by the phosphorus status of the soil, the age of maturity of the plant and the climate. Average P content of fresh grass is typically approximately 3g/kg DM, although values between 1.7 and 6.6 g P/kg DM have been reported (MAFF, 1990). Forage maize generally has a lower average P content (2.6 g/kg DM) but a similar wide range.

Analysing British data, Withers et al. (2001) found that farmers are usually unaware of the impact of ingested P on manure quality and, in general, have no idea of the actual amount of P supplied to their livestock. This situation is aggravated by the tendency of feed companies to enrich concentrates (especially for monogastric animals) with inorganic P, resulting in concentrate feeds with P contents which may be twice that contained in grass.

P intake must be balanced with requirements, otherwise manure N/P ratio will decrease, inducing P enrichment of the soil where manure applications are made based on N content (Powell et al., 2002). These authors comment that the addition of inorganic P in feed results in higher soluble P content in the soil, although for farms with high stocking rates (> 1.2 LU/ha), the balance of dietary P on its own, will be an insufficient mitigation measure.

9.1.1.1 Increased efficiency of P in animal feed

NON-RUMINANTS

Supplementing the diet with the enzyme phytase is an effective means of increasing the breakdown of phytate P in the digestive tract and reducing the P excretion in the faeces. For poultry it had been suggested that P excretion can be reduced up to 70 % and manure volume by up to 14 % as a result of using dietary phytase (Graham et al., 2003). The extent to which these enzymes are likely to be used by the pig and poultry industry will be largely influenced by the cost of the enzyme relatively to the cost of supplementing diets with inorganic P. There is evidence that in addition to increasing P utilisation, the inclusion of phytase also improves the digestion of the macro-minerals calcium and magnesium, of the trace elements zinc and copper and of amino-acids (Jongbloed et al., 2000). The addition of 500 units of phytase may result in 0.8 g extra digestible P, but also in 0.4-0.7 g digestible Ca. Clearly there are other potential environmental benefits to be gained from the inclusion of phytases in the diets of pigs and poultry. Despite the apparent environmental advantages of including phytase enzymes in the diets of pigs and poultry, they are not used in all situations, despite the fact that to do so is usually cost-neutral. Industry suggest that, in the UK, phytase is incorporated into approximately 65%, 50% and 30% of the diets of piglets, growing/fattening pigs and sows, respectively, and that its use overall is increasing at about 25-20% per year. The main reason for the lower levels of inclusion in certain diets is that the enzyme is not stable at temperatures used in some plants for the manufacture of compounds for growing/fattening pigs and sows. For poultry, phytase enzymes are typically included in around 40% of broiler diets and 80-90% of layer diets. The low level of use in broiler diets and those of other birds is due mainly to the effect of enzymes on litter quality.

RUMINANTS

The results of many studies have confirmed that dietary P concentration is the dominating factor affecting faecal P excretion, and that dietary management should be taken as the first defence against P build-up on farms (Chapuis-Lardy et al., 2004).

While many sheep and beef cattle may derive most of their P from forages, substantial quantities of purchased P are fed to dairy cows either incorporated in compound feeds or as mineral supplements. In a recent UK study, feed P accounted for 65% of total P brought onto the farm. Similar percentages have been reported in the Netherlands (Valk et al., 2000). These data confirm that dietary P management, particularly for dairy cows, may play a key role in reducing P imports on dairy farms (Kuipers et al., 1999; Valk et al., 2000; Powell et al., 2001).

Phosphorus supplementation of ruminant diets is essential for profitable and sustainable livestock production. However, there is evidence that the levels of dietary P in dairy cow diets are significantly higher than recent research would suggest necessary (Valk and Sebek, 1999; Wu. And Satter, 2000). Reasons for this have recently been reviewed (Satter, 2000) and include concerns over the variation in P contents of feeds and uncertainties associated with P availability in mixed diets. Studies in the UK have also indicated that the nature of forage in ruminant diets can influence the relative proportions of water soluble P in faeces (Shah, 1999). While the proportion of water soluble P in faeces of lactating dairy sows was < 25% on a grass silage based diet, there was a three-fold increase in water soluble P when whole crop cereal silage was included in the diet (at 60% of the forage dry matter).

In order to reduce P losses, P supplied should be adjusted to their requirement and strategies to improve P availability should be implemented. This approach relies on an accurate knowledge of P availability and P requirement according to the physiological status of pigs.

9.1.1.2 Improving the knowledge of the P value of feedstuffs and diets

Apparent total tract digestibility and relative bioavailability are the two major systems for assessing the P value of feedstuffs for pigs. In Western Europe, the concept of apparent digestibility is extensively used by the nutritionists, who refer to published tabulated values. Because P digestibility greatly differs between feedstuffs (from 19% in sunflower meal to 90% in whey, through 47% in peas), these values allow a reduction of the safety margin when formulating diets for pigs compared to the formulation of diets on a total P basis.

Animal factors affecting P apparent digestibility: In most cases, apparent digestibility of P is assessed with growing pigs fed below their P requirements. Under these conditions, endogenous P losses are minimised and P absorption is maximised. Moreover, the question arises whether values obtained with pigs weighing 40-50 kg can be used when formulating piglets and sows diets. Actually, P digestibility seems to increase with body weight in growing-finishing pigs fed below their requirement, at least from 30-60 kg.

Dietary factors affecting P digestibility: phytic P, non phytic P and plant phytase. It is established that phytic P, which is the main storage form of plant feedstuffs and accounts for 50 to 80 % of P in these materials, is poorly available to monogastric animals. Plant phytase is a 6-phytase which improves digestibility to pigs. This enzyme is present in different amounts in unprocessed seeds (rye, triticale, wheat, barley) but not in maize, oats and processed seeds (soyabean meal, rapeseed meal). The presence of feedstuffs displaying a high endogenous phytase activity in mixed diets raises the question of additivity of digestible P contents. Moreover, a substantial part of plant phytase denatures at temperature over 70° C. Therefore, in order to achieve an additive formulation system, one has to calculate separately the digestibility of phytic and non phytic P and the release of digestible P from plant phytase. Such relationships are the basis for an additive system and are worth of being improved. Indeed, factors such as the solubility of phytates and their site of localisation in the grain or seed probably affect their digestibility (vb. In tekst). Other factors such as the storage duration, the presence of high levels of dietary cations (e.g. Ca) that stabilise phytates or form insoluble salts with phosphates, the particle size resulting from grinding may also affect P digestibility and the efficacy of endogenous phytase.

9.1.1.3 Improving P digestibility

First the use of highly digestible P supplements should be favoured. However, most stategies implemented refer to improvements in phytic P utilisation by pigs. Efficient strategies such as developing pigs expressing salivary phytase, thus achieving almost complete digestion of phytic P were proposed. Beside, substantial improvements in P digestibility were achieved by introducing “low-phytate” cultivars, thereby reducing the proportion of phytic P in total P from 80 to 35 % and from 70 to 40 % in maize and barley respectively. However the global concern regarding genetically modified organisms may compromise the future development of these grains.

9.1.1.4 *Supplementing diets with microbial phytase*

Four microbial phytases are currently authorised in the EU as additives in pig feeding: three 3-phytases and one 6-phytase. In France, microbial phytase is currently introduced in most diets for pigs because of its well documented positive effect of P digestibility.

9.1.1.5 *Accounting for plant phytase*

There are several ways to improve plant P digestibility. The first one is to introduce feedstuffs with high intrinsic phytase activity in diets in order to release P from other feedstuffs, providing the diet is not heated. Rapp et al. observed that microbial phytase is better protected against denaturation than plant phytase. However, the variability of phytase activity encountered within feedstuffs is large. Therefore, when formulating a pig diet, we recommend not accounting for more than 500U of plant phytase in order to avoid any overestimation of its content in digestible P. This corresponds to a maximum of 0.4 g digestible P released by plant phytase per kg diet.

9.1.1.6 *Reduced P- content in poultry manure*

Poultry manure is very rich in P and inappropriate application to crop land results in negative effects on air, water and soil contamination. Decreasing the P content of manure through nutritional changes of the diet is, compared to other alternatives, a powerful, cost-effective approach to reduce environmental contamination from poultry farms. Reducing the P content of feeds, phase feeding, selecting the mineral sources on biological values and the use of phytases will reduce P contamination and also cost of production helping farmers to meet environmental regulations.

In the past, there has been little pressure to decrease excretion, so poultry producers have typically overfed N and P. Extra supplementation of diets with N and P as an assurance of productivity increases the amount of nutrients excreted in faeces and urine and might even result in reduced performance (Ferket, Van Heugten, Van Kempen and Angel, 2002).

Research has shown that, as dietary P levels increase, faecal P level increase gradually until the point at which tibia ash is at a maximum, and then increases steeply (Waldroup, 1999). Therefore, the biologically available P content of the diet should not exceed the requirements of the bird to maximize performance. In relative terms, more P is needed to maximize bone calcification than to maximize body weight or feed efficiency. Fritts and Waldroup (2003) indicated that P levels for broilers can be reduced by up to 30% with respect to NRC (1994) recommendations with no negative impact on productivity. In fact, Waldroup (1999) indicated that during the later stages of production, when a significant amount of feed is consumed, there is little need for supplemental P in a typical corn-soybean meal diet. Field observations indicate that broiler chicks perform well even in the absence of any mineral source of P for the last seven days of fattening. However, very low levels of P in the diet reduces bone breaking strength and increase the percentage of broken bones during processing, resulting in more downgrades and reduced animal welfare (Chen and Moran, 1995; Gordon and Rowland, 1997).

The amount of P excreted depends on three major factors: 1) the amount of total P that is consumed, 2) the efficiency of their utilization and 3) the amount of endogenous P. The total P requirements of poultry can be reduced using more digestible sources, avoiding interactions with other nutrients (Ca), and incorporating adequate enzymes, mainly phytases, in the feed (Kornegay, Denbow, Yi and Ravindran, 1996; De Boer, Van Der Togt, Grossman and Kwakkel, 2000).

Phase feeding. P requirements vary with age and physiological status of the bird. Therefore, to keep unnecessary P losses to a maximum, continuous changes in diet composition are needed. Phase feeding programs are relatively easy to implement and they are probably the main tool available to reduce P contamination to the environment. In birds for meat production, P requirements decrease with age. However, P excretion to the environment increases with age of the bird, probably because the knowledge of requirements is better for young than for old birds.

9.1.2 Breeding of genetic lines of pigs and poultry

So far breeding of genetic lines of pigs and poultry has mainly been carried out with the aim of obtaining higher growth rates and better feed conversion. Indirectly, more efficient feed conversion should lead to less excretion of N and P per unit of product. However, not much information is available on this specific aspect of breeding.

9.1.3 Reduction of livestock numbers

Reduction of livestock numbers is pursued and/or encouraged by certain member states and regions (the Netherlands, Flanders, ...) as a measures to reduce the nutrient input pressure and to comply with the Nitrate directive. Such measures have a lineair impact on the phosphorus production too.

9.2 Economic instruments

Taxing the phosphorus content of feed or fertilisers can be an incentive for farmers to reduce the use of P at farm level, having an effect on the input side of the P-balance. An environmental tax on phosphorus could reduce the application of phosphorus to fields in several ways:

- Less application of phosphorus to acreages to which commercial fertiliser is applied
- More even distribution of livestock manure, replacing commercial fertiliser
- Less intensive feeding of animals with feed containing phosphorus

9.2.1 Scenarios for the taxation of P-use (Denmark)

In **Denmark**[4], assessment of economic instruments for the control of nitrogen and phosphorus formed part of major preparatory work in 2003 for the Aquatic Environment Plan III which, on a foundation of transparency, self-management and

[4] The following information on the Danish taxation approach is largely based on an article by Hans J. Larsen of the Danish Ministry of Taxation (Larsen H. ,2005)

considerations of sustainable agricultural production, was intended to prepare for a basis of decision in the future control of the general effect of agriculture on the aquatic environment. The fundamental principle was that the discharge of phosphorus and nitrogen should continue to be reduced. The environmental policy aims were to be achieved in a manner that ensured the best environmental value for money, and an effort was to be made to reinforce the role of the individual farmer as an active environmental custodian through incentives and freedom of action. The objective was a simpler, more cost-effective system than the current control regime.

The following tax models have been assessed with reference to the control of phosphorus:

1. Tax on phosphorus in commercial fertiliser
2. Tax on mineral phosphorus in feeds
3. Tax on phosphorus in feed
4. Tax on phosphorus in feed combined with a basic deduction
5. Tax on phosphorus in commercial fertiliser and in feeds
6. Tax on phosphorus surplus
7. Need-based tax.

Scenario 1: Tax on P in commercial fertilisers

A tax on the phosphorus in commercial fertiliser (model 1) would be comparatively simple. Such a tax would increase the incentive to reduce phosphorus from commercial fertiliser, for example by paying more attention to the phosphorus count of the soil and by cultivating crops that require less use of phosphorus. It should however be noted that nowadays it is chiefly livestock farming that has an excessive phosphorus count and that the variation in the phosphorus needs of crops is not great, so that the quantity of the two effects referred to will be limited.

On the other hand there is usually a balance between the input and output of phosphorus in the case of plant growers who do not apply livestock manure. The reasonableness of a tax restricted to the phosphorus in commercial fertiliser is therefore questionable, since the effect would be uneven in that farms without access to livestock manure would pay a disproportionate amount of tax. The environmental effect would be chiefly derived from the fact that livestock manure would be transported further and spread on greater acreages than at present. The demand for phosphorus would fall to some extent. Because of the costs of transport in relation to realistic tax rates, the effect of this would be limited, though measurable. Other studies (Oosterhuis et al. 2000) confirm that taxes on mineral fertiliser have a very limited impact on the demand.

Scenario 2: Tax on added mineral phosphorus in feed

A tax on mineral phosphorus added to feed would result in more reduction (whether in the growth of the phosphorus pool or leaching) than a tax on commercial fertiliser. Mineral phosphorus is added to feed that is lacking in available phosphorus. It is thought that a tax on mineral phosphorus would be easier in administrative terms than the other taxes described. The environmental effect would consist in the reduction of added mineral phosphorus as a result of the increased use of phytase, it would reduce the use of feed with a high content of non-utilisable phosphorous and it would also reduce the safety margin (overfeeding).

Scenario 3: Tax on phosphate content of feed

A tax on all the phosphorus in feed would have similar but stronger effect than a tax on mineral phosphorous, other things being equal. The tax would be levied on the total content of phosphorus in feed mixtures for livestock, with the exception of the part never traded. There would therefore be tax on the phosphorus content of all forms of feed ingredients. This means that if corn, maize or soya were used in a feed mixture that was traded, a tax on the phosphorus content would have to be paid. In addition certain waste fractions used for feed would have to be taxed (e.g. mash from the breweries). It would be difficult if not impossible to impose tax on, and subsequently to monitor, livestock feed sold internally. The administration of a tax on feed sold between farms would be unlikely to be worthwhile in terms of the environmental potential of the tax. A tax on feed sold would increase the incentive towards own cultivation (which is in conflict with trade agreements).

Scenario 4: Tax on phosphorus in feed combined with a basic deduction

A tax on phosphorus in feed combined with a basic deduction corresponding to the natural phosphorus content of corn would mean that the natural phosphorus content would be more or less exempt from tax, which would be imposed on added feed phosphate and especially feeds containing phosphorus. In this way the economic gross burden on agriculture before return would be less than through a general tax on the phosphorus content of feed.

The basis of assessment corresponds to that for the previous, in other words the content of phosphorus in livestock feed that is sold by a corn and feed business. Home-grown feed and the sale of feed between farms would not be included because of administrative and regulatory problems. The tax would also have to be paid by the same businesses as in model 3. The basic deduction would be the same irrespective of the composition of the feed and of the animals to be fed.

A tax with a basic deduction linked to the phosphorus content of a kg of solids would have the same effect as a general phosphorus tax, but with a feed supplement per kg of solids, and it might be difficult to assess the quantitative changes a basic deduction would generate. However it would still involve discrimination between domestic feeds and imported feeds with high phosphorus content.

Scenario 5: Tax on phosphorus in commercial fertiliser and in feeds

A tax on phosphorus in feed and phosphorus in commercial fertiliser would reduce the phosphorus content of livestock manure and phosphorus applied in commercial fertiliser. The reduction in phosphorus content of livestock manure may be achieved through more precise feeding, choice of raw materials with high phosphorus availability (and if applicable low phosphorus content), stimulating the reduced use of mineral feed phosphate.

A combination tax based on the two alternatives described above might result in feed being taxed more than once – first a tax on the phosphorus in commercial fertiliser, then a tax on the phosphorus content of the feed produced with taxed commercial fertiliser when it is traded.

Scenario 6: Tax on phosphorus surplus

A tax on phosphorus surplus (model 6) taxes the agricultural phosphorus surplus. The surplus is calculated as the difference between the phosphorus input and the phosphorus output.

Tax is to be charged on the combined input of phosphorus (P in commercial fertiliser, P in added feed and P in waste) and is levied from importers and producers of commercial fertiliser and feed dealers and importers. Reimbursement is granted for the phosphorus content of goods that form part of agricultural output (i.e. milk, eggs, vegetable products etc.). The tax is repaid to the purchasers, e.g. dairies, abattoirs etc. If a farm is in balance in this way (input of phosphorus equal to output of phosphorus), the overall tax burden will be equal to zero.

One advantage of a tax on phosphorus surplus is that the basis of assessment of such a tax more directly addresses the environmental impact than a tax on commercial fertiliser and/or feed. A tax on phosphorus surplus is more cost-effective in terms of the farm's adjustment costs than an input tax. The tax would contribute to better distribution of livestock manure.

Under EU law and other international regulations, Danish-produced goods and imported goods must be on an equal footing in terms of tax. Over a number of years, some Danish producers will be able to draw on the quantity of phosphorus accumulated in the soil, which will give them a tax advantage. This may be problematic, since not all foreign producers would be able to avail themselves of the same advantage. Furthermore, allowances may be granted for phosphorus on which it is uncertain that tax has been paid in the past. However, in general the plant growers will also have to pay tax, especially in the longer term.

A tax on the phosphorus surplus would require a lot of administration, but would be easier than a tax on nitrogen surplus, since phosphorus cannot be bound from the atmosphere like nitrogen (nitrogen-fixing plants). It would therefore not be necessary to register the individual farm.

Scenario 7: Need-based tax

Finally, a need-based tax was assessed. It can be assumed that the addition of phosphorus to soil that has a high phosphorus content carries a risk of increased leaching of phosphorus. A tax aimed at preventing the addition of phosphorus to high-phosphorus soil would therefore address the environmental impact more directly than an input tax. However, a need-based tax cannot be recommended for administrative reasons. In particular it is considered difficult to define a form of sample-taking that could create a foundation for tax exemption/reimbursement of tax paid. Samples are currently taken on farms that wish to achieve optimum use of fertiliser. There is a great difference between the reliability and lack of ambiguity that must be present for an advisory sample intended to ensure optimum use of fertiliser and the sample on which the reimbursement of tax paid could be based.

9.2.2 Danish tax on added phosphorus in animal feed

As part of the government's commitments in the Aquatic Environment III 2005-2015, the Danish government effectively introduced by law of 28 April 2004 a tax of 4 DKK per kg of mineral phosphorus used in feed phosphate, with the exception of pet food. The Aquatic Environment III plan includes an objective of reducing agriculture’s excess phosphorus by 50 % compared to the excess in 2001/2002 by the end of 2015 (J. Larsen, 2005).

The tax on mineral phosphorus, combined with new knowledge, is expected to reduce the excess by 25 % by 2009. To compensate for this new tax, the county council tax is reduced from 0.43 % to 0.38 % for land used for primary production, i.e. land used for farms, horticultural establishments, nurseries and fruit orchards. The tax on phosphorus is paid for by the animal producers whereas the reduction in the county tax benefits the agricultural sector as a whole.

Another way to discourage P-production at farm level are levies raised directly or indirectly on quantities of P produced as manure beyond an authorized ceiling.

9.2.3 Levies on P-production/P-use at farm level (Netherlands and Flanders)

In Flanders as in the Netherlands, farmers are financially penalized when producing manure (expressed as kg of phosphorus and nitrogen) beyond the authorized maximum stipulated in the farm permit (see 8.2).

Apart from this superlevy of 0,99 € per kg of P_2O_5 and N, Flemish farmers pay a standard levy of 0,0111 € per kg of P_2O_5 and N on the manure production of their livestock plus a tax of 0,0223 € per kg of P_2O_5 or N on the use of mineral fertilisers or other types of fertilisers. Manure import is charged 2,4789 € per ton of material.

The superlevy of 0,99 € per kg nutrient means for instance that a pig farm pays around 20 € per head (place) per year, or about 8 € per animal produced. Contrary to the standard levy on manure production or fertiliser use, this is a substantial sum, large enough to have a potential discouraging effect on excess production.

All farms producing more than 300 kg of P_2O_5 are subject to the standard levy. The standard levy on fertilisers applies to all farms alike. However, at the present level the levy on mineral P is unlikely to influence the level of P used on arable land or to make an arable farmer switch from mineral fertiliser to animal manure, as the total amount of this level would not be higher than 2 or 3 euro per hectare at the maximum.

9.3 Reducing P-loss from the field

9.3.1 Rational fertiliser use based on soil and manure analysis

Although manure analysis by itself does not reduce the total amount of P that will end up on or in the soil, knowledge of the nutrient content in the manure and its fertilising value will help the farmer to make better use of the available resource, and to prevent excessive application of any given nutrient, including phosphorus.

In a similar way, applying manure and/or fertiliser strictly according to recommendations issued on the basis of the actual need of the crops helps to reduce excess of P, even though current recommendations in generally aim at an optimum production rather than at reducing the loss of P to the environment, as has been explained elsewhere in this study.

Such recommendations can be established in various ways: compensation for the expected uptake by the crop, by soil analysis or by leaf analysis. As P needs to be applied early in the season and plant uptake does not always reflects the actual P-status of the soil, leaf analysis is less appropriate in this case.

It should be noted too that in practice, where manure analysis is carried out on a more or less systematic basis (f.i. the Netherlands, Flanders), farmers tend to focus on the nitrogen content at present.

Reconciling production objectives and environmental impact ?

From the previous paragraphs it has become apparent that from the sheer agricultural point of view a certain 'overdose' of P appears may be needed, even if the level of this surplus required to maintain the fertility level of the soil can not always be quantified at present. At the same time there is still uncertainty about the acceptable level of loss from the environmental point of view.

For many soil types, the risk of P-saturation is small, even after repeated application of P-rates way beyond the strict requirement of the crop. However it seems to be clear that it may not always be possible to reconcile the present objectives of agricultural production and environmental protection by the present methods of P-fertiliser recommendation.

Research in the Netherlands (Breeuwsma en Ehlert, 1991) has shown that in order to bring an uncultivated soil low in P, to its optimum P-level (agriculture wise), a cumulative gift of about 1 000 to 1 500 kg of P_2O_5 is needed. When comparing these figures with the amount of phosphorus leading to P-saturation, one sees that such quantities can already lead to saturation on certain soils with a high watertable. This is illustrated by the following tables, the first whereof gives the amounts of P to be supplied to the soil in order to bring it from its basic P-level to an optimum situation, from the agricultural point of view.

Table 86: Advised rate of P stock fertilisation on various soils as in function of soil type and P-status (Henckens 1984)

		Advised stock fertilisation (kg P_2O_5/ha)	
Soil P status	**Pw***	**Sand, löss, riverclay**	**Marine clay**
Very low	1	1 710	1 500
	5	1 340	1 130
Low	10	990	780
	25	700	490
	20	440	230
Normal	25	210	0

* Pw: water extractible P in mg/100 g soil

The second table gives the quantities of phosphorus that are expected to lead to a situation of saturation when applied on an unfertilised soil.

Table 87: Surplus (in kg P2O5 per ha) leading to phosphate saturation on an unfertilised soil in function of soil type and reference depth

	Reference depth* in cm				
Soil type	**20**	**30**	**40**	**50**	**100**
'Beekeerd'**	770	1 200	1 530	1 750	1 940
'Veldpodzol'**	810	1 290	1 810	2 250	3 630

* Reference depth is the highest average groundwaterlevel

** Soil names of the Dutch classification system

The discrepancy between production objectives and environmental objectives is not limited to soils with undeep groundwater or to crops with high P-demand, as maintaining a good P-status requires a certain P-surplus in order to compensate for losses and fixation. A desk study by the DLO-Staring Center in the Netherlands, based on modelling, estimates that surplus of around 25 kg of P_2O_5 is required to maintain the optimum P-level of a common type of sandy soil on the long term. This means that on the long run, the soil will become P-saturated (Oenema en Van Dijk, 1994), even when from the agricultural point of view there is no question of overfertilisation.

9.3.2 *Maintaining optimum soil conditions*

Phosphorus is but one of many crop production factors and the efficiency of P-uptake and P-use is very much dependent on the status of the other factors.

As has been explained before, some of these factors will have a direct effect on the availability of P to the plant, the most prominent whereof is pH. Maintaining an optimum pH of the soil, for instance by liming is therefore an essential element in P-management. Control of pH should preferably be done based on soil testing, as overliming will have an adverse effect on P-availability.

Other factors do not influence P- availability in a direct way, but will reduce P-uptake when they become limiting factors themselves, hampering crop growth. Most common examples of limiting factors are the pH and the elements nitrogen, potassium, calcium, magnesium and (more and more) sulphur, but also micronutrients may play a role, often in connection with pH. Again, the role of soil testing in assuring a well balanced nutrient supply can not be stressed enough.

Soil organic matter is another important parameter, not only as a source and regulator of nutrients, but also contributes to the improvement of soil structure and of the water economy.

9.3.3 *Erosion and run-off control*

Erosion is the detachment and movement of soil or rock by water, wind, ice or gravity. Soil erosion is a natural process, occurring over geological time. Most concerns about erosion are related to accelerated erosion, where the natural rate has been significantly increased by human activities such as changes in land cover and management.

Wind erosion redistributes the soil particles with no apparent pattern. In water erosion, soil is being transported along the slope and re-deposited in lower lying areas, or ends up directly in the watercourses. Except for the most dramatic types of gully erosion, the transported soil particles originate from the top layer of the soil, i.e. the part of the soil richest in organic matter, but also in phosphorus.

In Europe, soil erosion is caused mainly by water and, to a lesser extent, by wind. In the Mediterranean region, water erosion results from intense seasonal rainfall on often fragile soils located on steep slopes. The area affected by erosion in northern Europe is more restricted and moderate rates of water erosion result from less intense rainfalls falling on saturated, easily erodible soils (e.g. the Loess Belt). In Eastern Europe, former large state-controlled farms produced considerable erosion problems due to combined effects of land consolidation, field enlargement, the use of heavy machinery, and tillage practices.

Most phosphorus under field conditions is strongly attached to soil particles. Phosphorus can move into surface waters associated with soil particles during erosion, especially where the land has been recently manured or fertilised with phosphorus and not incorporated.

Runoff is the most important direct pressure of severe soil erosion. Processes that influence runoff must therefore play an important role in any analysis of soil erosion intensity, and measures that reduce runoff are critical to effective soil conservation.

Soluble phosphorus can move off-site with runoff water during heavy rainfall or irrigation. Runoff from livestock confinement areas and from livestock waste applications to cropland and grazing lands can contribute to phosphorus contamination of surface water.

Studies showed that in the rolling loamy areas of central Belgium (sensitive to soil erosion) about 50 % of the P measured in the surface water is present as organically bound phosphorus in suspended soil particles. Research demonstrated that no-till farming methods reduce soil erosion by 75 percent and total phosphorus loss by 40 percent compared to a conventional tillage system. However, no-till actually had higher losses of soluble phosphorus in runoff water than did the conventional system.

Best Management Practices for phosphorus should therefore include erosion and runoff control. Erosion not only moves soil, but also moves absorbed phosphorus into surface water. Runoff moves livestock waste into surface water. Measures to control soil erosion and runoff can greatly reduce phosphorus movement into surface water from agricultural fields.

9.4 Manure treatment and processing

9.4.1 General

One way to reduce nutrient surpluses at farm level is to withdraw part of the nutrients from the cycle at the stage of manure. This withdrawal can take several forms. In the case of nitrogen, the nutrient can be transformed from its nitrate or ammonia state into other chemical f.i. gaseous compounds, no longer useful in plant nutrition, such as N_2 or N_2O, by chemical processing or by simple incineration.

Manure acts as a carrier of nutrients. This means that nutrients, contained in manure, can be manipulated and be transported from one place to another. Handling and transportation cost per unit of nutrient can be high, especially when the nutrient content of the manure is low. Therefore in general manure is being applied to the field as closely as possible to the production site. Moreover, sheer elimination of manure is seen by many as a waste of nutrients, not compatible with the principles of sustainable development. However, in areas with structural surpluses, processing and export of manure is seen as one method (next to others) to establish equilibrium between supply and uptake.

In order to overcome the problems of manageability of the manure and its transportation cost, several techniques have been developed in recent years to treat or to process raw manure into a product easier to handle and cheaper to transport. This is notably the case in the Netherlands, the Flanders region of Belgium and the Brittany region of France, areas with high livestock densities where possibilities to redistribute the manure surpluses within the borders of the country or region are limited because of various constraints: the livestock density itself, distance to recipient farms or legal restrictions in neighbouring areas.

At the end of the 1980's the **Dutch** goverment urged the stock farming sector to take 25 million kilograms of P_2O_5 or the equivalent of about 6 million metric tons of pig manure) out of the natioal nutrient cycle by 1995 through processing. A number of large scale initiatives were started. However with the exception of the processing of veal manure these large scale initiatives led to nothing despite the enormous amounts of money invested. The Promest factory, with a capacity of 500 000 metric tons per year and requiring an investment of a hundred million guilders (more than 50 million euro) was shut down after two years. Ther were various causes for these failures: high cost per unit treated, insufficient support from the sector, problems with location and permits, market uncertainty for the end product. In addition, in 1995 the EU prohibited the continuation of subsidies for large scale manure processing and long distance transportation. These negative experiences led to growing scepticism about centralized, large scale manure processing. Especially in the pig sector, there is a tendency to look for solutions at farm level.

In **Flanders**, manure processing is the third pillar of the government policy to comply with the Nitrate Directive, after reduction of P production at the source and improved efficiency of nutrient use. Farms producing over 10 tons of P per year have a legal obligation to dispose of the manure outside the Flemish agricultural sector. As was the case in the Netherlands, there is a growing interest in small scale systems, after initial failures with large scale treatment projects.

The French region of **Brittany** is considering manure processing as an effective instrument to reduce local supluses, but here the focus remains on N rather than P.

In the **UK**, incineration of dry poultry manure has been practised, with or without energy recovery, for quite some time.

Denmark and also the **Po valley regions of Italy** have seen in recent years the development of biogas installations, but this approach has little effect on the total amount of P.

In other member states, even in those with high (local) surpluses of manure, processing and long distance transport are apparently not being seen at this moment as an effective tool of the manure policy.

9.4.2 Manure treatment and processing techniques

Liquid-solid separation is one of the most common manure treatment practices to reduce organic and inert materials from animal manure. Solids removal can be achieved using the following biological, chemical and physical methods:

- Gravity/sedimentation
- Mechanical separation
- Flocculation
- Aeration
- Anaerobic processes

Solid-liquid separation is the partial removal of organic and inorganic solids from liquid manure. Liquid manure systems are popular among livestock and poultry operations because they make manure easy to handle, store, treat biologically in lagoons and land apply.

Separated solids may be used for composting, refeeding or generation biogas (methane). Separating the solids from the liquid manure makes the liquids easier to pump and handle. It also helps reduce potential surface and groundwater pollution, because less nitrogen, phosphorus and other constituent are in the separated liquid.

The main objectives of solid-liquid separation are to physically separate and remove the suspended solids and some of the dissolved solids from the liquid manure. Several methods are available to separate solids from liquids (reference: Solid-liquid separation of animal manure and wastewater. Mukhtar, S., Sweeten, J.M. and Auvermann, B.W. Texas Agricultural Extension Service). Sedimentation (solids settle by gravitation) and mechanical separation are the two most common techniques used for this purpose.

Mechanical separation

The types of **mechanical separators** include screen separators, centrifuges and presses (screw or belt type). The screen separators are classified as stationary, rotating and vibrating screens. The stationary inclined screens use gravity to separate the liquid manure from the solids. Liquid manure is pumped to the edge of a screen. Liquids pass through the screen, while solids accumulate and slide down the screen to be deposited on a collection pad or auger. Vibrating screen separators have screens that vibrate rapidly, which helps keep the screen from excessive clodging. Liquid manure is pumped onto the screen at a controlled rate. The liquid passes through the screen and is collected into a container underneath it. The separated solids remaining on the screen move to the screen edges. Rotating screen separators have a continuously turning or rotating screen. A scraper removes the solids that collect on the screen; the liquid passing through the screen is collected in a tank.

Centrifuges separate solids from liquid using centrifugal force to increase the settling velocity of suspended particles.

Types of presses include roller presses, belt presses and screw presses. A belt press uses a flat fabric belt, which runs horizontally between rollers. The rollers squeeze the liquid manure through perforations in the belt, which retains the solids. A screw press uses a cylindrical screen with a screw-type conveyor in the centre. The screw conveys the solids retained on the screen to the discharge end for solids. The screw conveyor also compacts and removes water form these solids during transport.

Each kind of separator works best in certain types of livestock operations.

With suitable technologies a nutrient removal of up to 80 % for phosphorus and 50 % for nitrogen can be achieved. With this treatment option, nutrients can be concentrated in the solid phase (10-20% of the initial mass) and transported to other regions without nutrient surplus. Using separation techniques, the phosphorus compounds on the whole slurry are largely removed into the solid fraction. Centrifuges are the most efficient types of mechanical separators concerning phosphorus removal (70% removal). Screw presses are less efficient, but become efficient combined with nitrification/denitrification processes. Table xxx compares the performance of the more common separators on livestock slurries.

<u>Flocculation</u>

The removal of solids, P and other suspended or dissolved constituents can be improved by adding chemicals to the influent of solids removal processes.

<u>Aerobic treatment</u>

A key purpose of such installations is the removal of unwanted ammonia via the nitrification/denitrification processes, but there are other requirements as well including the reduction of organic load. Aerobic treatment can also remove a portion of the nitrogen and phosphorus by biological uptake, but the composition of micro organisms, which is about 50% carbon, 10% nitrogen and less than 1% phosphorus limits nitrogen and phosphorus removal.

<u>Anaerobic treatment</u>

Anaerobic digestion (fermentation) is one of the most important treatment measures available for animal manures and other organic wastes. It is a common technology for the purification of municipal and industrial waste waters which not only reduces their environmental impact but which also produces a useful biproduct in the form of methane. The use of anaerobic fermentation for waste treatment is widely demonstrated in Asia with several million small scale biogas plants in China and India. However, in Europe, the use of this technique is very limited with a great deal depending on a political framework to create an attractive environment to promote this technique for a sustainable utilisation of renewable energy sources. Anaerobic digestion can achieve a substantial decrease in organic carbon, but it has little effect on nitrogen, phosphorus or potassium.

For techniques of manure processing also see:

http://www.nhm.ac.uk/mineralogy/phos/manure.htm

9.4.3 *Economic and technical feasibility*

In order to make manure treatment successful, its cost should not be prohibitive and markets are to be found for the end products. In the past several initiatives already failed for these reasons.

In a Dutch study of 1998 ((Van Ruiten Adviesbureau, 1998) focusing on the possibility of P-recovery for the phosphate industry, the following conclusions were drawn with respect to the economic and technical feasibility of manure processing in the **Netherlands** as a way to reduce P-surplus.

- Cattle manure hardly offers possibility for processing, as the P concentration of the manure is very low. The potential market for dried cow manure is limited to hobby growers.

- From the technical point of view, veal calf manure offers certain possibilities, but the the potential would be limited to about 800 tons of P_2O_5 per year

- Processing of pig manure is considered too expensive to offer an alternative to other methods such as low P-feed, redistribution of manure or reductions in livestock numbers

- Incineration and gaseification of chicken manure is seen as the most promising method to withdraw significant amounts of P from the nutrient cycle. However, problems of obtaining operating licences, lack of interest from the financial sector, emission regulations an uncertainty about future energy prices would hamper such developments. Moreover, dry chicken manure can easily be exported.

The Centre for Best Available Techniques (BAT) was founded by the Flemish Government, and is hosted by the Flemish Institute for Technological Research (VITO). The BAT centre collects, evaluates and distributes information on environment friendly techniques. Central in this translation is the concept "BAT" (Best Available Techniques). BAT corresponds to the techniques with the best environmental performance that can be introduced at a reasonable cost.

Manure processing in Flanders aims at the neutralization of nutrients in manure (e.g. turning nitrates into N_2) or at making it suitable for export to other countries requiring organic fertilisers. A broad range of techniques is available that can theoretically be used for this purpose. However, practical experience is obtained with only with the techniques listed hereunder.

Liquid manure	**Solid manure**	**Manure gasses**
Storage Anaerobic digestion Mechanical separation Aerobic treatment Chemical oxidation Algae culture Stripping of NH3 Electrolysis Coagulation /precipitation Evaporation Ultrafiltration Reverse osmosis Ion exchange Activated coal treatment	Pre-drying Storage Lime treatment Composting Drying Incineration Pelletising	H2S removal Dust filter Acid scrubber After burner Biofilter Biowasher Biotrickling filter Alcaline scrubber Activated coal filter De-NOx

Nearly all manure treatment systems, independently combine two or more of these techniques. A BAT analysis was done for 4 representative pig manure treatment scenarios consisting of the following techniques:

1. Manure spreading on land (reference)
2. Anaerobic digestion and spreading of digested manure on land
3. Separation of liquid and solid fractions of manure. Land spreading of liquid manure fraction within Flanders. Export of solid fraction to nutrient deficient regions / countries with or without prior composting, drying or incineration.
4. Same as previous scenario but liquid fraction treated by aerobic digestion prior to land spreading in Flanders
5. Same as previous but liquid fraction not land spread but purified to below 125 mg/l COD, 25 mg/l BOD, 15 mg/l N and 2 mg/l P and discharged into surface waters.

For poultry manure land spreading was compared to export with prior composting, drying or incineration.

This analysis showed that poultry and pig manure treatment according to the three last scenarios resulted in a significant reduction of nutrient pollution in surface and ground water. However, two major obstacles prevent a generalised implementation of pig manure processing in Flanders at present:

- Manure regulation in Flanders imposes 100 % manure treatment for certain groups of farmers without allowing land spreading of nutrient-poor liquid manure. The only scenario for pig manure that may be used by those farmers is scenario no. 5 which is not technically proven. Poultry manure treatment does not have this problem.

- Costs for pig manure processing are very high and range between 50 – 130 % of the farmer's income. Manure processing will make some farms unprofitable and many farms uncompetitive. Economic feasibility of poultry manure treatment is less problematic.

Best Available Techniques (BAT) are techniques that are proven in practice, that have the best overall environmental result and are not too costly. BAT for pre-dried poultry manure processing is incineration, export without treatment or composting + export. No BAT are available for pig manure processing due the excessive costs of the techniques. Only in a few exceptional circumstances farmers could cope with the costs. In these cases BAT consist of the following steps:

Scenario 1: 50 % or more of N/P can be spread on farmers land.

1. Separate manure with e.g. centrifuge into liquid and solid fraction
2. Heat solid fraction by incineration or by co-composting with poultry manure + export.
3. Spread liquid fraction (if no salt excess occurs on farmers land)

Scenario 2: 10 - 50 % of N/P can be spread on farmers land

1. Separate manure with e.g. centrifuge into liquid and solid fraction
2. Heat solid fraction by incineration or by co-composting with poultry manure + export.
3. Partially eliminate N from liquid fraction by aerobic treatment or by ammonia stripping
4. Spread nutrient impoverished liquid fraction (if no salt excess oc-curs on farmers land)

Scenario 3: No N/P spreading on farmers land allowed

No BAT, technical feasibility has not been shown in practice. The major hurdle is to obtain an effluent from the liquid fraction that can be safely discharged into surface waters. Approaches that may reach this goal in future consist of steps 1 and 2 mentioned above followed by:

3. Partial elimination of N from liquid fraction by aerobic treatment or stripping
4. Membrane filtration and/or evaporation
5. One or more additional purification steps or export of heat-treated liquid fractions.

Anaerobic digestion or coagulation / precipitation techniques may complement the above approaches but are no solution for the manure problem as such. Moreover finding and establishing markets for manure products outside Flanders requires permanent attention as conditions changes continously.

9.4.4 *Effect on manure application methods and on fertilising strategies*

The use of manure leaves the farmer with little or no choice with respect to the mutual quantities of nutrients applied, as the elements are present in a more or less fixed ratio. In countries and regions such as the Netherlands or Flanders, were ceilings are imposed on both nitrogen and phosphorus rates (as organic manure), the maximum allowed rate for one element cannot be filled in entirely by manure as the other nutrient may become a limiting factor. To balance fertilisation additional gifts of the missing elements as mineral fertiliser are needed.

Apart from making the material more transportable and removing nutrients from the cycle, some forms of manure treatment can alter the ratio of nutrients present in the residual material.

Separation of pig slurry into a solid and a liquid fraction does not reduce the total quantity of nutrients, but has a marked effect on the P./N ratio. Studies from the Netherlands and Flanders show that after separation, around 75 % of the phosphorus fraction in pig manure is found back in the solid fraction while most of the nitrogen ends up in the liquid fraction, altering the P/N ratio from around 0,5 in the fresh slurry to 0,05-0,10 in the wet fraction. Using flocculation, this ratio can be reduced even further.

This means that instead of one single type of manure, the farmer obtains two products, differing not only by their physical appearance and absolute nutrient content, but also by the relative presence of the various elements. As a direct consequence, farmers can make more use of manure to fill in the maximum allowable rates for both nitrogen and phosphorus. This is for instance the case in Flanders, where up to now P, rather than N, was the limiting factor for the dosage of manure.

9.4.5 Manure export

Manure transfer of excess manure to neighbouring farms, villages or even regions areas is a common way to reduce local surpluses and to have a more even distribution of nutrients. Any such transfer bears a transportation cost, and therefore there is a limit to the transportation distance for every type of manure. As a general rule, liquid manure (slurry) is more expensive per kg of nutrients to transport than drier manure.

In most cases manure is transferred by road to nearby regions, but long distance transportation of dried manure or manure products by ship is also taking place. Within the country or region of origin, manure export may lead to an internal shift in nutrient use: dry manure (e.g. poultry manure is exported and being substituted by other types of local manure less easy to transport (e.g. pig of cow slurry).

Although farmers at the receiving end usually welcome manure as a useful and most often cheap source of nutrients, this is not always the case with governments and authorities not in favour of such transfers for fear of a negative impact on their own nutrient balance, health or contamination problems.

Barriers to reduce or to control the inflow of manure take the form of permits, product certificates, veterinary certificates and transportation documents or even straight refusal of import. During breakouts of animal diseases, borders may be completely closed to import of animal manure or manure products. Therefore at present the possibilities to export manure on a continuing basis are not guaranteed. To overcome this uncertainty problem, the idea was recently put forward in the Netherlands to create underground capacity for the long term storage of processed manure, with a view on later use or export. In this way, large quantities of phosphorus (and other elements) could be withdrawn temporarily from the nutrient cycle, to be injected again when the supply of good quality (= low cadmium) phosphorus ore would dwindle in a few generations from now. However there are no concrete plans as yet to implement this idea.

In a study commissioned by the Flemish government and carried out by the University of Leuven (Tollens E. et al., 2002), the possibilities, constraints, requirements and necessary incentives for the export of Flemish animal manure products to foreign (including overseas) regions were explored. Organic farms, farming sectors with high added value (fruit, flowers, vegetables) and areas with soils low in organic matter (Mediterranean, Africa, Southeast Asia) are considered by the authors to provide the best market opportunities for such products.

The main constraints for increased export cited by the report were the following:

- Low bulk density of the products
- Low and variable nutrient content
- Presence of heavy metals in particular copper and zinc
- Scale of the production units, lack of cooperation within the sector
- Uncertainty about the futur developments
- Unfavourable product image
- Competition from local sources of organic matter
- Transportation cost

Processed and dry manure contains considerably more nutrients per unit weight than unprocessed manure. To illustrate this, the following table gives an idea of the average major parameter values in raw and in processed pig slurry (source SSB)

Table 88: Composition of raw and treated pig slurry (source SSB)

Parameter	**Raw slurry**	**Treated manure (fermented)**
Dry matter	83 kg/tonne	886 kg/tonne
Organic matter	54 kg/tonne	618 kg/tonne
Nitrogen	7.8 kg N/tonne	19.4 kg N/tonne
Phosphorus ()	4.5 kg P_2O_5/tonne	53.5 kg P_2O_5/tonne

With a NPK content in the order of 130 kg per tonne, processed manure still compares unfavourably with mineral fertiliser such as DAP (64% nutrients), ammonium nitrate AN (33% nutrients) or muriate of potash MOP (60% nutrients). This means that the organic matter content of manure products and the presence of nutrients other than NPK are necessary sales arguments.

Transportation costs for processed manure vary widely and the relationship with distance is far from clear. In other words nearby destinations are not necessarily cheaper than remote countries. The most important factor determining the unit price of manure shipping is the quantity to be transported. Reductions of up to 50%

as compared to the standard price can be negotiated for the shipment of large quantities. The following tables provide an idea of the unit price for the shipment of manure products from Flanders to various destinations in Europe and overseas (source Tollens et al. 2002).

Table 89: Indicative CIF transportation cost of manure products ex-Antwerp in 20 feet (= 20 tonnes) containers to selected destinations

Destination	€/container	€/tonne
China	679	33.95
Malaysia	438	21.90
Morocco	970	48.50
Tunisia	747	37.35
Latvia	497	24.85
Romania	899	44.95
Ghana	1 477	73.85
India	960	48.00
Tanzania	1 166	58.30
Brazil	766	38.30
Colombia	1 461	73.05

Table 90: Transportation cost of manure products by truck and by train from Flanders to selected destinations

Destination	€/tonne	
	22 T Truck	Train*
Bulgaria	130	106
Hungary	74	71
Lithuania	119	-
Poland	72	54
Romania	117	109
Czech republic	59	48
Slovenia	72	62
Slovak republic	68	58

* based on a 200 tonnes load in big bags

Part 3 Case studies

10. The Flanders region of Belgium

10.1 Origin of P-surpluses in Flanders

The Flanders region of Belgium is among the areas within the European Union with high surpluses on its nutrient balance. This situation is mainly the result of an explosive intensification of livestock holding (including dairy farming) after the second world war.

Indeed, since the 1960's, increasingly intensive methods of livestock farming, in particular of cattle, pigs and poultry, have resulted in a surplus of animal manure in the Flanders region of Belgium, which primarily means a surplus of minerals (nitrogen and phosphate). Above all, the emergence and growth of "land-independent" (intensive) stock farming establishments in the sandy regions of the western and northern provinces have contributed to this state of affairs.

The major reason for this is that the dominant soils of these regions are not suitable for a high level of production of traditional arable crops such as wheat or sugar beets, and that the available area per farm is small. The possibility to import cheap raw materials for cattle feed via the seaports of Antwerp and Ghent and the good infrastructure have encouraged the development of intensive stock farming in these regions. As a counterweight to the import of cattle feed, there are substantial exports of products (meat, eggs, milk, cheese, etc.). However, as the increased production of nutrients, contained in the animal manure, is only partially compensated by the increased in uptake by the crops, the resulting balance has taken the form of a large and structural surplus of mainly nitrogen and phosphorus, leading to groundwater and surface water contamination, in particular by nitrates. With respect to phosphorus a considerable build up of reserves in the soils took place (see Figure 44 on page 134), sometimes even leading to situations of phosphorus saturation.

Although the signs of the negative effects were already recognised early, it was fairly recently only that measures were gradually introduced to limit the loss of minerals to the environment. Although the emission of nitrogen is just as harmful from an environmental point of view as the emission of phosphate, the Flemish government, following the example of the Dutch authorities, has originally geared its policy measures to phosphate (P_2O_5). The significance of this is primarily practical. Indeed, nitrogen is more difficult to incorporate in an analysis of inputs and outputs, due to its presence in the form of volatile compounds such as ammonia (NH_3) and nitrogen gas (N_2). In European legislation however, nitrogen has been chosen as the "yardstick" element (EU Nitrate Directive 91/676/EEC). Nevertheless, P_2O_5 has remained an important element in the current Flemish legislation.

In 1991, the Flemish government has launched its 'manure action plan', which has since then been adapted on several occasions in order to comply with the Nitrate Directive. Contrary to other member states, the Flemish policy has aimed from the beginning to reduce N-surpluses as well as P-surpluses. In order to implement its policy, the Flemish government has set up a specialized agency within the Flemish Land Authority (VLM), know as the 'Manure Bank'.

In the current Manure Action Plan, parts of the Flemish territory have been designated as N-vulnerable zones in the sense of the Nitrate Directive (up to now there is no full agreement between the Flemish authorities and the EU on the delimitation of these zones). Other areas have been designated as 'P-saturated'. General maximum rates apply on the rest of the territory. As a general principle, the strictest applicable rate for a given area prevails.

Up to now Flanders has not yet attained full compliance with the Directive. In a recent court case (C221/03), the European Court judged that, by failing to adopt the necessary measures to implement completely and correctly Articles 3(1) and (2) and 4, 5 and 10 of Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (OJ 1991 L 375, p. 1, ‘the Directive’), in relation to the Flemish Region, and Articles 3(1) and (2) and 5 of that directive in relation to the Walloon Region, the Kingdom of Belgium has failed to fulfil its obligations under the Nitrates Directive.

10.2 Specific regulations concerning P-production and P-use in Flanders

Although the Flemish policy aims in the first place to compliance with the Nitrate Directive, it contains several elements that particularly refer to phosphorus. This is reflected in a number of regulations, the more important ones are listed hereunder.

License policy

In the current Flemish farming permit system, P is the yardstick to measure the size of a livestock farm. In other words, livestock holdings hold P-production rights. For every species of farm animals, P-coefficients are set.

Fertilisation standards

Maximum fertiliser rates have been set for grassland and for all crops, and are expressed in kg of N and P_2O_5 per hectare. In the case of N, a distinction is made between mineral N and N from organic sources. With respect to P, no such distinction exists. However, mineral P -use has steadily and significantly decreased over the past years. In other words, the link between P use and N use has become more important.

- General rates

General maximum rates apply in all areas without further specific restrictions:

Table 91: Maximum admissible general rates

	kg P_2O_5/ha	kg N from manure
Grassland:	130	250
Maize:	100	250
Crops with low N-requirements:	100	125
Other crops	100	200

Higher rates are admitted when two crops are combined within one year, but only after prior permission by the Manure Bank of the Flemish Land Authority has been obtained. In this case the following maximum rates apply:

Table 92: Maximum admissible general rates on crop combinations

	kg P_2O_5/ha	kg N from manure
Grass + maize	125	310
Grass + other crops	125	250
Vegetables + vegetables	125	250

In the latter two combinations, these rates do not apply on crops with low N-demand.

- Vulnerable zones

Several types of vulnerable zones are distinguished: areas for the production of drinking water, nitrate sensitive areas, and 'newly' designated vulnerable zones (it should be noted that the EU Commission does not agree with the current delimitation of vulnerable zones in Flanders)

Within the vulnerable zones, three types of restrictions apply with respect to N and/or P.

Table 93: Maximum annual rates in the vulnerable zones

	kg P_2O_5/ha	kg N from manure
Grassland:	100	170
Maize:	100	170
Crops with low N-requirements:	80	125
Other crops	100	170

Table 94: Maximum annual rates in vulnerable zones with management agreement

	kg P_2O_5/ha	kg N from manure
Grassland:	100	140
Cereals	100	140
Maize:	100	14
Crops with low N-requirements:	80	100
Other crops	100	140

Table 95: Maximum annual rates in vulnerable zone with general derogation

	kg P_2O_5/ha	kg N from manure
Grassland:	100	230
Grassland + maize	100	230
Winterwheat + non leguminous green manure	100	200
Sugarbeets or fodderbeets	100	200
Brussels sprouts	100	200

- Phosphate saturated areas

Phosphate saturated areas have been delimited in certain parts of the territory, where repeated application of high doses of animal manure on sensitive soils (= predominantly sandy soils with low P-sorption capacity) has taken place in the past. These areas are mainly situated in the provinces of Antwerp and West-Flanders.

In the saturated areas, P application is limited to **40 kg of P205** per ha and per year.

A proposal to limit P-application on fields with low phosphate binding capacity, and with low actual phosphate reserves is currently under preparation. In this proposal, the following maximum rates are being put forward. Moreover, application of P can only take place after soil analysis, and after a certificate has been delivered by the manure bank.

Table 96: Maximum annual rates on soils with low P-binding capacity (proposal)

	kg P_2O_5/ha
Grassland:	90
Maize:	80
Crops with low N-requirements:	70
Other crops	70

With respect to N, maximum allowable rates of the zone in which the field is situated apply.

10.3 Manure treatment and processing in Flanders

In Flanders, manure processing forms the third pillar of the government's Manure Action Plan. Under the current legislation, manure treatment is compulsory for livestock units exceeding a certain size. The percentage of manure to be processed increases with the size of the livestock farm, as illustrated in the following table.

Table 97: Percentage of manure production to be processed in function of farm size (situation 2003)

Manure production (kg P205/year	**2003**
7 500 – 10 000	30
10 000 – 12 500	50
12 500 – 15 000	75
> 15 000	90

In the Flanders legislation, manure treatment (mestbewerking) and manure processing (mestverwerking) are clearly distinct notions.

Manure treatment:

The action of modifying the characteristics of animal manure and/or other types of fertilising materials with the aim of recycling the nutrients nitrogen and phosphorus on soils situated within the Flemish region.

Manure processing:

The treatment or processing of animal manure in such a way that the nutrients contained in the manure:

- are being mineralised and solid residues left over after mineralisation are not brought on arable land situated within the Flemish region, unless these residues have previously been transformed into mineral fertiliser

- are being recycled in such a way that the recycled end product is not brought on land situated within the Flemish region

In this sense, manure treatment may or may not imply a withdrawal of nutrients from the Flemish nutrient cycle. Manure processing implies that the nutrients are being transferred outside the region, or remain within the cycle, but only as mineral fertiliser, and the term covers a wide range of interventions, including export of minimally treated dry poultry manure.

The development and implementation of manure processing techniques is basically left to the private sector. However, the government agency Mestbank (Manure Bank) plays in important role by coordinating various initiatives via VCM (Vlaams Centrum Mestverwerking or Flemish Centre for Manure Processing) which it presides, by providing information and by initiating scientific research. In the meantime, it delivers efforts to find outlets for the end products of the manure treatment process.

Since the 1980’s, a large number of initiatives have been taken in Flanders to build manure treatment installations of various types and at various scales. So far no single technology has proven to be the better. Some large scales installations were effectively built, only to be closed before even going into operation. However, through a process of trial and error, a regional manure processing capacity was gradually being built up.

By the end of 2003, the Flemish government had granted 197 permits for manure processing installations. Another 48 dossiers were being dealt with, while just 8 requests had been given negative reply. For various reasons and because of the experiences of the past, small scale installation are becoming more popular. At present only 4 installations with an annual capacity of over 100 000 tons of manure each do exist.

While manure processing in Flanders has made great strides, the available capacity remains insufficient, especially with respect to pig manure. From a survey carried out by VCM in 2004, the operational capacity was estimated at 9 400 tons of P_2O_5 per year.

Major problems encountered in the development of sufficient capacity are:

- Difficulties to obtain building and operating permits, due in part to the lengthy and complex procedures
- Stringent discharge standards for the effluents
- Long period required to bring technical concepts to the operational stage
- Hesitation by banks and other providers of credit to invest in (so far) unproven technologies
- Import ban of end products of manure processing in the nearest ‘natural’ outlet (the Walloon region)

10.4 Effects of the government policy

P-balance calculations, carried out in the framework of the annual state of the environment report (MIRA) of the Flemish government indicate a gradual decrease of the annual surplus of P between 1990 and 2003 from nearly 38 000 tons (on a total P-consumption of nearly 55 000 tons) to less than 13 000 tons (on a total P-consumption of just over 32 000 tons). This improvement is caused by various factors: decreased production of P in animal manure (minus 11 000 tons), increased uptake by the crops (plus 2 500 tons), and decreasing use of mineral P-fertiliser (minus 11 600 tons).

In the mean time, the continuing surplus has lead in many areas to highly increased levels of P-reserves in the soil, or even to phosphorus saturation in particular zones with soils vulnerable to excess P. Even today, many soils continue to receive more phosphorus than is strictly needed. The state of the environment report MIRA 2004 mentions that 85% of the arable land and 66% of the grassland received P-rates beyond the recommended rate.

At present, manure surpluses at farm level are being redistributed to 'deficient" farms or exported to neighbouring countries or regions. In 2003, almost 14 000 tons of P were transferred to other farms within Flanders, 16 % whereof were situated in the vicinity. In the same year, a net export beyond the Flemish borders of almost 2 600 tons of P took place, mainly to France.

10.5 Cross compliance in Flanders

Among the cross-compliance conditions proposed at present by the Flemish government, none is in particular dealing with the topic of phosphorus.

However three items can directly related to phosphorus management, namely carbon content, pH and erosion control. In this proposal, farmers would be obliged to carry out a minimum number of soil analyses to monitor the organic matter content and the pH-status of the soil. As has been mentioned before, pH has a noticeable effect on the availability of P (and therefore the efficiency of uptake) while the organic matter plays a role as a regulator of nutrient supply.

Erosion control measures will contribute to reduce the risk of direct loss of phosphorus to the surface water. As has been seen earlier, such losses are responsible for half the load of phosphorus in the river systems in the loamy region of central Belgium.

11. The Brittany region of France

11.1 Agricultural productions/origin of the nutrient surpluses

Brittany is the most Western region of France and is made up of four departments: Côtes-d'Armor, Finistère, Ile-et-Vilaine and Morbihan.

From the 1960's onwards, the agriculture of Brittany has gradually changed from a family based semi autarchic type of agriculture to an intensive agriculture based on livestock production and horticulture. Taking up about 65% of the territory, Brittany has become nowadays the first agricultural region of France in terms of turn over, and the second in terms of horticultural area. Around 1970, Brittany produced 8.7% of the national agricultural produce. By 2000, this figure had risen to 12%. Employment in agriculture reaches 7% of the active population and contributes 6% to the region's GDP, as compared with national figures of respectively 3,4 % and 2,8%.

The increase of agricultural production is mainly due to the development of intensive pig sector, mainly based on imported feedstuffs. Pig production comes first in terms of turnover and the region's pigs account for 56 % of the national herd. The four departments of Brittany, lead by Côtes d'Armor and Finistère, are the first producers of pig meat nationwide.

Dairy farming occupies the second place. With 21% of the national production, Brittany is the leading region of France, l'Ile-et-Vilaine being the department with the highest production figures. Beef production represents 10% of Brittany's agricultural produce and accounts for 15 % of France's beef.

With 17% of the regional agricultural production, poultry (meat and eggs) comes third, and represents 31% of the national poultry sector. Poultry is mainly concentrated in the Côtes d'Armor department.

The following table provides the total number of animals held per department by the end of 2003 (source Agreste - Statistique Agricole Annuelle).

Table 98: Livestock numbers in Brittany per department (2003)

	Côtes d'Armor	**Finistère**	**Ile-et-Vilaine**	**Morbihan**	**Total Brittany**
Cattle	568 000	475 500	679 500	411 500	2 134 500
Pigs	2 870 000	2 853 000	1 307 000	1 395 760	8 425 760
Poultry (eggs)	11 000 000	3 900 000	900 000	4 300 000	20 100 000
Poultry (meat)	12 500 000	14 000 000	5 170 000	8 800 000	40 470 000
Turkeys	3 400 000	2 600 000	1 400 000	6 300 000	13 700 000

At the same time, Brittany has become a major horticultural region, occupying the first place in France with respect to fresh vegetables and potatoes. In terms of surface area, Brittany comes second after Nord-Pas de Calais. Vegetable production is mainly concentrated along the northern coastline, especially around Saint-Pol de Léon and Paimpol.

11.2 Nutrient surpluses and water quality

Due to the geological substrate, predominantly impervious and devoid of major aquifers, Brittany has a dense surface water system with irregular flows. Surface water is providing 80% of the drinking water, the remaining 20% being produced from numerous small wells.

Due to the development of the intensive livestock sector and the use of imported feedstuffs, combined with the continuing use of mineral fertilisers, Brittany has moved from a general nutrient deficit in the 60's to a considerable balance surplus, negatively affecting the quality of the water. Since the 70's, the concentrations of nitrate, phosphorus, organic matter and residues of pesticides have increased significantly. Until recently, attention was mainly paid to the pollution by nitrates and pesticide residues. The annual nitrogen balances deficit, most of which is lost to the surface water, is estimated at around 110 000 tons (including nitrogen from mineral fertilisers), or more than 75 kg of per hectare of agricultural land.

The whole territory of Brittany was designated vulnerable zone. Structural surplus zones (Zones d'excédents structurels) are defined as those areas (cantons) where the load of nitrogen from animal sources exceeds the limit of the Nitrate Directive of 170 kg N per year and per hectare. In 1996, 71 'cantons' were considered to have a structural surplus. In 2002, this number increased to 104.

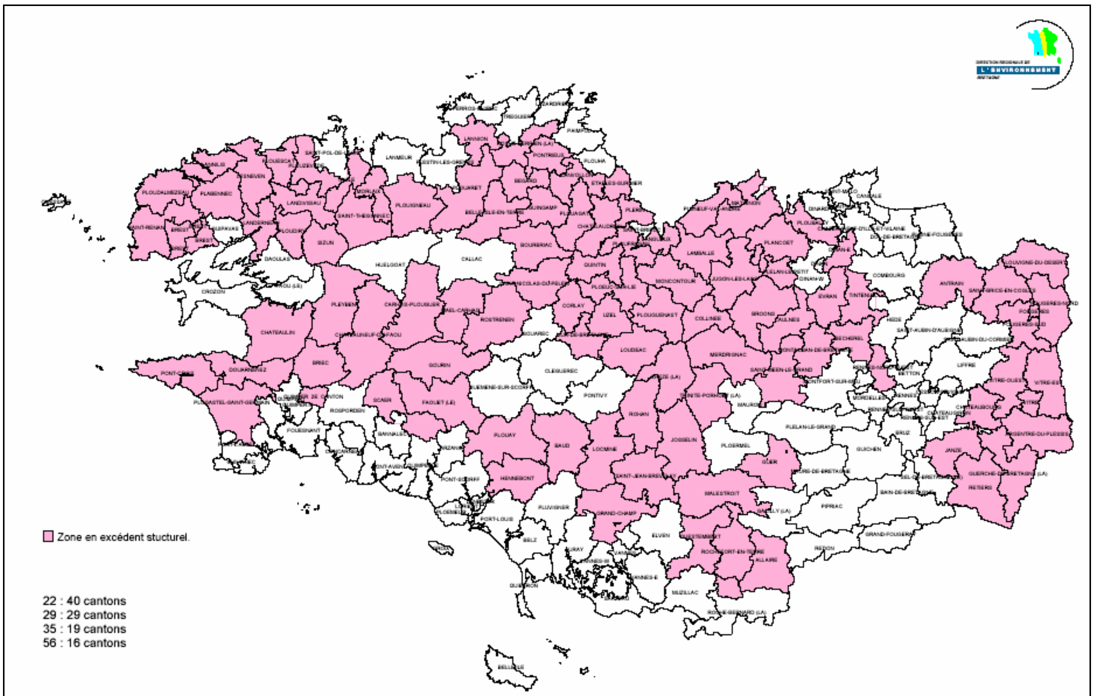


Figure 50: Structural surplus zones in Brittany (2002)

11.3 Nutrient status of the soils

The intensification of the agricultural production in Brittany has had marked effects on the nutrient status of the soil, in particular in the areas with high livestock density.

The soils of Brittany are in general well supplied with organic matter, between 2% and 8%. However in the last 30 years, a gradual decline in the organic matter status of the soil was observed. Results of more than 60.000 soil analysis carried out in the periods 1980-85 and 1990-95 show an average decline of 0.6% in 10 years time, with negative effects on soil fertility, soil structure, water holding capacity and erodibility.

From a situation of phosphorus deficiency at the end of the Second World War, the soils of Brittany now have evolved to a situation of relative surplus. At present the average P-content of the soils of Brittany as measured by the Dyer method is nearly 400 mg P_2O_5/kg soil, while from the agricultural point of view, a concentration of 220-240 mg/kg is considered to be optimal. In more than half of the municipalities, soils are excessively rich in phosphorus, in particular in the horticultural areas and in the intensive livestock zones. The current phosphorus status as presented by the following figure is a good indicator of systematic over-application of manure in the past decades.

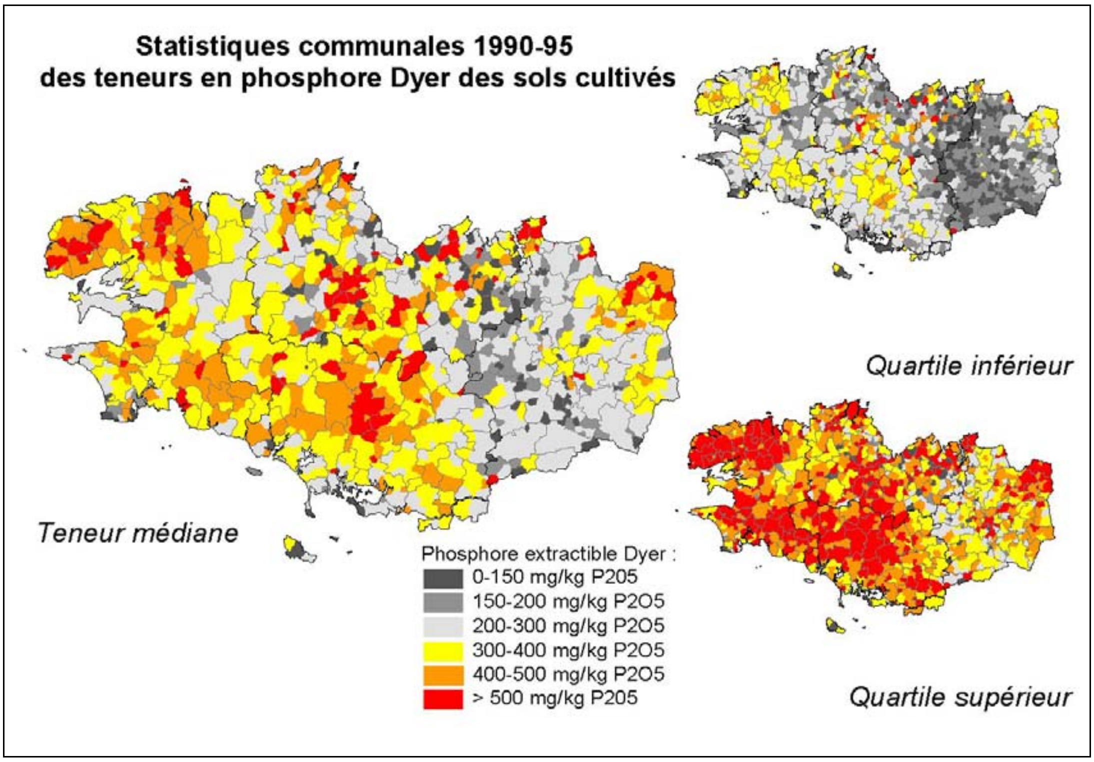


Figure 51: P-status of the soils in Brittany 1990-1995 (source ENSAR)

High rates of available P in the topsoil increase the risk of direct loss of phosphorus to the surface water by erosion, and of leaching of P to the groundwater.

11.4 Evolution of phosphorus use - current P balance

After the Second World War the soils of Brittany were known to be in general deficient in phosphorus. Basic slag from the iron industry was the first source of mineral phosphate, to be replaced later on by superphosphate and DAP. From the 70's onward, animal manure gradually became the main supplier of phosphate to the soil. Due to a change in agricultural practice and to the arrival of new types of fertilisers, the relative share of mineral forms of P-fertiliser has gradually decreased (Arrousseau, 2001). According to Cann et al. (1999), the consumption of mineral phosphate fertilisers in Brittany has dropped faster than in the rest of France: from 35 kg of P/ha in 1980 has decreased to 14 kg P/ha in 1997.

However, as was the case in other countries or regions (f.i. Flanders, the Netherlands, Denmark, Northern Italy), the import of feedstuffs has largely compensated for the reduction in mineral P fertiliser use.

According to Giovanni (2002) and depending on the department, the load of phosphorus from organic sources in Brittany varies from 93 kg P_2O_5/ha of agricultural land (Ille-et Vilaine) to 152 kg P_2O_5/ha (Finistère). This means that animal manure has overtaken mineral fertiliser as the main source of phosphorus by a large margin.

The P/N ratio of manure can vary considerable according to animal species; from around 0.45 for cattle manure to around 1 for poultry manure. This means that fertilising strategies focusing on nitrogen may lead to an overdose of phosphorus. Spreading of manure at the rate of 170 kg N/ha will provide about 105 kg of P_2O_5/ha, well above the recommended rate for several crops.

Balance calculations carried out by Aurousseau (2001) on figures of the year 2000 indicate a balance surplus for the Brittany region of around 30 000 tonnes, comparable with the surplus of 38 135 tons of P, obtained in the balance calculations of the current study (see Table 30). According to the same author, around 4 000 tonnes of this balance surplus is actually lost to the surface water, while the remainder contributes to the soil stock. The average flux of P from the agriculture to the surface water is estimated at 2 kg per year.

11.5 Response strategies to nutrient losses

The policy of the French government in general and of the local governments in Brittany in particular has been aiming so far mainly at controlling of the nutrient surplus from agricultural sources through the implementation of the Nitrate Directive, whereby the focus entirely lay with nitrogen. Only more recently the scope has been widened to the entire Water Framework Directive, meaning that other elements, including phosphorus, are receiving attention. The main tools operated by the Breton authorities to reduce the nitrogen surplus are the **action programme**, the **complementary actions** and the **reduction programme for the structural surplus zones**.

Action programme

Since 1994, the entire region of Brittany has been declared vulnerable zone in the sense of the Nitrate Directive. This means that the action plans, aiming at the reduction of pollution of the waters by nitrates of agricultural origin, are applicable to all the Breton farms. The main element of the current action programme is the obligation to apply a balanced fertilisation approach meaning that:

- A maximum limit of 170 kg per ha of N of organic origin is to be observed
- A register is to be kept of all nitrogen applied (organic and mineral)
- A provisional fertiliser (nitrogen) plan is to be established yearly (31 March)

As is the case in other member states, a calendar is to be respected with respect to the spreading of manure, and particular rules apply along water bodies, on sloping or on frozen ground.

Drainage of humid zones is forbidden, as is the turning of grassland in submersible zones.

Complementary action zones

Special rules apply in the so-called complementary action zones (Zones d'Action Complémentaire or ZAC), established in catchments that are feeding drinking water production points. Measures to be taken include:

- Obligation to have a covering crop during the winter period
- Maintaining a grass cover on the strips along river banks
- Ban on the application of nitrogen on crops planted on turned grassland within a period of three years
- Maximum of 210 kg N/ha (organic plus mineral)
- No increase allowed in livestock numbers

Reduction programmes in structural surplus zones (Zones d'Excédent Structurel (ZES)

As was mentioned before, ZES are those areas (cantons) where the load of animal manure exceeds the equivalent of 170 kg of N per hectare of agricultural land. In these areas, additional abatement programmes are in force since 2001 in order to bring back the average organic nitrogen load to or below 170 kg N per hectare. The overall objective is to reduce the surplus by nearly 44 000 tons of N, to be reached by 2006. The measures comprise:

- Instauration of a ceiling to the surface area per farm available for spreading manure (in order to limit the rush for available land)
- A ban on the extension of livestock numbers, apart from a limited margin to allow the establishment of young farmers or to assure the viability of small farms
- Obligation for a farm to transfer or treat manure in function of the size of the farm (12 500, 15 000, 17 500 or 20 000 kg of N in function of the canton)

Farms situated within the excess zones have to make the necessary efforts to reduce the nitrogen surplus, such as:

- Manure treatment: biological treatment, denitrification, composting or combustion
- Manure transfer to cantons outside the ZES area (and where the organic nitrogen load does not exceed 140 kg/ha)
- Reduction of nitrogen quantities at the source (f.i. via low nitrogen feed)
- Reduction of livestock numbers
- Increase of the available land spreading area

The surplus reduction methods, including manure processing will be discussed in more detail in the following paragraphs.

11.6 Surplus reduction methods

The authorities of Brittany have approved a number of surplus reduction methods (procédés de résorption), to be used by farms that are under the obligation to treat or to transfer part or all of their manure. These are published in an official list. The official inventory of approved methods contains 19 techniques or groups of techniques, ranging from deodorising to manure processing or incineration. The same list provides the percentage of N reduction that can be obtained by each method. Figures range from 0% for phytase use to 100% for incineration.

The following table presents a selected number of techniques from the list together with the effectiveness on N-reduction as put forward by the Breton authorities. The expected effect on P-content was added by the authors.

Table 99: Selected officially approved methods of manure treatment

Measure	**N reduction**	**P-reduction**	**Comment**
Working under of manure	0	0	More land available for spreading
Use of phytase	0	25 - 70	P-figures put forward by Brittany
Biphase feeding	17	17	
Composting of pig manure	50	0	
Composing of poultry manure	30	0	
Biofiltration (f.i. Solepur)	80	0	
Thick bed of straw or sawdust	29-62	0	
Physico-chemical separation	15-40	?	Providing partial transfer outside ZES
Drying of poultry manure	100	100	Providing manure is transferred
Reduction of livestock numbers	100	100	
Combustion of poultry manure	100	100	Providing ashes are not returned to land
Methanisation	100	100	Providing manure is transferred

It should be noted that most of the methods imply the transfer to land outside the surplus zone of the end-product that will still contain part of the nitrogen and most of the phosphorus present in the raw manure.

11.7 Manure transfer - manure processing

According to figures published by the Prefecture of Brittany in October 2004 (MIRE, 2004), out of the 23 050 professional farms situated within the ZES zones, 13 900 do not have the necessary land to spread all the manure they produce.

In order to reduce the surplus at the cantonal level, 1 916 farms are under the obligation to treat or to transfer manure. Out of these, 414 produce over 20 000 kg N/year each and have a total annual surplus of 14 437 tons of N.

Manure processing is mainly done in small scale or mobile facilities at the farms. Most of these are biological treatment or composting installations. At present 297 farms do have a treatment facility at their disposal or have access to such an installation. At present the more successful treatment facilities belong to large individual pig producing units. The smaller farms have to call upon semi-collective of mobile unit. With respect to the latter, the Breton prefecture is aiming at two units in each of the four departments.

Two large scale projects for the centralised methanisation of slurry with co-generation of electricity are currently being financed by the ADEME, FEDER and l'Agence de l'eau Loire-Bretagne.

A project for the incineration of poultry manure is being frozen, the current price of the electricity not being sufficient to assure profitability. Small scale combustion at farm level or on a semi collective base is being explored in the Finistère department.

Most the methods of manure treatment used at present aim at the elimination or reduction of the N. This may provoke or amplify the disequilibrium between nitrogen application and other elements, in particular phosphorus. Therefore the following accompanying measures are being proposed by the French authorities.

- Use of phytase in animal feed
- Spreading of manure products only on land not subject to erosion risk or sufficiently distant from water courses
- Adapting the practices in order to reduce the risk of run-off
- Limiting the rate of P application

With respect to the latter, the Water agency of Loire-Bretagne proposes a maximum limit of 250 kg P_2O_5 per hectare to be adjusted in function of the crop and of the sensitivity to erosion. Although the maximum rate of 250 kg seems rather high compared with the needs of most crops, this measure will at least reduce the risk of excessive applications of manure products poor in nitrogen but rich in other elements.

Removal of P from the manure is being proposed as another measure, but would most certainly have an impact on the cost of manure treatment. Therefore, this is only compulsory for treatment units with a annual capacity of over 25 000 tons of nitrogen.

Moreover, since 2004 farmers who have the obligation to treat or to transfer manure should limit the P-application to 150% of the expected uptake by the crop. As less than 2000 farms fall within this category, the effect of this measure will be limited.

11.8 Effect of the measures taken

According to a report by the government of Brittany, the actions aiming at a reduction of the regional nitrogen surplus (estimated in 2001 at 110 000 tons N) by 44 000 tons by 2006, has resulted so far (2004) in a drop of 36 400 tons. A little less than half of this drop (15 000 tons) was attribute to a reduction in the use of mineral fertilisers, and just over half to the decreased use of organic fertilisers in the ZES (21 400 tons).

The reduction of the use of manure in the ZES was attributed to the following factors:

- 9 200 tons/year by the transfer of manure to non surplus zones
- 5 600 tons/year by the use of biphase feeding
- 4 300 tons/years by manure processing (essentially biological treatment of pig slurry)
- 1 300 tons from the reduction in livestock numbers
- 1 000 tons by making available additional land areas for spreading

It should be noted that not all of these measures have an impact on the P-balance. Using an average P_2O_5/N ratio of 0,66, and considering that only manure transfer, reduction of livestock numbers and increase of the land area have an impact on the P-balance, the effect of the measures on the latter balance can be estimated at 7 590 tons of P_2O_5, or around 3 400 tons of P per year, corresponding to 10 to 15% of the current annual balance surplus.

11.9 Specific regulations on phosphorus

As was explained earlier, the efforts of the Breton authorities to deal with the issue of nutrient surplus have been directed mainly at solving the nitrate problem.

From the above paragraphs it is clear that the negative role of phosphorus (including phosphorus from agricultural sources) on the ecosystem in Brittany is fully acknowledged and that awareness of the phosphorus problem has been growing considerably in recent years.

The phosphorus issue is not yet, or only very partially or indirectly, addressed in the current legislation. As an example, all over France the fertiliser programmes to be established in the framework of the obtainment of operating licences are all based on nitrogen only, with no reference whatsoever to other nutrients with the exception of the Vendée region, where the 'Réglement Sanitaire Départemental' (R.S.D.) imposes a limit to P application of 100 kg of P_2O_5 per hectare. As has been seen before, this corresponds in average with around 170 kg N per hectare, and is as such not more restrictive than the Nitrate Directive rules.

On the other hand, a number of existing legislative texts appear to provide a sufficient basis (or at least the beginning of it) to tackle the phosphorus issue too, as can be deducted from the following paragraphs. In order to preserve the full significance of the text it was left in its original form and was not translated (source: Eau et Rivières de Bretagne).

- **Le Schéma Directeur d'Aménagement et de Gestion des Eaux (SDAGE LOIRE BRETAGNE),** approuvé par arrêté du Préfet coordonnateur de bassin, indique dans son chapitre VII.5.3 que « le phosphore est un élément déterminant dans la genèse de l'eutrophisation des eaux douces et la réduction de ses apports dans les eaux doit permettre d'agir sur le phénomèn. C'est pourquoi il convient de mettre en œuvre les préconisations du chapitre VII.5.6 "Les pollutions par l'agriculture" : La maîtrise des apports de fertilisants ne suffit pas à écarter tout risque de dégradation de la ressource du fait de la variabilité des conditions climatiques. Il importe donc d'avoir, même en situation d'apports équilibrés, des barrières au transfert d'éléments polluants et de disposer de milieux naturels au rôle épurateur.
- **Le décret n° 96-540 du 12 juin 1996**, relatif au déversement et à l'épandage des effluents d'exploitations agricoles non soumises à la législation des installations classées précise dans son article 3 : «L'épandage des effluents d'exploitations agricoles tant en ce qui concerne les périodes d'épandage que les quantités déversées doit être effectué de manière que en aucun cas, la capacité d'épuration de sols ne soit dépassée compte-tenu des apports de toutes substances épandues sur les terres concernées et des exportations par les cultures. »
- **L'arrêté ministériel du 2 février 1998** applicable aux installations de traitement des lisiers relevant de la rubrique 2751 de la nomenclature dispose dans son article 37 que : «les quantités épandues sont adaptées de manière à assurer l'apport des éléments utiles aux sols ou aux cultures sans excéder les besoins ».
- **L'arrêté ministériel du 30 avril 2002** relatif au référentiel de l'agriculture raisonnée indique que le plan prévisionnel de fumure doit être établi chaque année en « ajustant les apports d'azote, de phosphore, et de potassium aux besoins des plantes ».
- Depuis 1976, et conformément à la législation des installations classées pour la protection de l'environnement, les élevages ne peuvent être autorisés que si les dangers ou inconvénients qui résultent de leur exploitation pour la protection de la nature et de l'environnement sont prévenus par des mesures que spécifie l'arrêté préfectoral.

On 9 September 2004, the Administrative court of Rennes has cancelled the extension permit of a pig farm in the Morbihan department, based on the following considerations. Again the text was not translated in order to preserve its full meaning.

> Par jugement du 9 septembre 2004, sur recours d'Eau & Rivières de Bretagne, le Tribunal Administratif de Rennes a considéré qu'en autorisant une extension d'élevage porcin soumise aux dispositions des articles L 511-1 et suivants du code de l'environnement :
>
> - basée sur une étude d'impact « abordant succinctement la question des rejets phosphorés »
>
> - "comportant eu égard à la charge en phosphore du plan d'épandage des risques certains de pollution des eaux"
>
> le Préfet avait commis une erreur manifeste d'appréciation compte tenu des dangers existants notamment pour la santé et la salubrité publique »

It can be expected that, for lack of quantitative standards and a better defined legal framework on phosphorus, this decision can (and probably will) be contested. In order to provide working legal framework, vague definitions such as 'the nutrient requirement of the crops' will need to be defined more precisely.

12. The Po-valley region of Italy

The following text is largely based on articles and information provided by G. Bonazzi and G. Provolo.

12.1 Livestock systems in northern Italy

While cattle is responsible for about half the manure production in Italy, even in the Po-valley region, local surpluses of manure in Northern Italy can often be linked with intensive livestock holdings of pigs and poultry.

The pig farming sector in Italy involves 250,000 farms. The sector employs approximately 60,000 workers, of whom 28,000 work on livestock farms and the rest are employed in the pork processing industry.

The economic importance of the related meat processing industry probably represents the most evident feature of pig farming in Italy, 85% of which is made up of "heavy" pigs, reared according to strict production regulation applied particularly to feeding technique. The pigs are slaughtered when they reach a live weight of over 156 kg, and their meat is used for making typical cured pork products; pig farming became concentrated in the Po valley, which is where the dairy producers and cereal cultivations were located, together with the pork markets provided by the great urban centres and the best transport system.

The number of head increased from 7,298,000 in December 1968 to 9,360,000 in 1988 and 8,329,000 in 2000. This means that between 1968 and 1988, during which time per capita pork consumption increased by 271%, the Italian pig population only increased by 28%, forcing Italy to import nearly 38% of its domestic requirement. It is estimated that, in general, the farms specialised only in the breeding phase hold 27% of the sows, and sell piglets to the fattening farms. The fattening farms have approximately 58% of the total fattening places, raising suckling pigs born both in Italy and abroad, usually from northern European countries. The closed cycle farms have 73% of the sows and 42% of the available fattening places, and constitute the prevalent type of farm among the larger-scale concerns.

Today, 73.6% of Italy's pigs are raised in the four regions of Lombardy, Emilia-Romagna, Piemonte and Veneto, accounting each for 36.7%, 20.8%, 9.3% and 6,7% respectively. Back in the 1960s almost all fattening farms were annexed to dairies to utilize the whey produced from milk processing for feeding purposes. Gradually these farms evolved to the closed cycle, self-sufficient in terms of piglet supply and organised in larger and highly specialized units. The concentration of production and the reorganisation of livestock farms radically changed the nature and the dimensions of Italian pig farming.

12.2 Housing systems - manure characteristics

The quality of pig manure in terms of solid concentration and nutrient content depends on the characteristics of housing, storage and land spreading. Pig excretions in Italy can be considered to be entirely in the form of slurry, with an average dry matter content (DM) of 3%.

In the fattening sector concrete solid floors were dominant in the past and is still common in the small rural units. The manure is removed in liquid form together with the wash water and sent to the storage facilities. The DM content here is very low, 1% or less.

More common are pens with solid concrete floor inside and external alley with slatted floor and collection slurry pit underneath. The concentration of solid is a bit higher due to the reduced use of water to clean the inside part of the pen.

In the new buildings two other types of floor are increasingly adopted: partially slatted floor and fully slatted floor. The latter is very well accepted by farmers for the cleanness of the animals and the higher DM content of the slurry. Very often under the slats a continuous storage of slurry remains, therefore high emissions of ammonia occur and artificial ventilation is required. In the farrowing sector, crates are disposed over large collection pits and slurry is removed only at the end of the lactating period when the rooms are emptied. Similar type of housing is common for piglets in the post- weaning period.

Mating and gestating sows are usually kept in pens very similar to those described for fatteners. If these sows are kept in confined units the floor is solid with only a small slatted area on the rear and a small collection pit underneath.

Nowadays there is widespread use of systems for fast and frequent slurry removal from the collection basins underlying the slatted floor (scrapers, flushing systems, etc.). The most widely used type of manure storage is the earthed lagoon. Estimates show that 30% of storage facilities are tanks against 70% lagoons.

Land application of manure is operated at the surface of the soil and the incorporation by ploughing follows only after 2 or 3 days. Slurry spreading is also operated on the growing crops like maize, by broadcasting with irrigators. Only in a few cases, for example close to the residential areas, farmers are obliged to incorporate the slurry directly into the soil.

12.3 Farming system and the environment

Very high ammonia emissions come from slurry storage in open lagoons and surface spreading as is commonly practiced in Northern Italy. Although no figures are available concerning atmospheric losses of phosphorus from manure application, these can be expected to be low.

Over the last few years, in addition to the increase in the amount of nitrogen in the ground water, there has also been an increase in the quantities of this element in the surface water, i.e. rivers and lakes, causing eutrophication problems. Very serious is eutrophication phenomena are noticed in the northern Adriatic Sea.

Emissions into the soil of phosphorous and heavy metals are a matter of special concern.

Data on the actual saturation level of phosphates in the soil are currently not available for Italy. Nonetheless, according to Italian researchers (Bonazzi) there is at least one reason for assuming that phosphate saturation, and the subsequent leaching into groundwater, is not (yet) a pressing problem. Indeed, the percentage of sandy soils more vulnerable to leaching of phosphates is relatively small. However, particular attention is required on this type of soil when the pH is less than 6.5.

12.4 Phosphorus loads in Lombardy

In the previous chapters, the 2003 overall surface balance for the Lombardy region of Italy was established at 9.4 kg of P per hectare of agricultural land.

More detailed studies of the phosphorus loads in the Lombardy region of Italy were carried out recently by G. Provolo of the Agricultural Engineering Institute at Milan (2002, 2004). In this study mass balances of phosphorus inputs (manure and fertiliser) and outputs (uptake by crops) were calculated at the level of the municipalities, and an evaluation was made taking into account soil characteristics. The results of these calculations are presented graphically in the following maps. All figures are expressed in kg of P_2O_5 per hectare and should therefore be divided by 2.29 to obtain kilograms of P. While there are no direct figures on the actual P-status of the soil, it can be assumed that the relative P-content of the soils are reflected well by the map of the balance surpluses as presented in the last one of the three figures below (Figure 54).

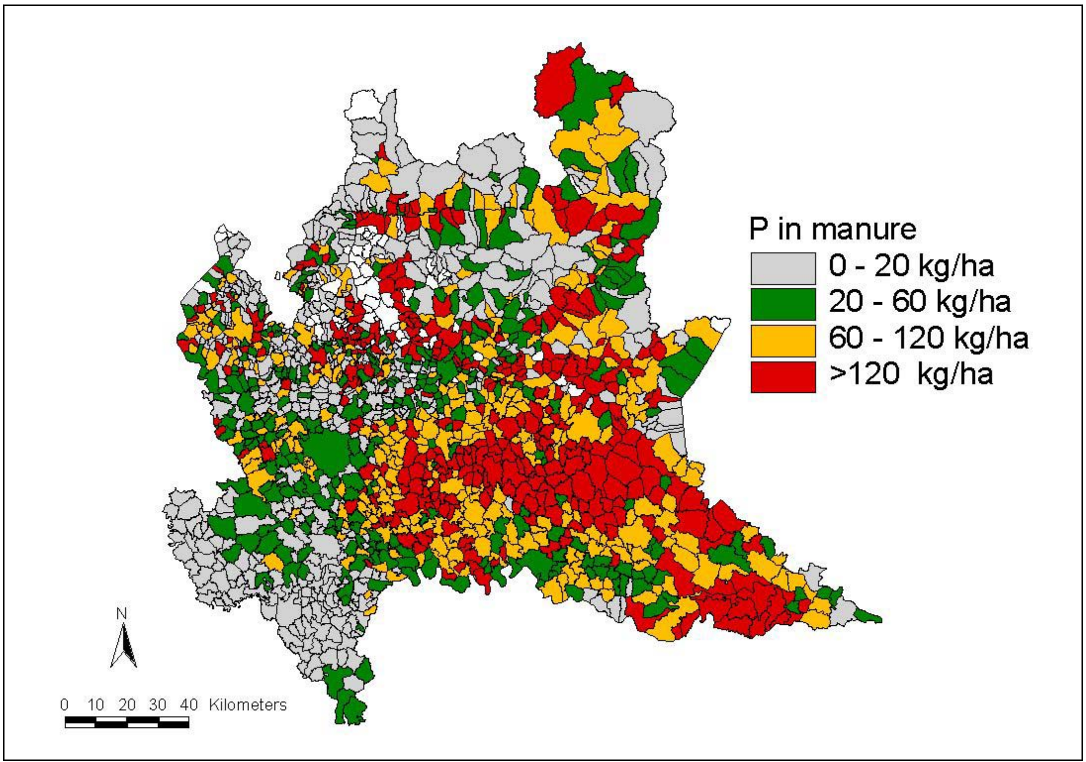


Figure 52: Lombardy region, manure production per municipality in kg of P2O5 per ha (source G. Provolo, 2004)

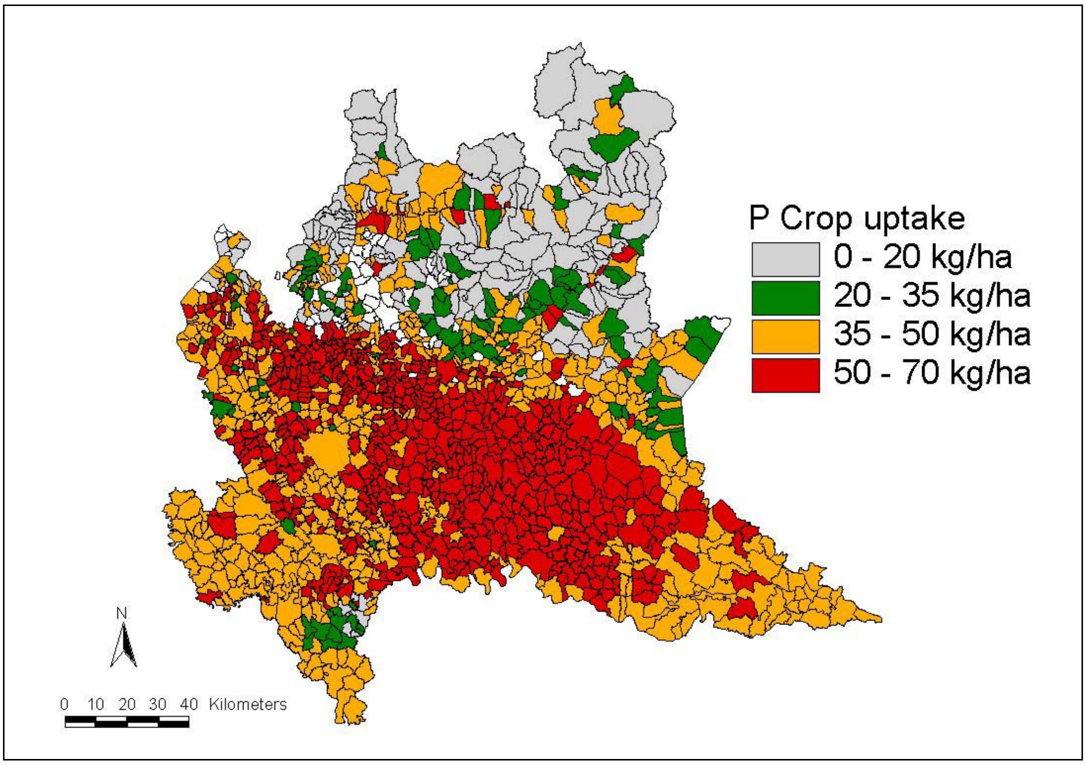


Figure 53: Lombardy region, calculated phosphorus uptake by crops in kg of P2O5 per hectare (source G. Provolo)

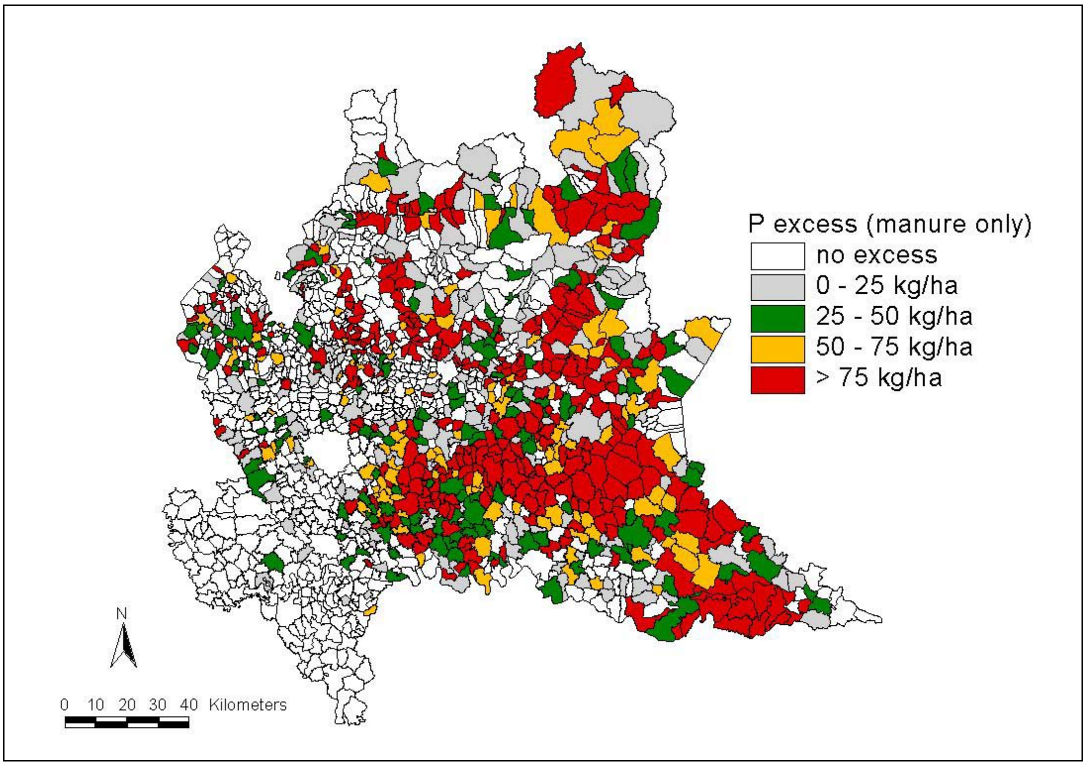


Figure 54: Lombardy region, phosphorus balance in kg of P2O5 per ha (source G. Provolo)

Manure production is the highest in the central and South-Easter parts of the territories. In many municipalities of this area, the amount of P available per hectare is double or more the expected uptake by crops. Annual P-surpluses (from animal manure only) reach more than 30 kg of P per hectare, and will be higher when including figures on mineral P-use.

In the mountainous or hilly northern parts of the region, with extensive agricultural systems and relatively low livestock density, crop uptake is sensibly lower than in the central part with well drained soils and double cropping systems. In the South-West, uptake by the crops is somewhat lower than in the Centre or in the South-East, but manure production is also smaller, resulting in a slight balance surplus only.

While various authors agree that there is no immediate risk of phosphorus saturation; solutions should be found in the longer term to alleviate the pressure from phosphorus, thought to be at non-sustainable levels in several municipalities. Hereby transfer of manure to non-surplus areas is one of the most obvious suggestions. In order to illustrate the magnitude of this task, the following map indicates the theoretical surplus of phosphorus per municipality expressed in tons of P_2O_5. Expressed in quantities of untreated pig slurry, one ton of P_2O_5 corresponds to about 500 tons of fresh manure, assuming an average P205 content of 2 kg per ton.

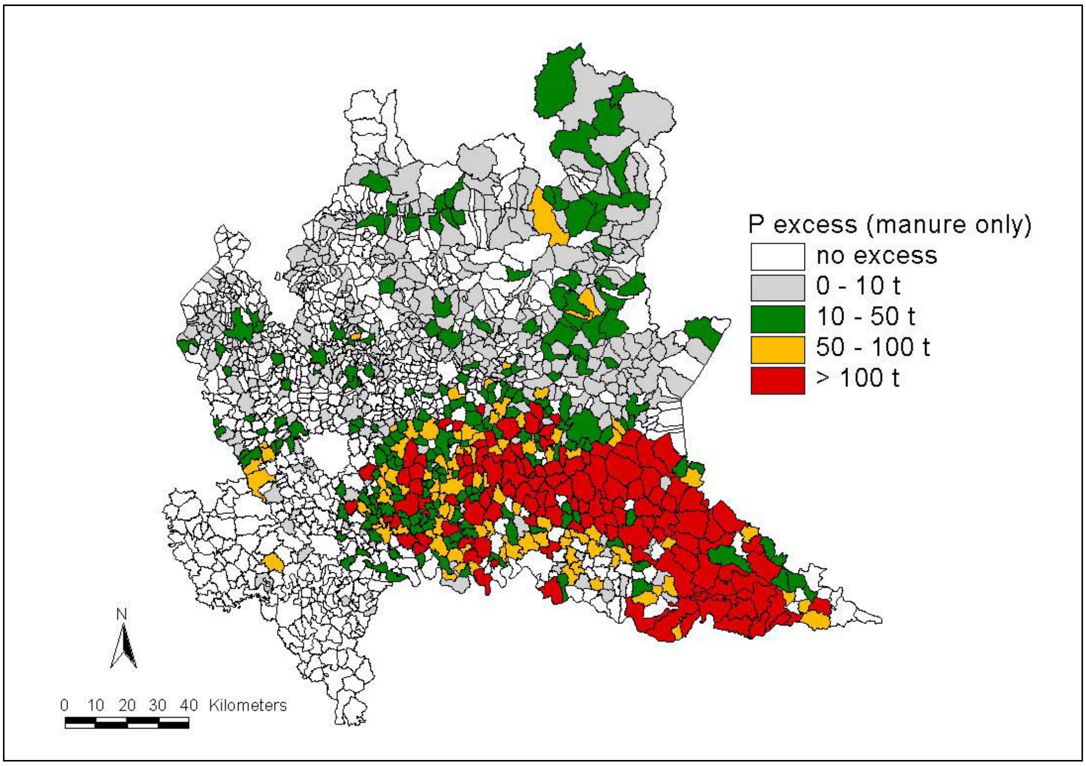


Figure 55: Lombardy region, excess of manure per municipality expressed in tons of P2O5 (source G. Provolo)

12.5 Response strategies

12.5.1 Manure processing

In order to reduce the quantity of manure to be disposed off on pig farms various types of slurry treatments are being practised.

Coarse/solid separation by rotating or vibrating screens is the most common practice, and the solid fraction obtained can be exported to distant areas with a high demand for organic fertilisers, thus reducing the farm surplus. In some cases farmers apply composting to the solid fraction, to make the product more attractive for farmers outside the surplus area.

A certain number of farmers apply aeration of the liquid fraction resulting from the solid separation. A 40 % reduction of nitrogen can be achieved and that enables to increase the manure load per hectare. In the future this system will no longer be allowed, to avoid ammonia emissions into the atmosphere, as usually will happen when the plant is not operated in a proper way. In any case this type of manure treatment is not expected to have any significant effect on the phosphorus content.

A higher N reduction is achieved by aerobic treatment plants with pre-denitrification, oxidation-nitrification and sedimentation, with discharge of the treated effluent into a municipal sewer. A number of farms in Northern Italy have adopted with success this treatment line. Negative results were obtained, on the contrary, by systems designed to discharge the treated effluent to surface water bodies, as they were not able to meet the more severe standards of the environmental regulations. In the case of discharge onto sewers, some of the phosphorus will be withdrawn from the nutrient cycle, although only temporarily. In both types of manure treatment, the likelihood of phosphorus rapidly reaching the surface water is increased.

In cooperative projects operated by group of farmers, centralized treatment plants have been developed in the high livestock density areas of Northern Italy. These projects however have not been successful because of the high costs of treatment per pig place and of the pollution impact by the residual load of the treated effluent.

Better results seem to be achieved by cooperative services for on-farm treatment of animal manure and subsequent long-distance transport and distribution of the animal wastes or their solid fractions. One of these services is operating in the province of Modena.

In the 1980's, the number of anaerobic digestion system in Italy constructed for treating pig slurry was reported to be over 50. Since then, the situation has changed substantially as many of these were taken out of service in the meantime. This can be explained in part by the fact that the farmer's concern was not energy recovery, but the elimination of nutrients. Indeed anaerobic digestion is effective in reducing carbon content, but not nitrogen and phosphorus content. Therefore this type of technology did not really provide an answer to the pig farmer's main problem, manure surplus.

A new generation of simplified and low-cost biogas systems is now being developed, based on the use of low-cost cover of a slurry storage tank. These systems have been developed not only for energy recovery but also to control odours and stabilize the waste. In recent years, around 80 of these simplified plants have been installed in Italy. Nowadays the Government offers incentives for such on site production of electric energy from biomass. Another new development is the strong in crease in the number of farms making use of underground pipelines connected to irrigation systems to transport and apply slurry to the fields.

It appears that, while manure treatment is on the increase, none of the systems put forward have a significant effect on the quantity of phosphorus ultimately ending up on agricultural land. On the other hand, manure treatment largely improves the feasibility of exporting excess nutrients to neighbouring nutrient deficient regions.

Major improvements still can be made concerning the application of manure on the land. Current methods of surface spreading seem to enhance the risk of runoff and consequently of direct loss to the surface water.

12.5.2 Socio-economic developments - license policy

The number of farms is decreasing while the average size is increasing. Farms are facing strong difficulties in finding workers, and employ more and more people from non EU countries. Municipal regulations have become very strict, and permits for new units, or to enlarge the existing ones are almost impossible to obtain.

12.5.3 Legislation

Italy has only recently transposed the European Nitrate Directive (EEC 676/91) into a national Regulation; the implementation is only at the first phase. At national level, the maximum amount of manure that can be applied to the land is the annual production from 4 tonnes of live weight per ha, irrespective of the animal species. However, phosphorus use is not limited as such by any existing binding legislation and only guidelines on P content on manure are available (Bonazzi, 2005).

In Northern Italy, the regions of the Po Valley have issued more stringent rules on animal manure disposal, each according to its legislative and regulatory autonomy. A permit (Emilia-Romagna and Lombardia Regions) or a notice (Veneto Region) to the competent Authority is required in order to be able to spread animal slurry.

In these regions vulnerable zones, based on hydrogeological criteria, have been identified. In addition, the three Regions have identified areas where slurry spreading is prohibited. These areas are:

- non cultivated soils
- land with slope over 15%
- poorly drained soils
- zones within a radius of 200 m from a well for drinking water;
- zones within a strip of 5 m from the water courses; and excavation areas.

These measures will effectively have an effect on the loss of nutrients to the groundwater or to the surface water (although even on soils having slopes of less than 15%, runoff will still be high if no specific measures are taken).

The manure application rate in Emilia-Romagna, Lombardia and Veneto Regions is based on nitrogen. In Emilia-Romagna and Lombardia, the maximum N application rate is 170 kg N/ha per year (210 kg in the first four years after the application of the regional regulations) in vulnerable zones and 340 kg/ha per year in non-vulnerable zones. In Veneto, the application rates of N are differentiated according to four classes of vulnerability that are being identified.

In order to obtain the spreading permit, farmers should demonstrate a given ratio between N in livestock manure or number of animals (tonnes of liveweight) and available agricultural land area. A detailed fertiliser plan, which shows the balance between N supply to crops (from animal manure, mineralisation of soil organic matter and mineral fertilisers) and crop needs is required, if livestock density is higher than a given value (around 2,000 pig places). These measures will also limit the amount of phosphorus applied as manure.

A minimum storage capacity is required, according to manure characteristics (i.e. farmyard manure or slurry). The minimum slurry storage capacity must be equivalent to the manure production in 4 months (for cattle or dairy farms, depending on the Region) or 6 months (for other types of livestock production), with some possibilities to reduce this requirement in specific conditions (e.g. where there is slurry treatment, small farm size or moderate rates of slurry production). The minimum required storage capacity for farmyard manure is 3 months.

By imposing a minimum storage capacity, the need for applying manure during inappropriate periods or for disposal of manure in inappropriate ways is strongly reduced.

12.6 Expected future developments

While there is an increasing demand of safe and high quality meat, pork production on organic farms is expected to increase, but will reach hardly 2% of the total production. Welfare and environmental regulations will force the smaller producers out of business, the size of farms will increase but the total number of pigs is expected to decrease.

Concerning manure management, partially slatted floor will be adopted in the new buildings, slurry tanks with vertical walls for storage will replace lagooning, band spreading and injection of slurry are expected to be adopted in many situations. In the coming years, the use of biogas plants, in the simplified version, is expected to become widespread as a response to the incentives offered by the Government.

Part 4 Conclusions and recommendations

13. Conclusions and recommendations

13.1 Perception of the P-surplus problem by the MS

In the past years, the relative contribution of agriculture to the total emission of phosphorus to the surface water has increased, and agriculture is now thought to be the biggest contributor, even though the emission mechanisms are not yet fully understood. The emission from agriculture is attributed to runoff, erosion risk and leaching, all linked directly or indirectly with balance surpluses.

Phosphorus surplus in agriculture is not perceived equally by all member states as an existing or potentially pressing problem. Only few member states or regions have already put in place a specific policy directed at controlling P-use in agriculture that goes beyond the strict implementation of the Nitrate Directive. These are situated mainly in North-western Europe: the Netherlands, Flanders, Ireland, Denmark, Sweden, not surprisingly countries with relatively high proportions of vulnerable soils and/or high P-surpluses. Actions taken so far include rules on livestock density, maximum P-application rates, taxes or levies on P-production or P-use. In other countries such as France and Italy, also having considerable local P-surpluses, concern on phosphorus is clearly growing, but this has not resulted in concrete action as yet.

Several countries questioned in the framework of this study consider the current pressure of phosphorus as acceptable or less relevant, and refer to the sorption capacity of the dominant soils or to the low level of P-input in their agriculture to underline their point of view. Moreover, measures taken in the framework of the implementation of the Nitrate Directive are considered to have a sufficient controlling effect on phosphorus too. Unawareness of the importance of the erosion factor or of the potential problem of P-saturation, may also explain the apparent lack of interest in this subject.

Up to now, P-emission control by the member states was mainly focusing at reducing the discharges by households and industry. In the meantime, the relative contribution from agriculture has increased considerably, but uncertainty remains on the exact role, importance and mechanisms of phosphorus from agricultural sources. Therefore, it is recommended that the issue of phosphorus in agriculture be put on the agenda of all member states, and that more efforts are made to assess the current situation and to study the consequences of the projected future agricultural developments.

13.2 Current P-fertilising strategies - advisory systems

Phosphorus is an essential factor for crop growth and is an important agricultural production factor. Contrary to for instance nitrogen, phosphorus can build up in the soil and remain available for long periods of time. Unless the soil is P-saturated, phosphorus is not leached readily from the soil. Negative effects of high P-rates are unknown. For all these reasons farmers are adopting a different fertilising strategy for phosphorus than for instance for nitrogen.

Due to the limited mobility of phosphorus in the soil, P-fertilisation in the EU 25 is traditionally based on medium or long-term strategies. Contrary to nitrogen, P-fertilisation does not only aim at compensating for the expected uptake by the crops but also at gradually bringing the available P-level of the soil to an agronomical optimum. Once this P-status has been reached by the soil, the uptake of newly added P is at its optimum, and P-dosage is taking into account only the expected uptake plus an 'unavoidable' loss rate.

One should also bear in mind that phosphorus has an important residual effect, and therefore P-application is conceived for crop rotations rather than for individual crops.

High soil P-levels are not known to have any negative impact on crop production or on product quality. Therefore there is no 'natural' incentive to reduce the dosage of this element, and current advisory systems have a rather high built-in security margin with respect to P-dosage, for instance to compensate for the lowered uptake rate of maize on cold soils. This is also the case for the horticultural sector, where (unnecessarily) high P-rates are commonly recommended.

For the same reason, farmers on soils with high P-status are not necessarily paying as much attention to the recommendations on P issued by advisory institutes as they would do for other elements. Instead, the quantities of fertilisers or manure applied will be based on other considerations such as nitrogen rates. Depending on the type of manure available, this may lead to a serious under- or overdose of phosphorus, in function of the N/P ratio of the fertilising agent.

Current advised P-rates are typically based on agronomic and economic considerations only, but have a favourable effect in the sense that systematic or massive overdose can be avoided while crop requirements remain adequately covered. When advised P-rates are systematically and strictly followed, soils with excessive P-status will gradually evolve towards the optimum range, thus reducing the risk of P-loss through leaching or erosion. Some authors doubt if the currently advised rates on soils with high P-status are compatible with the environmental objectives.

With respect to P-fertilisation strategies the following recommendations can be made:

- Due to the fact that most of the current advisory systems have a rather comfortable safety margin with respect to P dosage, there would be room in many cases to lower the recommended rates without noticeable effect on yields or on crop quality. This requires a thorough review by the advisory services of their current systems. Lower advice on soils with normal P-reserves will lead to lower P-surplus. Soils with a P-status beyond the optimum range would faster return to the normal situation through the 'mining effect' caused by the incomplete or zero replacement of phosphorus removed by the crops.

- When manure or other sources of organic fertilisers are used, quantities applied are often based on estimates or on average figures, without taking into account the actual nutrient content of the material. Regular if not systematic analysis of the manure would greatly improve the accuracy of the fertilising schemes. In Flanders, manure analysis has become standard practice and is supported by local authorities through financial incentives. Laboratories in the EU should be encouraged to offer similar services.

- With respect to mineral fertilisers, certain popular NPK formulas assumed to be balanced (because they contain more or less equal quantities of N, P and K), are seldom tuned perfectly to the actual soil status and crop requirements. Still they are widely used because of their price and availability. Custom made mixtures, tailored on the basis of soil analysis and field specific fertiliser advice, offer the best available alternative to standard compound formulae, and this practice should therefore be encouraged.

- At present there is a large diversity of P-extraction methods and of P-advisory systems. In most cases the advised rates are based on an assessment of the extractible soil phosphorus and extensive field experimentation. While extreme care is needed when comparing advice systems, there seems to be no urgent need for a complete harmonisation, as no single system can be pointed out as universally applicable. Determination of total phosphorus, easier to harmonise, is not a relevant option, as the link between total soil phosphorus and crop uptake is extremely weak.

13.3 P application methods

In the soil phosphorus is highly immobile, and therefore optimum P-application is less subject to seasons than other elements. Phosphorus not used in a particular season will become available in the following season, depending on the P-fixing capacity of the soil. However, in order to improve the effectiveness and efficiency of the phosphorus applied and to reduce the risk of P-loss a number of measures are recommended. Since erosion is one of the key mechanisms to P-loss, any measure to reduce erosion will have an immediate and positive impact on phosphorus too.

Among the recommended methods are:

- Spring application of manure rather than autumn application. With respect to phosphorus this practices leaves less room for P-fixation, and reduces the risk of P removal by erosion during the winter period. When spring application is hampered or made impossible (for instance because of the inaccessibility of the field), use of a cover crop or catch crop during the winter period is recommended.

- Row application of mineral phosphorus instead of broadcasting reduces the total amount of fertiliser required per hectare. This technique is in particular recommended on fields with a sufficient P-status, were no provisions are to be made for further increase of the soil P-reserves. Row application can be extended to organic fertilisers too pending the successful outcome of the ongoing trials.

- Rapid incorporation of the manure or sludge is preferred. Delaying the incorporation increases the risk of P-loss by erosion or run-off. In grassland, direct injection of liquid manure has proven its efficiency.

- Homogeneous application of fertiliser and manure is a prerequisite to build-up and maintain an even fertility status on the entire surface area of a the field or grassland, avoiding the occurrence of local hot-spots of increased risk of loss by leaching, run-off or erosion

13.4 The use of P-balances and P-sensitivity maps

Input-output balances and sensitivity of the soils to P-excess were calculated for the EU member states, as far as possible at the NUTS II/III level. In order to do so, use was made of EUROSTAT data on livestock and agricultural production. Data on mineral P-fertiliser use were obtained from IFA.

Sensitivity of the soils in the EU 25 to P-loss was assessed on the basis of the European soils map, using a specially developed set of pedotransfer rules to estimate the intrinsic P-sorption capacity of the soils. The European erodibility map was adapted in order to take into account the important erosion factor.

Soils with low P-binding capacity are found mainly in the northern MS: UK (Scotland), Finland, the Netherlands, Germany. Poland, the Baltic states. Erosion is the main risk factor in southern member states: Spain, Portugal, Italy, Slovenia and Greece.

At the national level the highest balance surpluses (> 10 kg of P/ha) are found in Slovenia, the Netherlands, Greece, Finland and Denmark. The extremely high balance surplus of Slovenia was linked with the known problems of erosion. Negative of very low national balance surpluses are found in the UK; the Baltic states, Portugal, Sweden and Slovakia. Only in Sweden can this be attributed (partly) to a deliberate government policy to keep surpluses as low as possible.

When looking at the local level, the NUTS II/III regions with highest P-surpluses are found mainly in the Netherlands, Greece, Belgium (Flanders), France (Brittany), Spain (Cataluna, Murcia), Italy (Po-valley regions), Finland and Ireland.

From the balance calculations it appears that surpluses are mainly linked with high input of P, from manure as well as from mineral fertilisers, but the efficiency of P-uptake plays an important role too. In a few cases only (e.g. Finland), mineral fertiliser use plays a decisive factor in the balance.

With respect to the use of P-balances and the assessment of P-sensitivity for policy purposes, the following recommendations are made.

- Care should be taken when interpreting the balance surplus. For soils with an overall low P-status or with high P-binding capacity, the efficiency of P applied is low, and relatively high surpluses are needed to bring the soil reserves to optimum levels. On soils already well provided with phosphorus, the same surplus may lead to increased loss by leaching, runoff or erosion. Therefore, maps on the actual P-status of the soil are important if not essential tools to any policy aiming at the control of the P-problem.

- Providing such figures can be found, the regional P-balances can be further improved by introducing data on manure transfer, regional fertiliser use and application of other forms of P into the balance calculation (e.g. for sewage sludge, see Table 49 on page 88). When assessing the situation in areas with intensive livestock production, this is essential.

- Another improvement would be to take into account only those soils that are effectively under agricultural use. It could be interesting to bring down the aggregation level even further, as within the NUTS II/III zones there may be a wide variation of pressures and soil vulnerability. Examples from the Netherlands, Flanders and Northern Italy show that such an approach is within reach.

13.5 Setting legal limits to P-application ?

In a few cases only (the Netherlands, Flanders, Vendée) is there a general legal ceiling on P-application. Not surprisingly these are areas where over the past decades considerable accumulation of soil P-has taken place. In Flanders, there is an even stricter ceiling to P-use in so-called P-saturated areas. Even in the latter case will the current ceilings rarely be a limiting factor to plant production.

Elsewhere, the use of sludge may be limited by the P-content and the P-status of the soils.

Indirectly, limiting livestock density in function of P-production, as is the case in Sweden, will decrease the risk of excessive P-application on the farm and will prevent the origination of local manure surpluses, but will not necessarily forbid the excessive use of other sources of P.

The maximum rates set on manure application in the framework of the Nitrate Directive (170 kg N/ha) or other regulation constitute a limit to P-application too, but the level depends strongly on the type of manure, poultry manure containing for instance more than twice the amount of P per kg of N, compared to cattle manure. Therefore, the limit set for nitrogen may or may not be a sufficiently limiting factor to P-application, and therefore it is recommended to issue more specific rules on P-use, in particular in sensitive zones.

A key issue is the delimitation of P-vulnerable zones and the definition of specific rules on P-application; the following points need consideration.

- While it would look attractive to impose uniform EU-wide legal ceilings to P application in P-sensitive zones, this would be a hard if not impossible task to achieve, unless production objectives are abandoned. Even more than with nitrogen, tolerable phosphorus rates differ widely in function of soil type, crop type, farming system and ecological conditions. The actual P-status of the soil, as determined by the analysis of available P, will determine in the first place how much phosphorus is needed for optimum crop production and to gradually bring the soil within the optimum soil P-range, without increasing the risk of unacceptable P-loss by leaching or erosion. Therefore in any delimitation of 'P-vulnerable zones', in view of the instauration of application ceilings, at least the following factors should be taken into account (see also paragraph 13.7).

- The actual P-status of the soil

- The P-binding capacity of the soil

- The risk of erosion and/or runoff losses

- In areas identified as P-saturated or nearly saturated, it is recommended to base maximum allowable rates on actual soil analysis figures rather than imposing a standard figure. For it appears that in extreme situations, any additional rate of P however small would exceed the environmentally tolerable level.

13.6 P balance per farm type - nutrient exchanges between farming systems

An analysis of the P-use on various farm types indicates that the highest P-balance surpluses at farm level are found in intensively managed dairy, pig or poultry farms and on pig farms, as well as on horticultural farms. For various regions, these farm types have developed in areas less suitable for arable farming or are now concentrated around ports or other entrances for cheap feed.

Low balance surpluses are found on arable farms and on extensively managed livestock farms. Unless they have access to cheap alternative sources of phosphorus, arable farms rely mainly on mineral forms of phosphorus. Mixed farming, with a perfect equilibrium between arable land and livestock rearing, offers in principle the best opportunities for recycling plant nutrients at farm level. However this farm type has become the exception rather than the rule.

The following actions would contribute to a more equilibrated use of the available P-resources.

Returning from the current situation of specialised farm types to the pre-EU-situation of mixed farming would almost automatically lead to a more equilibrated P-balance, but is hardly an option, even on the long term. Therefore the best option is to encourage a more intimate cooperation between surplus and non-surplus farming types. For specialised arable farms this would mean a partial substitution of mineral P by manure (or manure products). In order to achieve this goal, the use of manure by arable farms has to be made more attractive than is the case nowadays. In particular the following points would need to be improved:

- Consistent and regular quality of the product;

- The product has to be available at the right time and in the right place, which would require the set up of a logistical network;

- As many arable farmers are not familiar with the use of manure products, the applicability of the new approach needs to be made known through information and demonstration campaigns; and,

- Introduction, where appropriate, of incentives to the use of manure on arable land.

Mineral P-fertilisers would still find a place in particular applications and in those areas where manure products cannot be used or cannot be made available at a reasonable cost.

13.7 Areas at risk of P saturation/monitoring the P-status of the soils

From the confrontation of pressure and vulnerability, it appears that at present, only a few regions with high surpluses are situated in areas with a high proportion of vulnerable soils. While the resulting maps provide a good overall picture of the current pressure and sensitivity situation, caution should be observed in interpreting the results, as they may contain an important (but in the current approach unavoidable) bias caused by the allocation of mineral fertiliser use. Another important factor influencing the actual pressure is the internal redistribution of manure, which could not be taken into account at this time.

So far instances of actual P-saturation (being the situation whereby massive leaching of phosphorus to the groundwater can take place), have been observed and mapped in the Netherlands, and to a less extent in Flanders. However also in other regions with similar conditions of soils and livestock density (North Germany, Denmark) this may already be the case. It should be underlined that at present the relation between the degree of P-saturation and the actual loss to the groundwater has not yet been clearly defined.

It is therefore recommended that the following actions be undertaken with respect to the assessment and monitoring of the P-status of the soils and to the identification and delimitation of P-saturated soils.

- At present systematic and/or detailed monitoring of the actual P-status of the soils is done in number of member states or regions thereof. Other states or regions that have not mapped the P-status of their soils as such would probably have sufficient analytical data to do so, and even to reconstruct the historical evolution of the P-status of the agricultural soils. When comparing (raw) figures on the P-status of the soils between member states, due attention should be given to the methods of analysis, in particular the extraction system.

- Applying the approach developed in the Netherlands to assess the P-saturation status, or an equivalent assessment method, would require considerably more and new work in a number of member states, but should be considered in all areas with similar soil conditions and balance surpluses. Indeed P-saturation assessment provides a useful if not necessary basis to define measures on soils with low P-sorption capacity and high risk of P-loss.

13.8 Legislation

13.8.1 *International Legislation*

Several Member States are signatories to multi-national environmental agreements and initiatives, the majority of which aim at the protection of marine resources and include nutrient management in the marine environment. International conventions of importance to phosphorus use in European agriculture include MAP (Mediterranean Action Plan), HELCOM (Helsinki Commission – Baltic Sea), OSPAR (Oslo & Paris Convention - North-East Atlantic), North Sea Commission, Baltic 21, The Global Environment Facility (GEF) Strategic Partnership on the Black Sea and Danube Basin. All of these international treaties gave an impetus to harmonise standards amongst all Member States of the European Union, particularly with regard to pollution of the seas. Common to the majority of the above mentioned treaties are the establishment of target reductions for phosphorus and reporting through source apportionment by sector and nutrient balances.

13.8.2 *European Legislation*

In Europe, phosphorus pollution threatens aquatic ecosystems, fouls water supplies, and diminishes the recreational and economic benefits of clean waters. However, the direct health effects of high nitrates in water explain the focus of European legislation on nitrogen management. Moreover, nitrogen leaches, runs off, converts from liquid to gas and vice versa, making it more difficult to manage. Phosphorus, on the other hand, binds tightly to the soil particles and is therefore controlled, *prima facie*, by runoff and erosion processes. However, phosphorus can also leach from the soil when its concentration builds up to very high levels.

Agricultural activities such as concentrated animal feeding operations, fertiliser application, and erosion/runoff on agricultural land contribute considerably to high phosphorus concentrations in surface water. The upgrading of wastewater treatment plants to include phosphorus removal and the shift to phosphate-free detergents resulted in an even higher relative contribution of diffuse phosphorus contamination from agricultural land. To date, there is no specific legislation that is directly concerned with the use of phosphorus in agriculture at the European level. However, many aspects of phosphorus related problems in farm practice are integrated at the European level in the sectoral policy areas and the related legal instruments of the Environmental Policy and the Common Agricultural Policy.

The European environmental legislation is the decisive factor in protecting the environment. Phosphorus related problems in farm practice are covered indirectly in the environmental policy areas of water, waste, biodiversity conservation and chemicals/air. Until the conception of the Water Framework Directive (WFD), which entered into force in 2000, policy was often addressed at single pollutants (e.g. nitrates) or single issues (e.g. groundwater, habitats). The groundwater directive, which is repealed with effect from 13 years after the date of entry into force of the Water Framework Directive, explicitly states that Member States shall take the necessary steps to limit the introduction into groundwater of inter alia, inorganic compounds of phosphorus and elemental phosphorus so as to avoid pollution of the groundwater. Since the environmental systems of soil and water are intrinsically linked, negative impacts on the soil frequently have effects on the water environment and vice versa. As a consequence, legislation on water issues indirectly affects soil and adversely the quality of water bodies is also dependent on consistent and sustainable soil policies.

The integrative approach of the WFD offers scope for integrating environmental issues such as diffuse phosphorus contamination from agricultural activities. In the legislative text of the Water Framework Directive, an indicative list of pollutants includes phosphates. Member States are required to identify pressures on surface water bodies. Among the information that needs to be reported on is the estimation and identification of significant diffuse source pollution from *inter alia* agricultural activities and as such includes diffuse contamination of phosphorus from agricultural activities.

The cross-cutting nature of the phosphorus problem provides excellent opportunities to deepen co-operation possibilities between environmental objectives and sectoral policies, in particular the EU Common Agricultural Policy. Both good farming practice and respect of statutory environmental standards, as established in the framework of the EU's rural development policy, may contribute to improved and timely implementation of directives and regulations at the Member State level. Analogous to this, respect of statutory requirements arising from the implementation of the nitrates directive is included within the framework of the reinforced cross-compliance measures in the 2003 CAP reform.

13.8.3 National Legislation

Around 80% of environmental legislation in the Member States originates at the European level. But to be effective, this body of law must be fully and correctly implemented at the Member State level. Implementation of directives and regulations by Member States is a complex process; for non-implementation, the Commission opens an infringement proceeding.

Three different groups of standards or requirements are applied with respect to nutrient related problems in farm practices. They are applied in different but sometimes overlapping situations in the Member States and comprise the Good Agricultural Practices of the Nitrates Directive, the Codes of usual Good Farming practices, and Good Agricultural and Environnement Condition practices and the statutory management requirements of cross-compliance. Different legislative acts refer to definitions, implementation and control of Good agricultural Practices, Codes of usual Good Farming Practices and GAEC Practices.

Information on specific legislations regulating phosphorus use in the different Member States was based on questionnaire-based analysis. Water quality norms with respect to phosphorus in surface waters exist in almost all the Member States and will be reviewed in the frame of the Water framework Directive. Legislation or (voluntary) guidelines regarding application of fertilisers exists in several countries, most often as a means to comply with Good Agricultural Practices as outlined in the Nitrates Directive, with the Codes of usual Good Farming Practices or with the Cross-Reference Requirements (GAEC Practices). Methods to reduce phosphorus production at the farm level are common practice in Flanders, the Netherlands, Sweden, Denmark and Austria. Only Flanders (Belgium) and the

Netherlands based their nutrient management legislation on phosphorus and have legal restrictions on the use of phosphorus fertilisers and the on-farm production of phosphorus.

13.8.4 Recommendations on a policy to reduce P-pollution from agricultural sources

An integrated approach from a combined agricultural and environmental perspective is recommended in order to tackle the problem of phosphorus pollution from agricultural activities. A major problem is the lack of knowledge of what is really happening at the farm level and what the effects on the aquatic environment are. Moreover, the links between farming practice, the amount of phosphorus that enters rivers and the effects of such pollution on the health of watercourses are complex and often depend on the character of the landscape.

The following recommendations could be made towards legislation:

1. Agriculture must play its part in ensuring that water is as clean and healthy as practicable, which translates in this case to reducing concentrations of phosphorus. The issue of phosphorus pollution of water should be addressed in the development of river basin management plans to apply from 2009 under the Water Framework Directive (WFD) in conjuction with action programmes under the Nitrates Directive. Should positive results not ensue then it may be necessary to establish a more coherent approach to the issue.

2. Long-term surpluses in risk areas can be tackled by reductions in inputs, through extensification, land use change and mutual adjustment of farming systems. Possible responses by agriculture include changes in management practice such as better soil conservation; better precision in applications of fertiliser; extensification of agricultural systems such as livestock reductions, lower yields with lower inputs, conversion to low-intensive farming particularly on sensitive soils; changes in land use within farming areas to include natural/seminatural habitats, woods, hedges and woodlands. Many of these farm practices should be and are incorporated in the Codes of usual Good Farming Practice, defined by the Member States.

3. Reductions in stocking numbers and fertiliser use but allowing intensification in risk-free zones should be and are to a large extent enforced by responses of the Common Agricultural Policy, through continued reforms, cross-compliance conditions related to direct payments, and continued agri-environment support. The Rural Development Regulation for the period 2007-2013 contains compulsory cross-compliance related to direct payments and its implementation offers further scope to implement better phosphorus management at the farm level.

4. Phosphorus pollution in surface waters ultimately requires a catchment approach. The establishment of a nutrient balance at field or farm level is a first step in budgeting phosphorus pollution. However, the extent to which phosphorus will impact upon a water body is determined by several catchment-related factors such as its size, the location of pollutant sources, the degree of hydrological connectivity, the characteristics of the soils, and the climate.

5. In order to be effective European environmental legislation must be fully and correctly implemented by the Member States, particularly in the case of diffuse contamination of waters where transboundary environmental health is at stake. A standardised reporting procedure on phosphorus is required in order to monitor and assess progress of implementation in the national legislation of the Member States.

13.9 Measures to reduce/control P surpluses

Input of P mainly comes from mineral fertilisers and from animal manure. In the past decades, the use of mineral P-fertiliser has in general decreased strongly in all member states; having an immediate and drastic effect on the P-balance. With respect to livestock, the situation is different. Livestock figures are still increasing significantly in some countries, while in other countries livestock numbers stagnate or decrease, often as a result of a deliberate policy to reduce the surplus of nutrients, nitrogen in the first place. P-production as manure has a direct link to livestock figures.

In spite of these evolutions mineral ¨P-fertiliser use has remained relatively high in some member states, mainly situated in the Mediterranean region. In these countries soils are in general deficient in phosphorus. Possibilities for further substitution of mineral P by organic P certainly, thus reducing the total input.

Apart from way to reduce the supplies of nutrients in general, a lot of efforts were made in recent years by the agricultural sector to specifically reduce the nutrient surplus in general and the P surplus in particular, however with varying results.

13.9.1 Input oriented measures

Feed composition

Reducing the P-content of manure by acting on the feed appears to be an effective, significant and proven technique, and is being practised at a large scale in several countries, resulting in a decrease in P content in manure of 10% or more. It is recommended that these ongoing efforts be continued.

Manure processing

Manure processing not only reduces the transportation cost of the product, but can also alter its composition. Not all methods are equally effective when it comes to removing P from the agricultural nutrient cycle. Techniques such as mechanical separation may broaden the application field for phosphorus from manure, and thus contribute to a further substitution of mineral P by organic P.

Large scale manure processing was tried in the Netherlands and in Flanders, but largely failed due to various reasons: profitability, technical problems, difficulties to obtain operating permits, lack of interest from the banking sector and uncertainty about export possibilities. Small-scale manure treatment is being practised and further being developed with more success, although it faces problems of a similar nature. In Denmark, France and Italy, small scale initiatives on manure processing are focussing on methods of methanisation and reducing local problems of mainly N-surplus.

Internal and external transfers already contribute to an more equilibrated spreading of the P-pressure from manure. However, export of manure and manure products is still hampered by regulations of various nature, high transportation and handling cost and, in some cases, the degree of acceptance of the product by the potential users. The possibility of export of manure products to non-EU countries has been explored (in Flanders), and markets have been opened, but no major breakthrough is to be expected from that side. Within the EU, national and local authorities make their own interpretation of the European legislation to define the rules on the import and use of manure and manure products on their territory. Even if not all EU MS are directly concerned by the problem of manure export, a general European approach is needed to establish a clear and unambiguous legal framework, regulating manure transfers within and between member states.

With respect to the economic feasibility of manure processing, a clear distinction is to be made between the treatment of poultry manure and processing of more liquid types of manure (pig or cattle slurry. At present, dried or composted poultry manure can be produced and transported at an affordable cost, can be exported with relative ease and is widely accepted by arable farmers as a suitable fertiliser and soil amendment, providing a substitute or valuable complement to mineral fertilisers. Processing and long distance transport of products from liquid manure (pig slurry) remains problematic and economically doubtful.

Incineration of dry poultry manure with energy recovery is an effective way of taking large quantities of P out of the nutrient cycle, but requires flexibility with respect to emission standards. Current electricity prices are not sufficient to make this method profitable.

In order to transform animal manure products further into a full alternative for mineral fertilisers, the following constraints should be lifted

- Low bulk density of the products
- Low and variable nutrient content
- Presence of heavy metals in particular copper and zinc
- Scale of the production units, guaranteed availability in sufficient quantities and in the right period
- Unfavourable product image

In order to compensate for the transportation cost (linked with the bulk density and nutrient content) the additional advantages of organic manures over mineral fertilisers should be put into the light: overall nutrient content, presence of oligo-elements, organic matter content.

Economic instruments

Taxes on the P-content of mineral fertilisers do or did exist in several member states. However it was proven that the level of these taxes was never sufficiently high to have an impact on the quantities used. Certain studies estimate that a fourfold increase in the current price of mineral fertilisers would be required to significantly reduce the use of P from this source.

A study on the potential impact of a tax on the cadmium content of mineral phosphorus fertilisers would merely lead to a shift to the use of low cadmium ores by the fertiliser companies, without any significant impact on the fertiliser consumption itself. No self regulating effect on P-use is to be expected from the current regulations concerning the Cu or Zn content in mineral and organic fertilisers, as these do not constitute a limiting factor to phosphorus input.

Following a study in Denmark on the impact (and the justification) of a taxation of P-use in agriculture, it was concluded that a tax on added mineral P in animal feed would be the most efficient and most equitable way to reduce the P-surplus. In 2004 such a tax was effectively established (4 DKK per kg of P). As a compensation for the additional cost, the land taxation was reduced. Through this measure, the Danish government hopes to reduce the current P-surplus in agriculture by 25%, i.e. half the reduction objective for P-emissions from agricultural sources.

In Flanders, a so-called superlevy is imposed on the production of P (and N) in manure beyond the authorised quota. Contrary to the low standard levy on P production (as manure) and on the use of off-farm sources of P (including mineral fertiliser), the level of taxation is in this case high enough (0.99 €/kg P_2O_5) to discourage overproduction.

Measures such as the above examples can thus contribute significantly to a reduction of P-surpluses and can be established in an equitable manner, but are not generally applicable. Care should be taken in particular that such measures do not hamper agricultural development in areas with high current balance surpluses but soils with low P-saturation degree, as these farms are still in the process of bringing the land to optimum P-levels. On the other hand, due attention should be given to the effect of P-taxation on the different farming systems that are present on the territory, in order not to penalise those farms that contribute little or not to the P-surplus.

13.9.2 Output oriented measures

Also on the output side, further improvements are possible. A well-balanced nutrient status of the soil, combined with appropriate management practices lead to higher yields and consequently to higher P-uptake. Methods of rational fertiliser use, based on soil analysis are a useful and effective tool to improve the balance. In all member states private or public institutes are available to provide such advice, but farmers do not always make use of such services. At present, methods of soil analysis are not completely standardised. Strictly speaking there is no need to do so, as the analyses are only a first step in the advice system. In order to establish the link between the nutrient status of the soil and the crop requirements (in terms of fertiliser needs), extensive field experimentation is just as important as the soil analysis itself.

Sensitive soils with low P-sorption capacity and high saturation risk are mainly limited to the acid sandy soils and histosols of North-western Europe. In most parts of the European Union however soil erosion is the most important pathway of P-loss to the surface water, independently of the sorption capacity of the soil. Therefore erosion and run-off control is an important instrument for reducing the effective loss of P to the aquatic environment. Such measures are already advocated or even imposed in various regulations, in particular in codes of good practice (Annex IV – erosion).

13.10 Case studies

Case studies were carried out of three regions with high pressure from P as manure, but with varying agro-ecological and economic conditions and with different legislative frameworks and policies.

13.10.1 Flanders region

The Flanders region of Belgium is among the regions with the highest current P-surplus, and in the past decades, the soils have accumulated considerable amounts of phosphorus reflecting the high livestock densities. Considerable parts of the region (though not as extensive as in the Netherlands) are vulnerable to excess P or already in an advanced state of P-saturation.

Phosphorus has been from the beginning at the focal point of the manure legislation, and the use of low-P feed is used widely to respect the P-production quotas. Important efforts are made in this region to develop effective and cost-efficient methods of manure processing, and manure exports (to France) already contribute significantly to the reduction of the surplus. Processing and export of dried or composted poultry manure is by far more successful than treatment of pig slurry. These developments however are still largely hampered by technical and environmental constraints, but mainly by the lack of long-term and firm perspectives for manure export. In particular the refusal by the nearby Walloon region to accept manure products from Flanders (or from any other source) prevents a major breakthrough of the export pillar of the Flemish manure policy.

The manure policy of the Flemish government of the past years has lead to a considerable lower surplus on the N and P balances. However, up to now, Flanders does not fully comply with the Nitrate Directive, and a new Manure Action Plan is under development.

13.10.2 Brittany

In Brittany, most efforts went so far to the strict implementation of the Nitrates Directive, meaning that little or no attention was given to phosphorus. The policy is aiming in the first place at a more even distribution of the manure pressure, in order to respect the maximum N-rate of 170 kg per hectare. Only recently more attention was given to the P-issue, mainly under the impetus from environmental movements and from water agencies wanting to implement the Water Framework Directive. In at least one case, a permit was refused to a pig farm on the basis of insufficient guarantees for the management of the phosphorus, based on an interpretation by the court of the existing legislation.

Farms situated within so called structural surplus zones are obliged to transfer manure to non-surplus zones, or to process all or part of it. In Brittany, manure processing is seen as the ultimate tool to solve the surplus problem. Several hundreds of farm scale and a few large scale installations are in operation, and more are in the planning phase. The methods used in generally do not affect the total amount of phosphorus.

According to a report by the government of Brittany, the actions aiming at a reduction of the yearly regional nitrogen surplus has resulted in a drop of 36 400 tons of N. A little less than half of this drop (15 000 tons) was attribute to a reduction in the use of mineral (nitrogen) fertilisers. Therefore, the relative drop in the P-balance will be considerably smaller.

13.10.3 The Po-valley region of Italy

In the north of Italy, with a comparable pressure in terms of kg of P per hectare of agricultural land as in Flanders or in Brittany, not much attention has gone so far to the theme of phosphorus, as soils are considered to be less sensitive to saturation. Manure surpluses are currently dealt with in the first place by redistribution and (small scale) processing by digestion.

However also in this region (as in other regions with similar situations) concern on the changing P-status of the soils is growing. In order to alleviate the pressure of P in the surplus areas, processing and transfer of manure are the first options looked at, rather than input oriented approaches.

14. Reference list

Arai, Y. and Sparks, D. L., 2001. ATR-FTIR Spectroscopic Investigation on Phosphate Adsorption Mechanisms at the Ferrihydrite-Water Interface. Journal of Colloid and Interface Science 241, pp. 317-326.

Baeyens, J. (1967, Nutrition des plantes de culture

Barrow, N.J. 1983b. On the reversibility of phosphate sorption by soils. J. Soils Sci., 34, 751-758.

Beaton, J.D., Roberts, T.L., Halstead, E.H., Cowell, L.E., 1995. Global transfers of P in fertilizer materials and agricultural commodities, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Beek, J. & W.H. van Riemsdijk (1979). Interaction of orthophosphate ions with soil. In: G.H. Bolt (ed.) Soil chemistry. B. Physico-chemical models. Elsevier Amsterdam. p. 259-284

Bergschmidt, Angela, Nitsch, Heike, Osterburg, Bernhard, 2003. Report of the EU concerted action ‘Developing cross-compliance in the EU – background, lessons and opportunities’. Institute of farm Economics and Rural Studies, Federal Agricultural Research Centre (FAL), Braunschweig.

Bignall E M and McCracken D I. 1996. Low intensity farming systems in the conservation of the countryside. Journal of Applied Ecology 33, 416-424.

Black, C.A. 1968. Soil-plant relationships. New York, USA, John Wiley & Sons.

Bleam, W. F., Pfeffer, P. E., Goldberg, S., Taylor, R. W., and Dudley, R., 1991. A 31P Solid-State Nuclear Magnetic Resonance Study of Phosphate Adsorption at the Boehmite/Aqueous Solution Interface. Langmuir 7, pp. 1702 - 1712.

Bomans E. et al (1996), Development of an indicator for agricultural nutrient balances for the OECD

Bomans E. et al (1996), Development of an indicator for agricultural nutrient balances for the OECD, progress report no.2

Bonazzi G. (?), Case study in intensive pig production inItaly

Bonazzi G. et al. (2005), Evaluation of nitrogen and phosphorus in livestock manures: Southern Europe (Italy)

Boniface, R. (1987), Diagnostic de la fertilité phosphatée des sols en fonction des méthodes d'analyse et fertilisation phosphaté d'entretien

Bøgestrand, J., Kristensen, P., Kronvang, P., Thyssen, N., 2005. Source apportionment of nitrogen and phosphorus inpunts into the aquatic environment. Draft report prepared by the National Environment Research Institute Denmark for the European Environment Agency.

Brown, D.J.A., 1988. Effect of atmospheric N deposition on surface water chemistry and the implications for fisheries. Environ. Poll., 54, pp. 275-284.

Brown, G., Mitchell, D.T. and Stock, W.D., 1984. Atmospheric deposition of phosphorus in a coastal fynbos ecosystem of the southwestern cape, South Africa. J. Ecol., 72, pp. 547-551.

Carton, O.T., and Magette, W.L., 1998. Teagasc manure management guidelines with special reference to intensive agricultural enterprises. In (ed.) Carton, O. Draft guidelines for nutrient use in intensive agricultural enterprises. Teagasc, Johnstown Castle, Wexford.

CBS Netherlands (2003 ?), Transport en gebruik van mest en mineralen 1994-2002

Ceotto E. (2002) Enhancing plant utilisation of livestock manure: a cropping system perspective

Cestti R., Srivastava J. and Jung S. (2003), Agriculture non-point source pollution control, Good management practices, Cheasapeake Bay experience

Chardon, W.J., O. Oenema, O.F. Schoumans, P.C.M. Boers, B. Fraters & Y.C.W.M. Geelen (1996). Verkenning van de mogelijkheden voor beheer en herstel van fosfaatlekkende landbouwgronden. Rapporten Programma Geïntegreerd Bodemonderzoek, Deel 8, Wageningen

Chaudhry, T.M. and S.M. Qureshi (1980). Agricultural Chemistry Section. Review of work 1926-80. ARI, Randojam, Government of Sindh.

COMIFER, 1991, Quelles fertilisations demain ? Premier forum Européen de la Fertilisation Raisonnée

COMIFER, 1995, Aide au diagnostic et à la prescription de la fertilisation phosphatée et potassique des grandes cultures

Cottrill B.R. and Smith K.A. (2005) Evaluation and control of nutrient excretion in livestock manures (draft ADAS)

Cox J. and Smith D. (?), Erosion and phosphorus mobility from agricultural catchments

Daly, K., 2000. P desorption from Irish soils. In: Tunney, H., Coulter, B., Daly, K., Kurz, I., Coxon, C., Jeffery, D., Mills, P., Kiely, G., and Morgan, G. Quantification of phosphorus (P) loss to water due to soil P desorption - R&D Report series No. 6. EPA, Johnstown Castle Estate, Wexford.

Debouche, C., Lambin, J., 2000. Ecobilan de l'exploitation agricole. Logiciel ECOFERME. FUSAGx.

De Clercq, P., Gertsis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J., Sinabel, F., (2001). Nutrient Management Legislation in European Countries, Wageningen Pers, The Netherlands, 347 pp.

Deckers, J. (1997) Landevaluatie. Unpublished Course Text. Faculty of Bioscience and Engineering. Katholieke Universiteit Leuven, Leuven: 301 p.

DEFRA UK (2004), Mapping the problem, Risks of diffuse water pollution from agriculture

Driessen, P., Deckers, J., Spaargaren, O. and Nachtergaele, F. (2001). Lecture Notes on the Major Soils of the World. Food and Agriculture Organization of the United Nations, Rome: 334 p..

EC, 2002. Evaluation de l'impact des mesures communautaires concernant le gel des terres. Rapport final Janvier 2002, European Commission, Agriculture DG, Brussels. http://www.cordis.lu/euroabstracts/en/october02/life03.htm

EEA-UNEP, 2004. High nature value farmland Characteristics, trends and policy challenges. EEA Report no1/2004.

EPA Ireland, 2001, Developing a national phosphorus balance for agriculture in Ireland (discussion document)

European Fertiliser Manufacturers Association (EFMA, 2000). Phosphorus essential element for food production.

European Fertiliser Manufacturers Association (EFMA, 2000). Forecast of food, farming and fertilizer use in the European Union — 2000 to 2010. EFMA, Brussels.

Eurostat, 2005. Organic farming in Europe. Statistics in focus, Agriculture and Fisheries 31/2005.

Fanning, K.A., 1989. Influence of atmospheric pollution on nutrient limitation in the ocean. Nature, 339, pp. 460-463.

FAO. 1984. Fertilizer and plant nutrition guide. FAO Fertilizer and Plant Nutrition Bulletin No. 9. Rome.

FAO. 1995a. Integrated plant nutrition systems, by R. Dudal & R.N. Roy, eds. FAO Fertilizer and Plant Nutrition Bulletin No. 12. Rome.

FAO. 2004. Use of phosphate rocks for sustainable agriculture, FAO fertilizer and plant nutrition bulletin 13.

Fisher, T. R., Melack, J.M., Grobbelaar, J.U., Howarth, R.W., 1995. Nutrient Limitation Of Phytoplankton And Eutrophication Of Inland, Estuarine, And Marine Waters, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Flachowsky G. and Lebzien P. (2005), Methodologies to reduce nitrogen (N) in manure of ruminant livestock (cattle, sheep and gaots)

Funaki Y. and Parris K. (2005), The OECD Agricultural Nutrient Balance Indicators, Establishing a consistent OECD set of Nitrogen and Phosphorus coefficients

Galloway, J.N., Dianwu, Z., Jiling, X. and Likens, G.E., 1987. Acid rain: China, United States, and a remote area. Science, 236, pp. 1559-1562.

Goh, K.M. and Williams, M.R., 1982. Distribution of carbon, nitrogen, phosphorus, sulphur, and acidity in two molecular weight fractions of organic matter in soil chronosequences, Journal of Soil Science, 33, 73-87.

Grobbelaar, J.U., 1974. Primary production in the freshwaters of the sub-Antarctic Island Mation. S. A. J. Antarct. Res., 4, pp. 40-45.

Harley L. (2004), Survey of EU cattle populations in December 20003 and production forecasts for 2004 (In Eurostat: Statistics in Focus, theme 5 14/2004)

Harley L. (2004), Survey of EU pig populations in December 20003 and production forecasts for 2004 (In Eurostat: Statistics in Focus, theme 5 15/2004)

HELCOM, 2004. The Fourth Baltic Sea Pollution Load Compilation (PLC-4) Baltic Sea Environmental Proceedings No. 93 http://www.helcom.fi/stc/files/Publications/Proceedings/bsep93.pdf

Hoeft R.G., not dated, Phosphorus: Agronomic, economic and environmental considerations

Holford, I.C.R. and Mattingly, G.E.G., 1975b. Surface areas of calcium carbonates in soils. Geoderma, 13, 247-255.

Howarth, R., Anderson, D., Cloern, J., Elfring, C., Hopkinson,C., Lapointe, B., Malone, T., Marcus, N., McGlathery, K., Sharpley, A., Walker, D., 2000. Nutrient pollution of Coastal Rivers, Bays and Seas, Issues in Ecology, ESA, pp. 15.

IFA (2005), Phosphate fertilizer nutrient consumption (www.fertilizer.org)

W. van Duijvenbooden et al. (ed.), Vulnerability of soil and groundwater to pollutants; TNO Comm. on Hydrological Res. Proc. and Information no. 38. Den Haag. pp. 1079-1088

IRENA-EEA, 2005. Draft IRENA Report. European Environment Agency.

Johnston A.E. et al (2001, The effect of phosphate fertilizer management strategies on soil phosphorus status and crop yields in some European countries, Actes Editions & IMPHOS

Jondreville C. and Dourmad J-Y. (2005), Methodologies to reduce nitrogen and phosphorus in pig manure

Kansas State University, 2002, Best management practices for phosphorus

Kardos L.T. (1964). Soil fixation of plant nutrients. In: Bear F.E. (ed) Chemistry of the soils. Reinhold Publishing Corporation, New York, pp: 369-394.

Kilroy G. and Coxon C. (2005), Phosphorus and the Water Framework Directive in the Shannon Pilot River Basin

King, D., Jones, R.I.A. and Thomasson, A.J (1995). European Land Information Systems for Agro-Environmental Monitoring. Institute for Remote Sensing Applications. Joint Research Center, European Commission. EUR 16232 EN.

La Jeunesse I. and Elliot M. (2004), Anthropogenic regulation of the phosphorus balance in the Thau catchment - coastal lagoon system (Mediterranean Sea, France) over 24 years

Laiti, E., Persson, P., and Oehman, L.-O., 1996. Surface complexation and precipitation at the H+-

Laiti, E., Persson, P., and Oehman, L.-O., 1998. Balance between surface complexation and surface phase transformation at the Alumina/Water interface. Langmuir 14, pp. 825 - 831.

Lajtha K. and Harrisson A.F., 1995. Strategies of phosphorus acquisition and conservation by plant species and communities, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Larsen, Hans J. (2005), The use of nitrogen and phosphorus taxation in Denmark for the control of the aquatic environment

Levy, H. and Moxim, W.J., 1987. Fate of US and Canadian combustion nitrogen emissions. Nature, 328, pp. 414-416.

Lewis, W.M., Grant, M.C. and Hamilton, S.K., 1985. Evidence that filterable phosphorus is a significant atmospheric link in the phosphorus cycle. Oikos,45, pp. 428-432.

Li, L. and Stanforth, R., 2000. Distinguishing Adsorption and Surface Precipitation of Phosphate on Goethite (a-FeOOH). Journal of Colloid and Interface Science 230, pp. 12-21.

Libert, B., 1995. The environmental heritage of Soviet agriculture. CAB International, Oxford.

Lookman, R., Geerts, H., Grobet, P., Merckx, R., and Vlassak, K., 1996. Phosphate speciation in excessively fertilized soil: a 31P and 27Al MAS NMR spectroscopy study. European Journal of Soil Science 47, pp. 125 - 130.

Lookman, R., Grobet, P., Merckx, R., and van Riemsdijk, W. H., 1997. Application of 31P and 27Al MAS

Lookman, R., Grobet, P., Merckx, R., and Vlassak, K., 1994. Phosphate sorption by synthetic amorphous aluminum hydroxides: a 27Al and 31P solid state MAS NMR spectroscopy study. European Journal of Soil Science 45, pp. 37 - 44.

Magette, W. and Carton, O., 1996. Agricultural Pollution. In: Kiely, G. (ed.) Environmental Engineering. McGraw-Hill, Maidenhead, UK.

Marschner, H. 1993. Mineral nutrition of higher plants. London, Academic Press Ltd., Harcourt Brace & Co. Publishers.

Mateos G.G. et al. (2005), Methodologies to reduce N and P in poultry manure through nutrition

McGrath, D., 1994. Organomicropollutants and trace element pollution of Irish soils. Science of the total environment, Vol. 164, pp. 125-133.

Ministry of the Flemish community (2004), Agriculture and horticulture in Flanders 2004.

MIRA-T, 2004. Milieu Rapport Vlaanderen. http://www.vmm.be/mira

Morgan, M.A., 1997. The behaviour of soil and fertilizer phosphorus. In: Tunney, H., Carton, O., Brookes, P. and Johnston, A. (eds.) Phosphorus loss from soil to water. CAB International, Oxon, UK.

Mortvedt, J.J. and beaton, J.D., 1995. Heavy metal and radionucleide contaminants in phosphate fertilizers, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Nanzyo, M., 1984. Diffuse reflectance infrared spectra of phosphate sorbed on alumina gel. Journal of Soil Science 35, pp. 63 - 69.

Nanzyo, M., 1986. Infrared Spectra of Phosphate sorbed on Iron Hydroxide Gel and the Sorption Products. Soil Science and Plant Nutrition 32, pp. 51 - 58.

Nanzyo, M., and Watanabe, Y., 1982. Diffuse Reflectance Infrared Spectra and Ion-Adsorption Properties of the Phosphate Surface Complex on Goethite. Soil Science and Plant Nutrition 28, pp.359 - 368.

Oosterhuis F.H. et al, 2000, A possible EU wide charge on cadmium in phosphate fertilisers: Economic and environmental implications

OSPAR, 2003. Nutrients in the Convention area. Inputs of Nutrients into the Convention area: Implementation of PARCOM Recommendations 88/2 and 89/4. http://www.ospar.org/documents/dbase/publications/p00191_Implementation%20of%20PARCOM%20Recs%2088_2%20and%2089_4.pdf

Parfitt, R. L., Atkinson, R. J., and Smart, R. S. C., 1975. The Mechanism of Phosphate Fixation by Iron Oxides. Soil Science Society of America Journal 39, pp. 837 - 841.

Parfitt, R.L., Hume, L.J. and Sparling, G.P., 1989. Loss of availability of phosphate in New Zealand soils. J. Soil Sci., 40, 371-382.

Paterson B.A. et al (2004 ?), Phosphorus management to reduce agricultur's impact on water quality

Persson, P., Nilsson, N., and Sjoeberg, S., 1996. Structure and bonding of Orthophosphate ions at the Iron Oxide-aqueous interface. Journal of Colloid and Interface Science 177, pp. 163 - 275.

Peters, R.H., 1977. Availability of atmospheric orthophosphate. J. Fish. Res. Bd. Can., \34, pp. 918-924.

Piccinini S., Verzellesi F. and Mantovi P. (2002) Biological nutrient removal in a full scale sequencing batch reactor treating pig slusrry, in in RAMIRAN 2002 Workshop of the Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture (RAMIRAN) (FAO European Cooperative Research) Proceedings 10th International conference Hygiene Safety, FAO and University of Veterinary Medicine, Kosice, Slovack Rep.

Poulsen H.D. et al. (2005) Quantification of nitrogen and phosphorus in livestock manure - the Danish normative system

Provolo G. (2002) Phosphorus loads in Lombardy (Italy) RAMIRAN 2002 Workshopof the Network on Recycling of Agricultural, Municipal and IndustrialResidues in Agriculture (RAMIRAN) (FAO European Cooperative Research) Proceedings 10th International conference Hygiene Safety, FAO and University of Veterinary Medicine, Kosice, Slovack Rep., pp. 445 – 448.

Provolo G. (2004) Nutrient load from agricultural source in Lombardy (Italy)RAMIRAN 2004 Workshop of the Network on Recycling of Agricultural, Municipal and Industrial Residues in Agriculture (RAMIRAN) (FAO European Cooperative Research) Proceedings 11th International conference Sustainable Organic Waste Management for Environmental Protection and Food Safety, FAO and CSIC,Murcia (Spain), pp. 93-96.

Reckhow, K.H., Beaulac, M.N. and Simpson, J.T., 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. EPA 440/5-80-011.Washington, D.C.

Runge-Metzger, A., 1995. Closing the cycle: obstacles to efficient P management for improved global food security, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Sauchelli V., 1965, Phosphates in agriculture

Schoumans O.F., 2004, Inventarisatie van de fosfaatverzadiging van landbouwgronden in Nederland

Schoumans, O., Ehlert, P. and Chardon, W. (2004) Evaluatie van methoden voor het karakteriseren van gronden die in aanmerking komen voor reparatiebemesting. Alterra-rapport 730.3, Wageningen.

Schoumans, O.F., A. Breeuwsma & W. de Vries, 1987, Use of soil survey

Schreiber H. et al., 2003, Nutrient emissions from diffuse and point sources into the river Danube and its main tributaries for the period fo 1998-2000 - results and problems (Diffuse Pollution Conference Dublin 2003)

Schröder J.J. et al., 2004, Gebruiksnormen bij verschillende landbouwkundige en milieukundige uitgangspunten

Schulte, E.E. and Kelling, K.A. (1996). Soil and applied phosphorus. Understanding Plant Nutrients, University of Wisconsin, 4p.

Sharpley, A., N., Hedley, M.J., Sibbesen, E., Hillbricht-Ilkowska, A., House, A.W., Ryszkowski, L., 1995. Phosphorus transfers from terrestrial to aquatic ecosystems, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Sibbesen, E., Runge-Metzer, A., 1995. Phosphorus balance in European agriculture – Status and policy options, Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management, Wiley, U.K. 480 pp.

Smith K.A., Jackson D.R. and Withers P.J. (?), Nutrient losses by surface run-off following the application of organic manures to arable land, 2. Phosphorus

Smith, K.A. and Chambers, B.J. (1995). Muck: from waste to resource. Utilisation: the impacts and implications. Agricultural Engineer Vol. 50 (3), Autumn, 1995.

Soil Service of Belgium (2004), Nutrient status report on the agricultural soils in Flanders (in Dutch)

Sparks D.L. and Hunger S. (?), Mechanisms of phosphorus stabilization in the soil environment: a molecular scale evaluation

Sparks, D.L., Hunger, S., , 2001-2002. Mechanisms of phosphorus stabilization in the soil environment: a molecular scale evaluation, Annual report to the Delaware Water Resources Center. Department of Plant and Soil Sciences, University of Delaware.

Stichting Natuur en Milieu (2005), Naar een totaal aanpak van het fosfaatprobleem in de landbouw

Swank, W.T., 1984. Atmospheric contributions to forest nutrient cycling. Water Res. Bull., 20, pp. 313-321

TEAGASC, 1998, Nutrient advice for phosphorus and potassium fertiliser, grazing and silage (leaflet)

Tejedor-Tejedor, M. I., and Anderson, M. A., 1986. "In situ" Attenuated Total Reflectance Fourier Transform Infrared Studies of the Goethite-Aqueous Solution Interface. Langmuir 2, pp. 203 - 210.

Tejedor-Tejedor, M. I., and Anderson, M., 1990. Protonation of Phosphate on the Surface fo Goethite as studied by CIR-FTIR and Electrophoretic Mobility. Langmuir 6, pp. 602 - 611.

Tiessen H. ed., 1995. Scope 54, Phosphorus in the Global Environment - Transfers, Cycles and Management., Wiley, U.K. 480 pp.

UNEP (1999), UNEP Global environment outlook 2000

University Ghent & University Leuven (1997), Fosfaatverzadiging van zandige bodems in Vlaanderen

USDA, 1980. Report and recommendations on organic farming. United States Department of Agriculture

Valk H. (2005), Methodologies ro reduce P in manure of ruminant livestock.

Van Bol V., Want D., Peeters A., 1996. Comparaison de trios méthodes de bilan pour l'azote, le phosphore et le potassium. In Bilans des éléments nutritifs en agriculture. Approches méthodologiques, mises en œuvre et interprétation. Comité Nitrates.

Van Dijk W.,1999, Adviesbasis voor de bemesting van akkerbouw- en vollegrondsgroentegewassen

van Riemsdijk, W. H., and Haan, F. A. M. d., 1981. Reaction of Orthophosphate with a sandy soil at constant supersaturation. Soil Science Society of America Journal 45, pp. 261 - 266.

van Riemsdijk, W. H., and Lyklema, J., 1980. Reaction of Phosphate with Gibbsite beyond the Adsorption Maximum. Journal of Colloid and Interface Science 76, pp. 55 - 66.

van Riemsdijk, W. H., Boumans, L. J. M., and Haan, F. A. M. d., 1984. Phosphate Sorption by soils: 1. A model for Phosphate reaction with metal-oxides in soils. Soil Science Society of America Journal 48, pp. 537 - 541.

Van Ruiten Adviesbureau/Projectbureau BMA (1998), Phosphate recovery from animal manure, the possibilities in the Netherlands

Vanongeval, L. and Bomans, E. (1997). Surplus calculations as a potential indicator for nutrient losses from agriculture to the aquatic environment. Study on behalf of the Land Department of Aminal (Ministry of the Flemish Community; Environment, Nature and Water Management Administration, Brussels). Soil Service of Belgium 32 p.

VCM, 2004. Overzicht van de wetgeving bij eindproducten van de mestverwerking. VCM v.z.w.

Verloo M et Liekens L., Influence de la teneur en CaCO3 du sol sur l'extraction de phosphates assimilable par différentes méthodes

Vidal C. (2002), A high-performance pigmeat industry with an environmental impact (In Eurostat: Statistics in Focus, theme 5 26/2002)

VLM, 1997. Phosphate saturation of sandy acid soil in Flanders. Vlaamse Landmaatschappij, Brussels.

VLM (Flemish Land Authorithy (2004), Annual report 2003 (in Dutch)

Walker F, not dated, Best management practices for phosphorus in the environment, Agricultural Extension Services, University of Tennessee

Wild, A., 1988. Russell's soil condition and plant growth. Longman Scientific & Technical, Harlow, Essex, UK.

Withney, D. A. (1998). Phosphorus facts. Soil, Plant and Fertiliser. Cooperate Extension Service, Kansas State University, Kansas.

Wossink A. and Benson G. (1999) Animal agriculture ans the environment: experiences from northern Europe

Zaccheo P, Genevini P., Ambrosini D. (1997), The role of manure in the management of phosphorus resources at an Italian crop-livestock farm

Zapata F. and Roy R.N. (2004), Use of phosphate rocks for sustainable agriculture

Other sources consulted:

Eurostat agricultural data

JRC European Soil Data Base Map Archive
http://eusoils.jrc.it
accessed 03/01/2005.

Geology 3710, Introduction to Soil Science, Lecture20, Valdosta State University, USA
http://www.valdosta.edu/~grissino/geol3710/soil20.htm
accessed 12/04/2005

Geo e-links
http://67.95.153.93/DevecolAfrica/GeoElinks/search/search.html
accessed 12/04/2005

INRA-SESCPF "A Tool for Estimating Soil Water Available for Plants Using the 1:1 000 000 Scale Soil Geographical Data Base of Europe" (Le Bas et al)
http://144.16.93.203/energy/HC270799/LM/SUSLUP/Thema3/562/562.pdf
accessed 03/01/2005.

Manure processing:

http://www.nhm.ac.uk/mineralogy/phos/manure.htm