ADDRESSING PHOSPHORUS RELATED PROBLEMS IN FARM PRACTICE

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SUMMARY

In 2005, on behalf of the European Commission, the Soil Service of Belgium, in collaboration with the Spatial Applications Division Leuven (SADL) of the Catholic University of Leuven, prepared a study on phosphorus related problems in the EU farming sector. The focus of this study is on the role and use of phosphorus in the agricultural sector of the current 25 European Member States, its actual and potential risk on the environment, on phosphorus legislation and on legal and practical measures that are or can be taken to reduce the losses of P from agricultural activities to the aquatic environment.

The phosphorus pressure on the agricultural land has been assessed at the regional scale (NUT II and NUT III) 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; the outputs were crop production, including pasture, all for the year 2003. The results calculated per NUTS II/III region vary from -20 kg P/ha of farmland (deficit) to just over 50 kg P/ha (surplus) but most regions fall within the range of -5 to +20 kg/ha. High P-surplus levels are most often, but not always, linked to high livestock density.

Pedotransfer-rules using the Soil Geographic Database of Europe (SGDBE) were used to define areas at potential risk to P-surplus, i.e. land with a low sorption capacity, high erosion rates and increased risk

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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. Limited sorption capacity is typical of the dominant soils of northern countries. Erosion risk appears to be the major driving force to P-loss in the southern member states. The resulting phosphorus sensitivity map was subjected to frequency analyses at European, Member State and NUTS II/III level. 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.

The document further analyses in extenso the steps already taken by the member states in compliance with the Water Framework Directive (including the Nitrate directive), the Midterm Review of the Common Agricultural Policy and other EU legislations to monitor and combat P-related problems, in particular those affecting the quality of surface water and groundwater. Legislation regarding the application of fertilisers exists in most member states, 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). However, only a few member states have put in place specific measures to control P-excess. These instruments can be of a legal, mandatory nature or can take the form of financial incentives.

An assessment was made of the financial and technical effectiveness of manure treatment and manure export, currently proposed as a means of reducing the nutrient surplus in areas with particularly high livestock density. The role of systematic soil testing for a better nutrient management was also highlighted.

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

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.

Key words: phosphorus, manure, farm practice

INTRODUCTION

In 2005, on behalf of the European Commission, the Soil Service of Belgium, in collaboration with the Spatial Applications Division Leuven (SADL) of the Catholic University of Leuven, prepared a study on phosphorus related problems in the EU farming sector *(Bomans E.[1], Fransen K[1]. , Gobin A[1]. , MertensJ[1], MichielsP[2]., Vandendriessche H.[1], Vogels N.[1])*.

The focus of this document is on the role and use of phosphorus in the agricultural sector of the current 25 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.

Environmental side effects of P-use in agriculture

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.

Current developments with respect to P use and P-management at farm level

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 ami, 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 (figure 1).

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

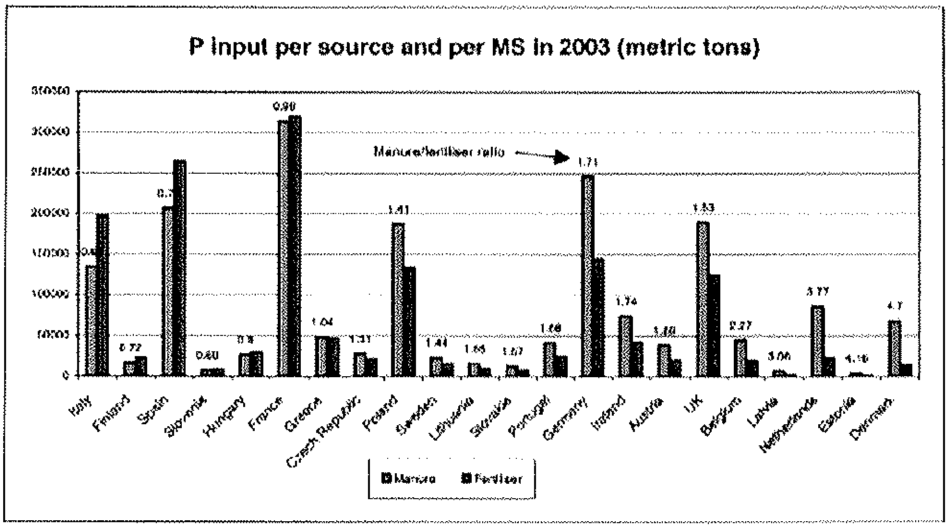


Figure 1: P input per source and per MS (2003)

arable farming. In the new member states, the use of inputs has sharply dropped during the transition period and is now picking up again (Figure 2).

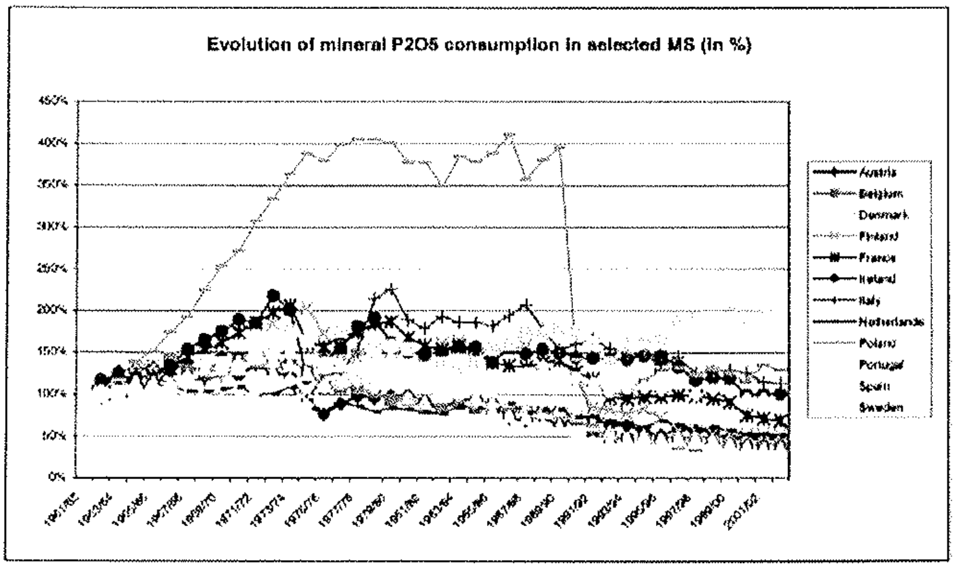


Figure 2: Evolution of P- consumption in selected MS (source IF A)

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.

Assessment of the pressure from P-use

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)

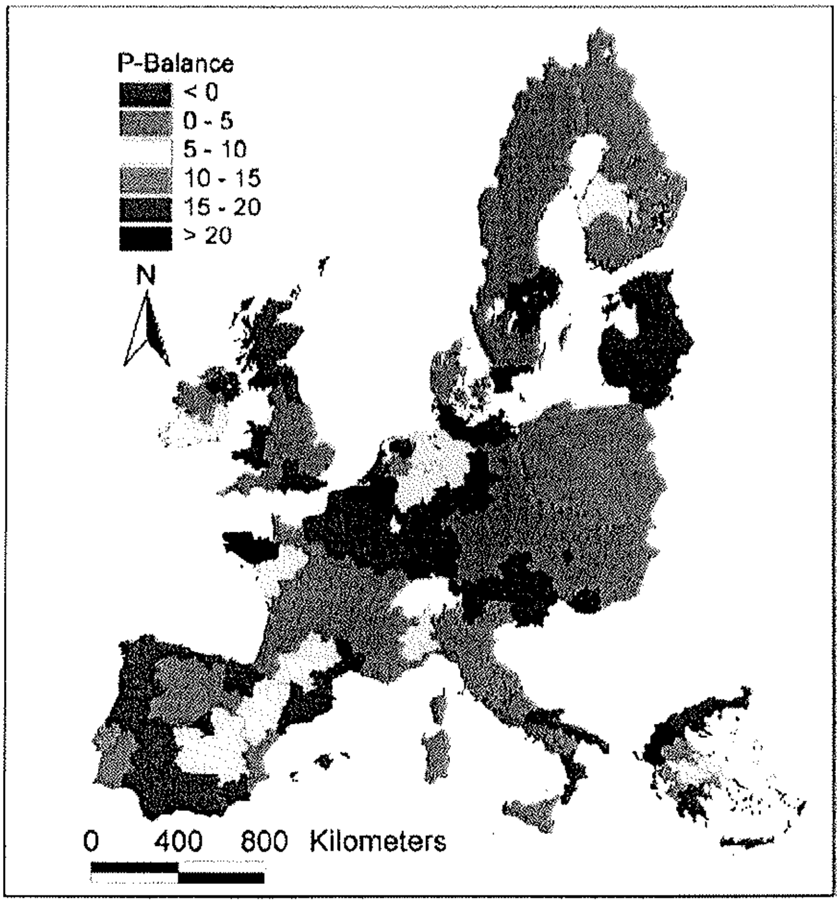


Figure 3: Balance result per NUTS II/III region

to just over 50 kg P/ha (surplus) but most regions fall within the range of -5 to +20 (Figure 3). 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.

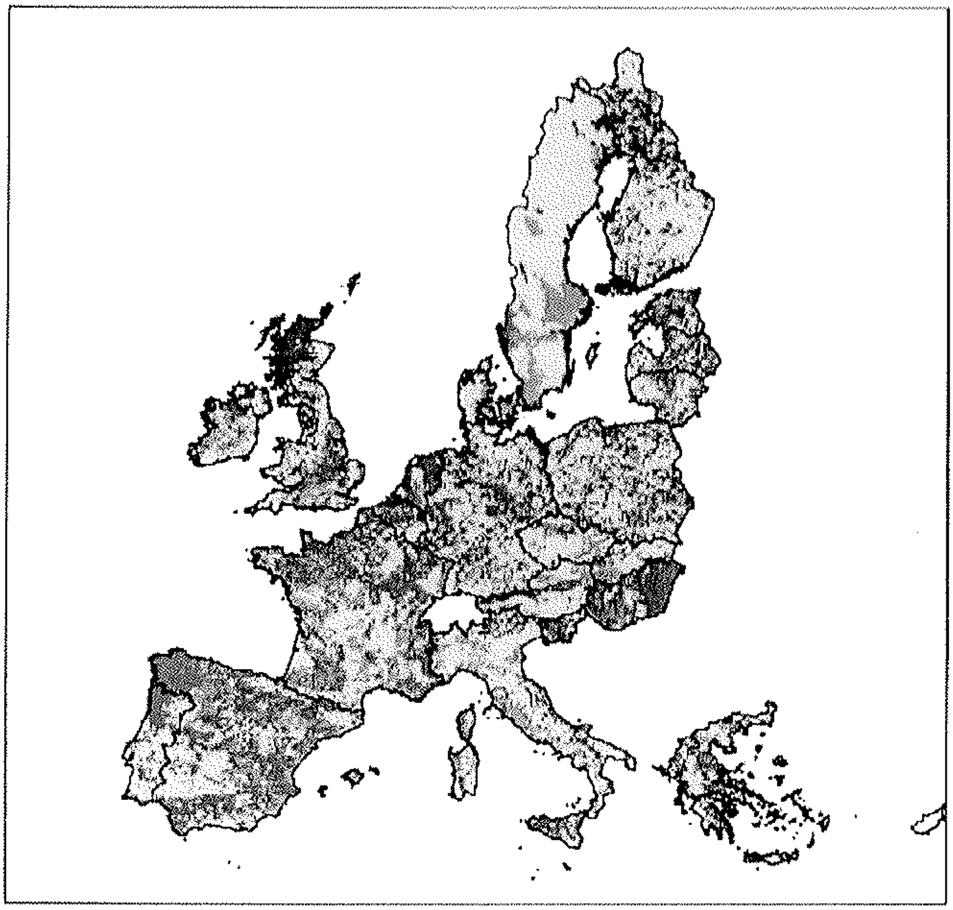
Although manure transfers are a known practice between regions and Member States with surpluses and deficits, reliable figures are not readily available but for a few cases. The significant impact of manure transfers on the P-balance for the Netherlands and Flanders demonstrates that internal redistribution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

Sensitivity to P-surplus - areas currently at risk of P saturation

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 die 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.



Dark red = highly sensitive, dark green = low sensitivity

Figure 4: Sensitivity to P surplus due to erosion and limited sorption capacity

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.

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 credible 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.

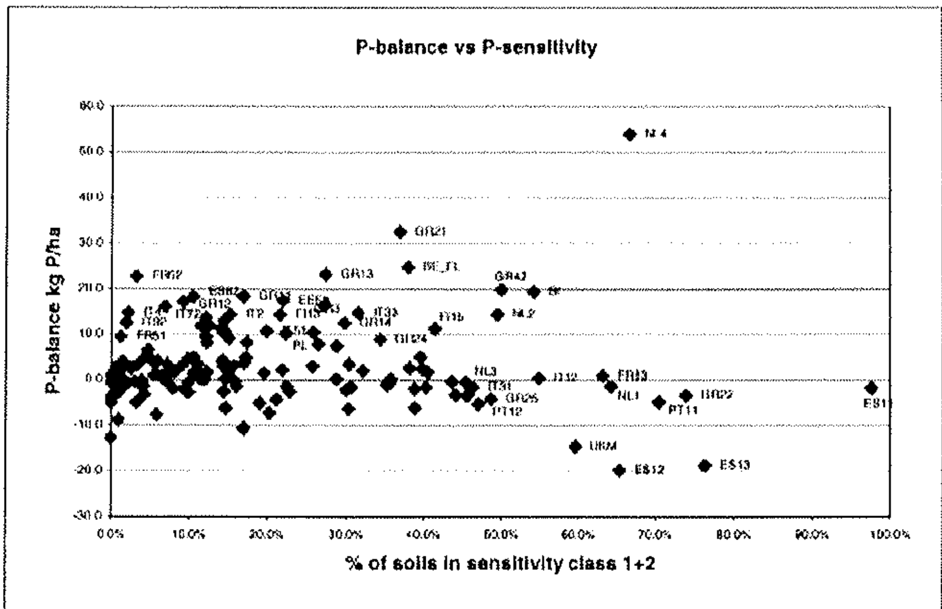


Figure 5: Comparison of pressure and vulnerability at NUT level

Actions taken by the member states

Monitoring the P-status

Monitoring the actual P-status of soils is taking place in several member states, sometimes at a detailed level (Figure 6). 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, since these soils require the build-up of P-reserves towards an optimum level.

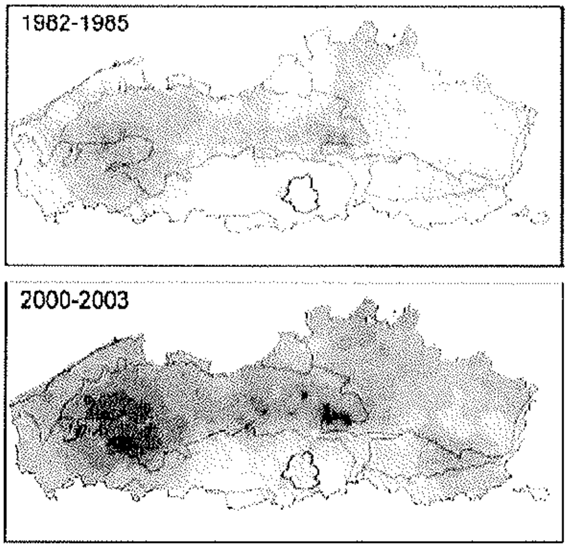


Figure 6: Evolution of the P-status of the soils in Flanders between 1982/85 and 2000/03 (the darker the color the higher the P-status), source: Soil Service of Belgium

Only in the Netherlands and in Flanders, zones vulnerable to or affected by P-saturation have been established (Table 1). 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.

Province (total area in km^2))	**Area of P-saturation (km^2)**	**Area at risk (km^2)**
West-Vlaanderen (3 144)	17	141
Oost-Vlaanderen 2 982)	40	380
Antwerpen (2 867)	6	42
Limburg (2 422)	10	46
Vlaams-Brabant (2 106)	0	1
Flanders (13 522)	**73**	**610**

Table 1: Land area with P-saturation and areas at risk in Flanders

Legal actions taken by EU and member states

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).

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.

Technical measures - economic incentives

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 manoeuvring 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.

Case studies: Flanders (B), Brittany (F) and the Po valley region (I)

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.

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.

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.

Conclusions and recommendations

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 P2O5 in Flanders or 9 € in the Netherlands) do have a marked effect on excess P-production.