Agricultural **phosphorus** legislation in Europe

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Preface

Phosphorus is gaining more and more attention because the limited availability of phosphorus sources asks for resource efficiency and because phosphorus losses can result in eutrophication of surface waters. One of the actions tackling these issues is the limitation of phosphorus fertilisation on agricultural land. There is no European Directive or other regulation concerning phosphorus application in agriculture. Nevertheless, some European countries and regions have legislation restricting phosphorus fertilisation accommodated under several kinds of legislations (Nitrates Directive, Water Framework Directive, etc.). However, this information is difficult to find and very diverse. In this study, recent legislation concerning the restriction of phosphorus application on agricultural land in Europe was gathered and compared. Experts in European countries/regions were contacted in order to obtain the national and regional regulations regarding phosphorus fertilisation. The information was controlled and inventoried. The different legislative systems, types of restricted fertilisation, the extent of limits, etc. were compared. It was investigated whether the legislations take the risk of phosphorus loss into account in the legislation.

The authors want to thank all contact and expert persons (see Table 1) for their time and efforts for providing the correct information of national or regional legislation and for suggestions and comments on the draft report.

The authors

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Summary

Phosphorus (P) losses from agricultural fields can cause eutrophication and ecological deterioration of surface waters. Although there is no general European Phosphorus Regulation or Directive, some European Member States address the agricultural phosphorus losses via national or regional legislation restricting the application of phosphorus. Most of this legislation concerns implementations of the Nitrates Directive (91/676/EEC) in terms of National Action Plans, the Water Framework Directive (2000/60/IEC) in terms of River Basin Management Plans and the Industrial Emissions Directive (2010/75/EU). In 2014, we inventoried this phosphorus legislation in European countries. Some of these countries (or regions) do not have direct phosphorus application restrictions in addition to the chemical fertiliser N and manure N restrictions in the Nitrate Vulnerable Zones. Other countries or regions have detailed, differentiated maximum phosphorus application standards. The diversity in systems used, e.g. maximum application standards, balance system, etc., complicates the comparison of international regulations. The regulations also restrict different types of phosphorus fertiliser: all types, only manure, only chemical fertiliser, etc. Some countries take only half of the phosphorus content in certain fertiliser types (compost and/or organic fertilisers) into account. The crop phosphorus export depends upon the crop type; for this reason, several countries and regions have crop type dependent maximum phosphorus application standards. We have compared the maximum application rates for grassland, maize, cereals, potatoes and sugar beets among Member States. Focusing phosphorus application restrictions on the high-risk P areas is likely to be the most effective way to reduce agricultural phosphorus losses. A few Member States do this by relating the maximum phosphorus application rates to the soil P status: higher/lower limits for lower/higher soil P content. The success of this approach depends upon the suitability of the soil P measurement method for estimation of P losses, and the extent of the difference between the crop P export and the application limit. The hydrological conditions and connectivity between the field and surface water are not taken into account, despite their value for a real P risk approach. Phosphorus transfers to surface waters by erosion and surface runoff can be restricted by installing a buffer zone where no fertilisation is allowed along waterways. The width of the zone (0.5-500 m) and the type of fertilisation restricted varies widely among Member States. We conclude that phosphorus legislation in European countries and regions varies from no direct regulation to strict maximum phosphorus application rates that depend upon fertiliser type, crop type, soil P content, etc. Minimising the P losses to surface waters will be facilitated if policymakers use a more agro-environmentally sound approach for restricting P fertilisation.

1 Introduction

The ecological status of surface waters has been improved over the last decades, but is still poor in many European lakes and waterways (Figure 1) (Kristensen, 2012). High concentrations of phosphorus (P), the limiting nutrient for algal growth in most inland surface waters, are especially problematic. Due to the reduction in point sources (industry and waste water treatment plants) agriculture is now often the main contributor to phosphorus losses to surface waters from rural areas (Bogestrand et al., 2005). Phosphorus is a finite resource. The issue of increasing the efficient use of phosphorus was recently tackled by the European Commission (Anon., 2013b) and others (Cordell et al., 2009; Schröder et al., 2011). Phosphorus is an essential nutrient for crop production and is therefore applied to the soil by chemical fertilisers, manure, compost, etc. Phosphorus can be lost from the soil via erosion, surface runoff, subsurface runoff, leaching and tile drainage. To limit these losses and to improve the ecological state of European surface waters, several mitigation options are possible (Schoumans et al., 2014). One of the options is to limit the phosphorus application in agriculture, but preferably without compromising crop yields. This can be done on a voluntary basis, by following phosphorus fertilisation advice. However, recommendations for P fertilisation differ more than threefold in Europe for similar soil-crop situations (Jordan-Meille et al., 2012). Another option is to limit phosphorus fertilisation by law. In contrast to nitrate, there is no European Directive or other regulation concerning phosphorus application in agriculture and P losses from agricultural land. The Nitrates Directive (91/676/EEC) states that eutrophication due to agriculture should be prevented, but phosphorus is not mentioned specifically in this Directive. Nevertheless, several actions have been taken by European Member States by means of national legislation or voluntary regional (agri-environmental) action plans. In the absence of a European legislative framework for phosphorus, these national or regional phosphorus regulations can be accommodated under several kinds of legislations (Nitrates Directive, Water Framework Directive, etc.; see section 3.1). Information concerning phosphorus legislation is difficult to find and is often obsolete. The goal of this study was to gather all recent legislation concerning the restriction of phosphorus application to agricultural land in Europe and compare the different approaches used. The focus is limited to one of the many mitigation options, namely legislation that restricts phosphorus fertilisation.

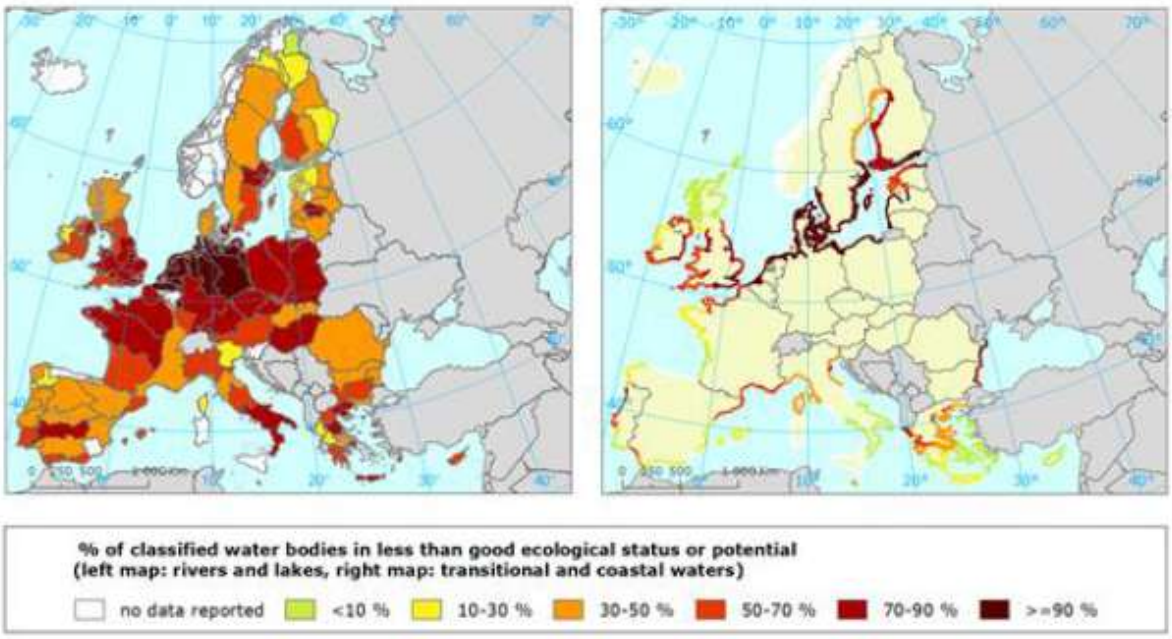

Figure 1. Ecological water quality status in EU Member States (Anon., 2012b)

2 Methods

In 2007, a compilation of the phosphorus regulations in Europe was performed as part of the EU-COST action 869 "Mitigation options for nutrient reduction in surface water and groundwaters at the river basin scale, in order to reach targets of the Water Framework Directive" and discussed with the participants of the COST 869 Member States in Hamar (Norway). A questionnaire was made (Appendix 1) and sent to the 27 Member States participating in COST action 869. By the end of 2013, a large portion of the information received was obsolete and needed updating. Experts in the various countries and regions were contacted in late 2013 or early 2014 to update this information using either the same questionnaire or targeted and detailed questions (Appendix 2). Other experts were contacted to edit and comment on the information gathered. The participating countries, regions, contact persons and experts can be found in Table 1.

*Table 1. Countries and regions participating, with their contact and expert person(s) (persons followed by * have provided the information on the legislation of their country or region)*

Country/Region	Contact person(s)
Austria	Peter Strauss*
Belgium (Flanders)	Fien Amery*, Georges Hofman
Belgium (Wallonia)	Charles Hendrickx*
Czech Republic	Josef Hejzlar*
Denmark	Line Block Hansen*, Hans Kjaer
England & Wales	Robert Willows*
Estonia	Alvina Reihan*, Arvo Iital*
Finland	Kari Ylivainio*
France	Rémi Dupas*, Chantal Gascuel-Odoux
Germany	Thorsten Breitschuh*, Anja-Kristina Techen*, Bernhard Osterburg*
Greece	Yiannis Panagopoulos*
Hungary	Peter Csatho*
Ireland	Stan Lalor*, Karl Richards*
Israel	Moshe Shenker*
Latvia	Viesturs Jansons*
Luxembourg	Jeff Boonen*, Simone Marx*
Northern Ireland	Donnacha Doody*
Norway	Marianne Bechmann*
Poland	Leszek Hejduk*
Scotland	Stephen Field*, Jannette MacDonald
Spain	Antonio Delgado*
Sweden	Johannes Eskilsson*
The Netherlands	Oscar Schoumans*, Maret Oomen

3 Results

3.1 European legislation

3.1.1 General

Phosphorus legislation in European countries and regions is part of several Directives, legislations, action plans, etc. European Directives are binding for each Member State; all of the stated objectives must be met. National authorities have to adapt their laws and legislations to meet these goals, but are free to decide in which way they want to achieve the goals. They can therefore take local human, technical and physical settings into account. In contrast to European Directives, European Regulations have a directly binding legal force in every Member State (Schoumans et al., 2011). Most national or regional phosphorus legislation described below is part of the national or regional implementation of EU Directives to reduce environmental pollution (Table 2). The most important Directives relating to phosphorus are discussed in following sections. Member States can also take actions in line with the Common Agricultural Policy (CAP) of the EU (section 3.1.4). Also conventions can contribute to national or regional legislation. One of the aims of the OSPAR Convention (Convention for the Protection of the Marine Environment of the North-East Atlantic) is to reduce the nitrogen and phosphorus inputs by 50% compared to the 1985 input levels (Anon., 2008).

Table 2. European Directives in relation to phosphorus aspects

Bathing Water Directive	76/160/EEC amended by 2006/7/EC
Directive on Dangerous Substances	76/464/EEC = 2006/11/EC
Urban Waste Water Directive	91/271/EEC
Nitrates Directive	91/676/EEC
Water Framework Directive	2000/60/EC
Groundwater Directive (daughter directive of Water Framework Directive)	2006/118/EC
Marine Strategy Framework Directive	2008/56/EC
Waste Framework Directive	2008/98/EC
Industrial Emissions Directive (replaces IPPC Directive 96/61/EC)	2010/75/EU

3.1.2 Nitrates Directive

The Nitrates Directive (91/676/EEC) is an integral part of the Water Framework Directive (section 3.1.3). The mail goal of the Nitrates Directive is to protect water quality across Europe by preventing nitrate pollution of ground and surface waters from agricultural sources and by promoting the use of good farming practices. The Member States have to (1) identify polluted or threatened waters, (2) designate Nitrate Vulnerable Zones (NVZs), (3) establish Codes of Good Agricultural Practice to be implemented by farmers on a voluntary basis, (4) establish action programmes to be implemented by farmers within NVZs on a compulsory basis and (5) monitor the progress of implementation, reporting and (as needed) revision of NVZs and action programmes. Although phosphorus is not mentioned in the Nitrates Directive, several implementations of the Nitrates Directive by Member

States have included phosphorus regulations. As manure application in NVZs is restricted by the limit of 170 kg N/ha/y (or higher N application standards in case of derogation), phosphorus application by manure is indirectly limited by the Nitrates Directive in these areas. This is also the case for other restrictions for manure in NVZs, e.g. regarding the manner of land application (not allowed when the soil is water-saturated, flooded, frozen or snow-covered), restricted periods for application, etc.

3.1.3 Water Framework Directive

The aim of the Water Framework Directive (2000/60/EC, WFD) is to protect surface waters and groundwater throughout the EU territory. Many water directives are part of this directive, e.g. the Nitrates Directive, the Groundwater Directive, and others. The main environmental objectives are to achieve and maintain a good status for all surface waters and ground waters by 2015, and to prevent deterioration and ensure the conservation of high water quality where it still exists. In order to achieve the objectives, River Basin Management Plans (RBMPs) have to be implemented. These plans should provide a clear indication of the way the objectives set for the river basin are to be reached within the required timescale. The first RBMPs were published in 2009; they are updated every six years.

3.1.4 Common Agricultural Policy

The Common Agricultural Policy (CAP) is the agricultural policy of the European Union. It implements a system of agricultural subsidies and other programmes. It was introduced in 1962 and has been reformed several times. The 'Agenda 2000' reforms divided the CAP into two 'Pillars': production support and rural development. The reform of 2003 has introduced the Single Payment Scheme (or Single Farm Payment) in Pillar 1. Each country can choose if the payment is established at the farm level or at the regional level. The farmers are obliged to keep their land in good agricultural and environmental condition (cross-compliance). Farmers have to respect environmental, food safety, phytosanitary and animal welfare standards. If farmers do not respect these standards, they pay a penalty in the form of a lower farm payment. In Pillar 2, several rural development measures were introduced including diversification, setting up producer groups and designating support for young farmers. Agri-environmental schemes became compulsory for every Member State. Phosphorus application restrictions can be part of Agri-Environmental Programmes (AEP).

3.2 Legislation in European countries and regions

Legislation concerning phosphorus fertilisation is reported for every country/region listed below. The legislation on phosphorus use in agriculture in European countries and regions varies widely. Some countries have elaborate limitations on phosphorus application on agricultural land. Other countries either do not have any phosphorus legislation or rely on voluntary measures as part of agri-environmental programmes (CAP) or on the restrictions on the use of manure (Nitrates Directive) to indirectly regulate the use of phosphorus. In this report, only direct regulations of phosphorus are reported and discussed in detail. Sometimes respondents spontaneously provided additional information regarding aspects of phosphorus regulations. This information was included in the report if it was specific and relevant for phosphorus. It is possible that other countries or regions have similar regulations, but that the respondents did not mention them.

Some countries or regions have phosphorus application limits (also called 'application standards' or 'maximum application rates'). The application limits can have a standard value, but can also be differentiated in relation to the type of crop, the phosphorus status of the soil or even the crop yield. Units for annual phosphorus applications are expressed in kg P/ha/y or kg P_2O_5/ha/y. Most legislations concern all (acceptable) materials of phosphorus applications, but sometimes only manure or only inorganic fertiliser are regulated. These differences should be taken in mind when comparing various regulations (see 4.2).

3.3 Austria

Austria has no maximum phosphorus application rates or other P restrictions. Only indirect regulations affect phosphorus application and losses, e.g. manure N restriction in the Nitrates Directive, Good Agricultural Practices and erosion control.

3.4 Belgium: Flanders (northern region)

3.4.1 General

Every four years, a new Manure Decree comes into force in Flanders as an implementation of the Nitrates Directive. The current Manure Decree (Anon., 2011) is valid in 2011-2014. This decree addresses phosphorus and nitrogen application.

3.4.2 General limits

Maximum total phosphorus application standards are listed in the Manure Decree (Table 3). The current application standards (2014) vary between 65 and 95 kg P_2O_5/ha/y. The limits depend on the type of crop. Indicative limits for the next Manure Decree (2015-2018) are mentioned (5−10 kg P_2O_5/ha/y lower than the standards of 2014). The maximum phosphorus application standards are approximately 5 kg P_2O_5/ha/y smaller than the general phosphorus export by the crop, resulting in a small negative phosphorus input into the soil. Phosphorus can be applied in the form of manure, organic materials or chemical fertilisers (only derogation farms cannot use chemical P fertilisers). Standard rates do not increase if more than one crop is cultivated in one year (standard rate of the main crop is valid), with the exception of one cut of grass or rye followed by maize (Table 3).

Table 3. Maximum total phosphorus application standards in Flanders (limits for 2015-2018 are indicative)*

Crop	Application limits (kg P_2O_5/ha/y)			
	2011-2012	2013-2014	2015-2016*	2017-2018*
Grassland (only mowing)	95	95	95	90
Grassland (not only mowing)	90	90	90	90
1 cut grass/rye + maize	95	95	95	90
Maize	80	80	75	70
Winter wheat - triticale	75	75	70	70
Other cereals	75	70	70	70
Other crops	75	65	55	55

3.4.3 Deviations from the general limits

Only 40 kg P_2O_5/ha/y can be applied on soils located in phosphate saturated areas. These areas are all areas that based on the study of Van Meirvenne et al. (2007) have a phosphate saturation degree (PSD) (0-90 cm) equal to or larger than 35% with a probability of 95%. There is only a protocol for the measurement of PSD in acid sandy soils (van der Zee et al., 1990a), which leaves a large part of Flanders left out of PSD measurement. About 65 km² (1% of the agricultural land) is designated as phosphate saturated area. Farmers in this area can be relieved of the strict application standard of 40 kg P_2O_5/ha/y if a soil analysis demonstrates a PSD smaller than 35%; in such a case the standard application rates in Table 3 are valid. If the soil analysis demonstrates a phosphate binding capacity ($0.5*(Fe_{ox}+Al_{ox})$) equal to or smaller than 25 mmol P/kg soil (0-90 cm) and if the content of P extracted by oxalate is equal to or smaller than 20 mmol P/kg soil (0-30 cm), then standard rates (Table 3) minus 10 kg P_2O_5/ha/y are applicable.

No phosphorus can be applied on soils located in protection zone type 1 of water extraction areas for drinking water. With the exception of direct excretion by two grazing livestock units per hectare, no phosphorus can be applied on agricultural soils located in vulnerable nature areas (nature areas, nature development areas, nature reserves and woods in the Flemish Region Plans) and on half-natural and potentially important grassland soils located in woodlands.

The general phosphorus application limits are not valid for crops under permanent structures (such as glasshouses and tunnel structures). The phosphorus dose for these soils is limited by the fertilisation advice.

Only 50% of phosphorus that is applied by qualified compost (VLACO) has to be taken into account to calculate the P application because compost has a substantial soil fraction.

3.4.4 Others

In Flanders, there are no subsidies for farmers that voluntarily apply less phosphorus than allowed by law.

Part of the farm's manure surplus must be processed or exported, but this is based on the nitrogen production of manure and not on phosphorus.

3.5 Belgium: Wallonia (southern region)

There are no maximum phosphorus application rates or other P restrictions in the Walloon Region. The only regulation affecting phosphorus application and losses is indirectly, e.g. by manure N restriction in the Nitrates Directive, Good Agricultural Practices and erosion control.

3.6 Czech Republic

There are no maximum phosphorus application limits or other P restrictions in the Czech Republic. The regulations affecting phosphorus application and losses are indirect, e.g. by manure N restriction in the Nitrates Directive, erosion control and buffer zone directives, and agri-environmental programmes. In the latter, farmers can have a free soil P measurement (every 5 or 6 years, organised by a state agency) and P fertilisation recommendation (not mandatory).

3.7 Denmark

Phosphorus from manure is indirectly restricted due to the limit of 140-170 kg N/ha/y for the entire Danish territory. There are also maximum application rates for total phosphorus, but only an a consultative basis (Anon., 2013d). A tax on mineral phosphates for feed (Anon., 2004a) was introduced in 2005, which has generally resulted in reduced phosphorus excretion (Damgaard Poulson, 2005; Damgaard Poulson, 2013). Phosphorus application by organic fertilisers consisting of less than 75% manure (mainly sludge) is restricted to 30 kg P/ha/y over a period of 3 years and to a maximum of 7 tonnes dry matter/ha/y (Anon., 2006a).

Animal farms that meet all three of the following criteria (1) wanting to expand or change their production unit, 2) draining into Natura 2000 areas overloaded with P and 3) falling under P class 1, 2 or 3 (see bullets hereafter) have additional restrictions for the manure phosphorus surplus (Anon., 2013a). This surplus is the phosphorus excretion of the farm animals (agreed table values or own measurements) minus the phosphorus export by the crop (agreed table values) plus/minus phosphorus in manure that is imported/exported (agreed table values, correction possible). Chemical fertiliser is not included in the calculations. When the manure account is in balance, no further restrictions are applied. If the surplus is positive, restrictions are applied, depending upon the soil type and phosphorus status:

- Class 0 (drained clay soils, Olsen-P < 4): no additional restrictions
- Class 1 (drained clay soils, 4 < Olsen-P < 6): phosphorus surplus can increase at maximum by 4 kg P/ha/y
- Class 2 (lowlands with Fe/P mole ratio < 20): phosphorus surplus is at maximum 2 kg P/ha/y
- Class 3 (drained clay soils, Olsen-P > 6): no phosphorus surplus is allowed

3.8 England and Wales

England and Wales have no legislation concerning phosphorus application in agriculture. The only regulation affecting phosphorus application and losses is indirectly, e.g. by manure N restriction in the Nitrates Directive.

3.9 Estonia

The Water Act (Anon., 2004b) determines how much phosphorus may be applied to agricultural fields in Estonia. Farmers have to report fertiliser applications in a field book. The phosphorus addition by manure is limited to 25 kg P/ha/y. Additional P can be applied by chemical fertilisers, but this amount is restricted to the crop requirement (Table 4). These optimal (and maximum) rates for P fertilisation for various crops, depending on the predicted yields, are defined in an attachment to the Code of Good Agricultural Practice. The soil P should be accounted for by calculating the soil P requirement coefficient, which depends on the Mehlich 3 P extraction concentration, the humus or the organic C content and the soil texture (PMK, 2013).

Table 4. Requirements for P (kg P/ha/y) for different crops depending on the predicted yield and soil P requirement coefficient.

Crop	Predicted yield (tonnes/ha)	Soil P requirement coefficient[$]				
		1.5	1.3	1.0	0.5	0.1
Barley	3	32	27	21	11	2
	3.5	35	30	23	12	2
	4	*	31	24	12	2
	4.5	*	34	26	13	3
	5	*	*	27	14	3
	5.5	*	*	29	15	3
Oats	3	23	20	15	8	2
	3.5	26	22	17	9	2
	4	27	26	18	9	2
	4.5	*	27	20	10	2
	5	*	*	21	11	2
	5.5	*	*	23	12	2
Rape	1.3	42	36	28	14	3
	1.8	*	39	30	15	3
	2.3	*	*	33	17	3
Peas	3	*	31	24	12	2
Potatoes	20	83	72	55	28	6
	25	90	78	60	30	6
	30	98	85	65	33	7
Clover	6	30	26	20	10	2
Lucern	6	39	34	26	13	3
Maize	6	*	39	30	15	3

[$] The soil P requirement coefficient depends upon the Mehlich 3 P extraction concentration, the humus or the organic C content and the soil texture (PMK, 2013).
* Soil fertility is too low to assess the P requirements for this crop yield

The Water Act also limits the fertilisation timing and sets regulations for buffer zones (see Table 17). No fertiliser use is allowed near karst springs and karst holes (10 m distance required, up to 50 m in Nitrate Vulnerable Zones). Phosphorus regulation can also be found indirectly in the Water Act: manure N restrictions and the maximum 1.5 livestock units per ha limit in Nitrate Vulnerable Zones.

3.10 Finland

Finland has no legislation restricting phosphorus fertilisation. Phosphorus from manure is indirectly restricted due to the limit of 170 kg N/ha/y for the entire Finnish territory. In addition, phosphorus application is limited because 95% of Finnish farmers voluntarily join the Agri-Environmental Programme (AEP). This Programme sets the advised phosphorus doses that may not be exceeded if the farmer wishes to receive subsidies (Valkama et al., 2009). The doses depend on the crop type, crop yield and the soil phosphorus status (Anon., 2007b). The soil phosphorus status is determined by acid ammonium acetate extraction (pH 4.65); the fertility class also depends upon the soil texture and the organic matter content (Ylivainio et al., 2014). The maximum P application rates in Table 5 are defined for basic yield levels. If yields are higher than 4 tonnes/ha for cereals, 3 tonnes/ha for rye or 1.75 tonnes/ha for oil plants, maximum P application rates are linearly increased by 3 kg P/ha for a yield increase of 25% (up to 6 kg P/ha, only for soil P classes where P application is allowed).

More total P can be applied by organic fertilisers than by chemical fertiliser as only 85% of P in manure (40% in manure of fur-animals, i.e. foxes, minks, finnraccoons and fitchets) and 40% of P in sludge is considered to be plant available in the current AEP. In the next AEP (from 2015 on) this will probably be increased to 100% for manures, and 60% for fur-animal manures and sludge.

Table 5. Advised phosphorus application rates (kg P/ha/y), to be followed under the Finnish Agri-Environmental Programme (Anon., 2007b). The advised rates are increased for higher than basic yields (see text).

Crop	Soil P status[a]		
	Poor	Sufficient	High
Cereals	28-34	8-14	0
Potato	70	55	0-20
Sugar beet	63	43	0-14
Grassland	32-40	8-24	0

[a] The soil P status depends upon the P concentration in the acid ammoniumacetate extract, the soil texture and the organic matter content (Ylivainio et al., 2014).

3.11 France

A ministerial decree (Anon., 2012a), the French implementation of the IPPC Directive (now IED), sets that the phosphorus fertilisation has to be in equilibrium with the crop export from the field and that the absorption capacity of the soils must not be exceeded. This legislation concerns "*Installations Classées pour la Protection de l'Environnement*" (ICPE). This applies to the largest farms, those with >100 dairy cows, >450 pigs or >30000 poultry. These ICPE farms have to prove compliance with the phosphorus equilibrium requirement by an impact study when setting up a new farm or expanding an existing one. There is no practical implementation on paper in which way the phosphate sorption capacity should be taken into account and how the administration should evaluate these impact studies. Similar to the Nitrates Directive, practical implementation of the ministerial decree falls under the responsibility of the local authorities (department or region). However, national guidelines exist to estimate the phosphorus balance: several ministerial circulars (15/05/2003, 19/08/2004, 07/09/2007) set animal excretion coefficients and crop P contents. The methodology to estimate crop yield is specified by local expert groups in each region, as part of the Nitrates Directive action programme. In conclusion, the implementation of this national decree varies strongly across France.

In this section, region of Brittany is taken as an example because the severe impacts of nutrient pollution from agricultural origin has forced the authorities to take action; this explains why phosphorus legislation is more advanced there than in other regions. The Loire-Brittany River Basin Management Plan (RBMP) (Anon., 2009d), developed and published according to the Water Framework Directive, re-emphasises the objective of reducing phosphorus transfer from agricultural diffuse sources. Particularly, the Loire-Brittany RBMP delineates 14 priority catchments, where balanced fertilisation must be achieved under the responsibility of the local prefect. Hence, local authorities must comply with both the IPPC/IE ministerial decree and the RBMP when deciding to authorise an ICPE farm. Administrative controls differ depending on the farm size, farm type and whether or not it is located in an RBMP priority catchment.

- Large (production >25000 kg N) or new farms must show a soil phosphorus balance (tolerance of 10% larger phosphorus input compared to phosphorus export). The phosphorus export is calculated by the crop yield and crop phosphorus content (the latter can be found in the agreed tables in Anon. (2009c)). There are no regulations under the ministerial IE decree regarding the way crop yields have to be measured (see above). According to the Nitrates Directive implementation in Brittany, the reference crop yield is the average of the three lowest yields over the past five years.
- Smaller farms (< 25000 kg N) and farms that are not new have maximum phosphorus application standards depending on the farm type (poultry or not) and whether or not it is located in a priority catchment (Table 6).

The limits are defined on a farm scale, not on a plot scale basis.

Table 6. Phosphorus application limits for small farms (< 25000 kg N) and farms that are not new in Brittany, in kg P_2O_5/ha/y.

	Poultry	Non-poultry
Priority water basis[a]	90	80
Non-priority water basin	95	85

[a] Moulin Neuf, Kerne Uhel, Etang au Duc, Guerledan, Gouet, L'Arguenon, Rophemel, La Valière, Villaumur, La Chapelle Erbrée

In the French department Maine-et-Loire, the phosphorus fertilisation is regulated by a departmental decree (Anon., 2009a), which is the implementation of the Nitrates Directive. This is a local initiative, because P problems had been identified in this department. The phosphorus fertilisation (by chemical fertiliser, sludge and manure) is restricted to 100 kg P_2O_5/ha/y (farm basis, no control on field scale). If it is not possible to apply less than 100 kg P_2O_5/ha/y, mandatory farm-specific measures should be taken to limit the transfer of phosphorus before the end of the Action Programme. These measures are based on a farm diagnosis made by an expert from the "*Chambre d'Agriculture*" and can include buffer strips, hedgerows, etc. A soil phosphorus analysis is mandatory in the current action programme (6 years) but the result has no practical implications. The 5th French implementation of the Nitrates Directive is expected in mid-2014. Because the new action programmes will be set at the regional level instead of at the department level, the departmental legislation of Maine-et-Loire will not be in force anymore and will not be included in the Pays de la Loire regional legislation.

3.12 Germany

In Germany, fertilisation of agricultural soils in regulated by the Fertilisation Ordinance (Düngeverordnung) (Anon., 2007a), the implementation of the Nitrates Directive (whole territory approach). Because the phosphorus fertilisation must correspond to the crop and soil needs (Anon., 2009b), the soil phosphorus concentration has to be determined at least every six years according to the Fertilisation Ordinance. Phosphorus fertilisation is not restricted by fixed application limits, but rather by a soil balance system. The soil phosphorus balance (soil P input minus output) must not exceed 20 kg P_2O_5/ha/y as a six-year average. All types of phosphorus inputs have to be taken into account. The phosphorus output can be calculated by official phosphorus contents of crops and the crop yield. The crop yield can be determined by weighing or estimation (forage crops, control the year after by a stable balance). These calculations do not have to be registered but must be available for auditing by the authorities. Since these regulations are poorly defined and verification of the calculated values has proven to be difficult, Ekardt et al. (2011) have questioned their effectiveness. This balance system offers flexibility to the farmer, because there is no yearly limit, the system takes crop yields and multiple crops during one entire year into account.

In addition to the balance limit of 20 kg P_2O_5/ha/y, the "soil need" (based on fertilisation advice) can be applied to soils with a phosphorus content below 20 mg P_2O_5/100 g, measured by calcium acetate lactate extraction. This soil P content corresponds to the upper limit of the target soil P concentration class, according to the German soil P fertility classes (Kerschberger et al., 1997).

In some federal states there are optional support programmes with the aim to reduce the risk of soil erosion or to establish buffer strips next to water bodies.

3.13 Greece

Greece has no maximum phosphorus application rates or other P restrictions. The only regulation affecting phosphorus application and losses is indirectly, e.g. by fertiliser N restrictions in the Nitrates Directive.

3.14 Hungary

Hungary has no maximum phosphorus application rates or other P restrictions. The only regulation affecting phosphorus application and losses is indirectly, e.g. by manure N restriction in the Nitrates Directive and Good Agricultural Practices in agri-environmental programmes.

3.15 Ireland

3.15.1 General

Every four years, a new Irish fertilisation legislation comes into force as an implementation of the Nitrates Directive. The current legislation (Anon., 2014a) is valid during 2014-2017.

3.15.2 General application limits

The phosphorus application limits depend on the soil phosphorus status and the crop type (Table 7 and 8). The larger the soil P content, the lower the limits. The result of the Morgan's test (extraction with sodium acetate at pH 4.8) classifies a soil into index 1 (low), 2, 3 or 4 (high) (Table 7 and 8). The soil analysis is not mandatory, except for derogation farms. When no soil analysis is available, index 3 is assumed. Tests older than 5 years are not valid, except when the results indicate index 4. Fields used for more than one crop in a year are permitted to receive the combined maximum available P application of the two crops being grown.

Both P applications by chemical fertiliser and organic fertilisers are considered, but only 50% of P in organic fertilisers is considered for P application calculations for soils of index 1 or 2. The P contained in concentrate feeds fed on the farm at rates greater than 300 kg of feed per 85 kg of organic N excreted is also included as a source of available P fertiliser.

Table 7. Maximum P application standards (kg P/ha/y) for grassland in Ireland depending on the soil P index (Morgan's test)

	P index (Morgan's test)			
	1 **0-3.0 mg P/l**	**2** **3.1-5.0 mg P/l**	**3** **5.1-8.0 mg P/l**	**4** **> 8.0 mg P/l**
General				
Grassland stocking rate [*] (kg/ha/y)				
≤ 85	31[1]	21[1]	11[1]	0[2]
86-130	36[1]	26[1]	16[1]	0[2]
131-170	41[1]	31[1]	21[1]	0[2]
170-210[3]	46[1]	36[1]	26[1]	0[2]
>211[3]	51[1]	41[1]	31[1]	0[2]
Cut only[$]				
First cut	40	30	20	0
Subsequent cuts	10	10	10	0

[*] Total annual N (kg) excreted by grazing livestock averaged over the eligible grassland area.

[$] Grassland with no grazing livestock on the holding or areas of farms where hay or silage is produced for sale off the holding on farms stocked <85 kg grassland stocking rate.

[1] An additional 15 kg P/ha may be applied on soils at P index 1, 2 or 3 for each hectare of pasture establishment taken.

[2] Manure produced by grazing livestock on a holding may be applied to index 4 soils on that holding in a situation where there is a surplus of such manure remaining after the phosphorus fertilisation needs of all crops on soils at P index 1, 2 or 3 on the holding have been met by the use of such manure produced on the holding.

[3] The maximum P fertilisation of grassland shall not exceed that specified for stocking rates less than or equal to 170 kg/ha/y unless a minimum of 5% of the eligible area of the holding is used to grow crops other than grass or a derogation applies in respect to the holding.

3.15.3 Deviations from the general limits

In addition to the maximum P application standards, 5 (2013-2014), 3 (2015-2016) or 0 (2017 and later) kg P/ha/y can be applied if this additional fertilisation dose is given by spent mushroom compost or by manure produced by pigs or poultry (from holdings without increase in the scale of the production since 1 August 2006).

Where proof of higher yields of cereals is available, an additional 3.8 kg P/ha may be applied on soils at P index 1, 2 or 3 for each additional tonne above a yield of 6.5 tonnes/ha. The higher yields shall be based on the best yield achieved in any of the three previous harvests, at 20% moisture content.

The fertilisation rates for soils which have more than 20% organic matter shall not exceed the amounts permitted for index 3 soils.

Table 8. Maximum P application standards (kg P/ha/y) for arable crops in Ireland depending on the soil P index (Morgan's test) and the crop type

	P-index (Morgan's test)			
Crop	**1** **0-3.0 mg P/l**	**2** **3.1-6.0 mg P/l**	**3** **6.1-10.0 mg P/l**	**4** **> 10.0 mg P/l**
Cereals	45	35	25	0[1]
Sugar and fodder beet	70	55	40	20
Potatoes (main crop)	125	100	75	50
Potatoes (early)	125	115	100	50
Potatoes (seed)	125	115	100	85
Maize	70	50	40	20[2]
Field peas	40	25	20	0
Field beans	50	40	20	0
Oilseed rape	35	30	20	0
Linseed	35	30	20	0
Swedes/Turnips	70	60	40	40
Kale	60	50	30	0
Forage rape	40	30	20	0
Asparagus (establishment)	40	25	15	10
Asparagus (maintenance)	27	17	10	7
Celery	88	65	55	28
Swede	70	60	45	35
Other vegetables	60	45	35	20
Apples (desert)	25	16	12	8
Apples (culinary)	20	12	10	8
Pears, cherries, plums, strawberries	16	8	4	0
Berries	20	16	12	8

[1] At pH ≥7: 20 kg P/ha/y can be applied on soils with P index 4.

[2] Must be incorporated prior to or during sowing

3.15.4 Other

In addition to the requirements regarding the manner of land application by the Nitrates Directive (no application allowed when the soil is water-saturated, flooded, frozen or snow-covered), the Irish implementation mentions other restrictions: no organic or chemical fertiliser nor soiled water can be applied when heavy rain is forecast within 48 hours (the Met Eireann weather forecast must be consulted) or when the ground slopes steeply (>20% for grassland, >15% for other land) and there is a risk of water pollution (having regard to factors such as surface runoff pathways, the presence of land drains, the absence of hedgerows to mitigate surface flow, soil condition and ground cover).

3.16 Israel

Israel has no maximum phosphorus application rates. However, new regulations (approved by 2011) restrict total P concentration in treated wastewater used for irrigation to 5 mg/L (1 mg/L if released to the environment). The new limits are gradually enforced and have large impacts given the widespread use of treated wastewater for irrigation (50% of total irrigation). There is also an indirect P application limitation due to the limitation for biosolids to the N crop demand.

3.17 Latvia

Latvia has no general maximum phosphorus application rates or other P restrictions. Waste water treatment plant (WWTP) sludge application is limited to 40 kg P/ha/y (or by heavy metal concentration or NH_4 concentration).

3.18 Luxembourg

In Luxembourg there is no direct legislation restricting phosphorus fertilisation. The manure P application is indirectly restricted by the manure N limit in the Nitrates Directive. In addition, phosphorus application by other fertilisers is also limited because 85% of farmers with 95% of agricultural land voluntarily join the programme of the Landscape Premium (Agri-Environmental Programme) (Anon., 2014b). In this program, maximum P application rates are defined for the parcels under this program (Table 9). The limits depend upon the crop type, the yield and the P fertility class. The latter is measured by the CAL-method (calcium acetate lactate) and varies between regions (Table 10). The limits are defined for a certain yield and are lowered or increased if the yield is lower or higher, respectively. The limits are only valid in case of application of mineral fertiliser, compost, sludge or the combination of mineral and any organic fertiliser (also manure). Application of manure alone is not limited by these application standards. Compliance is set on a 5 years basis (Landscape Premium period): the sum of P application during the 5 years is limited to the sum of the 5 yearly limits. In the 'very high' fertility class only solid manure and slurry (no compost, no sludge, no mineral P fertiliser) are allowed, and above 40 mg P_2O_5/100 g soil only grazing is allowed.

Table 9. Maximum P application rates (kg P_2O_5/ha/y) under the Landscape Premium programme in Luxembourg for a standard crop yield (in tonnes of dry matter/ha/y, except for potatoes (fresh matter))

	P fertility class[a]				
Crop	**Very low**	**Low**	**Target**	**High**	**Very high**
Cereals (50 t DM/ha)	120–125	90–95	60–65	30–33	0
Maize (15 t DM/ha)	180–186	150–156	120–126	60–63	0
Potatoes (35 t FM/ha)	162	132	102	51	0
Grassland (80 t DM/ha)	100–148	70-118	40–88	20–44	0

[a] See Table 10

Table 10. Ranges for P fertility classes in Luxembourg (mg P_2O_5/100 g dry soil measured by the CAL-method)

	P fertility class				
Region	**Very low**	**Low**	**Target**	**High**	**Very high**
Gutland	0–5	6–11	12–20	21–30	≥31
Ösling (stony soils)	0–7	8–14	15–23	24–35	≥36

3.19 Northern Ireland

The application of *chemical* phosphorus fertiliser is restricted by the Northern Irish Phosphorus (Use in Agriculture) Regulations (Anon., 2006b). Fertilisation is only allowed if the farmer can show that the applied amount is not above the crop requirement as determined by the RB209 fertiliser manual (Anon., 2010a). This crop requirement depends on the soil phosphorus status, determined every four years using the Olsen method (Table 11). The target soil P index is index 2 (Olsen P 16-25 mg/l) and index 3 for vegetables (Olsen P 26-45 mg/l). Advised phosphorus application rates are 0–125 kg P_2O_5/ha/y for winter wheat, 0–150 kg P_2O_5/ha/y for grass and 0–250 kg P_2O_5/ha/y for potatoes (Table 11). Advised application rates are higher/lower if the yield is higher/lower than the table values, except for potatoes. The correction for the yield is the P quantity additionally or not extracted compared to the standard yield, calculated by agreed table values (Anon., 2010a).

These application rates are also valid for a combination of chemical P fertiliser and other P applications (manure, organic fertilisers, etc.). The application of non-chemical fertiliser itself is not regulated, i.e. there are no restrictions if no chemical P is applied except for indirect restrictions resulting from the 170 kg N/ha/y limit implemented through the Nitrates Directive. Because crop needs are taken into account, phosphorus limits will be higher when two crops are grown in one year.

Derogation farms as defined by the implementation of the Nitrates Directive are restricted to a farm P surplus of 10 kg P/ha/y (Anon., 2010b).

In addition to the guidelines on land application of fertilisers under the Nitrates Directive (no application allowed when the soil is water-saturated, flooded, frozen or snow-covered), the Phosphorus Regulations set out additional restrictions: no chemical P fertiliser may be applied when

heavy rain is forecast within 48 hours (Northern Ireland Met Office forecast), on steeply sloping (>20%) ground where a significant risk of causing water pollution is determined after evaluating factors such as proximity to waterways, soil condition, ground cover and rainfall. Chemical fertiliser shall not be applied to any land in a location or manner which would make it likely that chemical fertiliser will directly enter a waterway or groundwater, or within 1.5 meters of any waterway.

Table 11. Soil P index categories and corresponding fertilisation rate for different crops in Northern Ireland (Anon., 2010a)

Soil P index	**0**	**1**	**2**	**3**	**> 3**
Soil P (Olsen P, mg/l)	0–9	10–15	16–25	26–45	>45
Crop	**Fertilisation rate (kg P_2O_5/ha/y)**				
Grass (establishment)	120	80	50	30	0
Grass (grazed)	80	50	20	0	0
Grass (silage)	150	120	90	20	0
Winter barley, winter wheat (8 t/ha)[a]	120	90	60	0	0
Spring wheat, spring barley, rye, triticale, oats (6 t/ha)[a]	105	75	45	0	0
Winter oilseed rape (3.5 t/ha)	110	80	50	0	0
Spring oilseed rape (2 t/ha) or linseed (1.5 t/ha)	90	60	30	0	0
Peas (4 t/ha) and beans (3.5 t/ha)	100	70	40	0	0
Potatoes (50 t/ha)	250	210	170	100	0
Sugar beet (60 t/ha)	110	80	50	0	0
Forage maize (40 t/ha fresh)	115	85	55	20	0
Forage swedes and turnips (65 t/ha)	105	75	45	0	0
Forage rape and stubble turnips (grazed)	85	55	25	0	0
Fodder beet and mangels (65 t/ha	110	80	50	0	0
Kale (40 t/ha cut)	110	80	50	0	0
Forage rye and forage triticale (20 t/ha)	95	65	35	0	0
Ryegrass seed	90	60	30	0	0

[a] Fertilisation rate is 5 kg P_2O_5/ha/y (10 P_2O_5/ha/y for oats) higher for P index 0, 1 and 2 if straw is removed

3.20 Norway

There are no maximum phosphorus application rates in Norway. However, livestock density is limited to maximum 2.5 livestock units per ha. Since the maximum livestock units are based on P content in excretion, this limitation corresponds to a limit of approximately 35 kg P/ha. Because this is only a restriction on farm basis, the phosphorus application on one parcel can be substantially higher or lower than 35 kg P/ha. Farmers, in small areas near highly polluted lakes, can get subsidies when they apply P fertiliser doses below national recommended levels, depending on crop type and soil P status.

There are also more indirect regulations of phosphorus, such as a 2 m buffer zone alongside surface waters. Subsidies are available to farmers who implement strategies that indirectly affect phosphorus (i.e. no tillage in autumn, grassy buffer zones along surface waters, sedimentation ponds, grass cover in landscape depressions and establishing a nutrient management plan).

3.21 Poland

Poland has no maximum phosphorus application rates or other P restrictions.

3.22 Scotland

A general binding rule in the Water Environment Regulations (Anon., 2013c) requires that fertilisers must not be applied to land in excess of the nutrient needs of the crop. This pre-authorised requirement allows farmers the flexibility in deciding the best method of compliance with the rule depending on their circumstances and will only be investigated where a breach of the rule is detected. There is no reporting system nor mandatory soil analysis. The regulations also require buffer zones to be maintained (see Table 17 below).

3.23 Spain

Spain has no general maximum phosphorus application limits or other P restrictions. The regulations affecting phosphorus application and losses are all indirect, e.g. by manure N restriction in the Nitrates Directive and erosion control in agro-environmental programmes. Only in the region of Extremadura, the phosphorus fertilisation for olive, rice, tobacco and deciduous fruit trees is limited to 80 kg P_2O_5/ha/y. Larger rates can be applied under special circumstances. A soil analysis is required every five years in this case as a basis for fertilisation and amendments.

3.24 Sweden

Livestock manure or other organic fertilisers may not be applied in quantities above 22 kg P/ha/y, calculated as an average for the holding's entire application area per year during the last 5 years. This regulation does not limit the application for a specific field but rather for the entire farm. The farmer can use standard values for P content of the manure, or calculate the P content by making a feed balance. Farmers with more than 400 animal units (as defined by the European Commission) or other facilities which fall under the Industrial Emissions Directive (2010/75/EU) can have additional specific obligations formulated in their permissions. Since the farmer has to account for the phosphorus situation in the field, stricter phosphorus standards are possible for a specific farm with high soil phosphorus contents. Sweden has no limits for chemical P fertilisation.

3.25 The Netherlands

3.25.1 General

Every four years in the Netherlands, a new fertilisation legislation comes into force as an implementation of the Nitrates Directive. The 5th Dutch Action Plan of the Nitrates Directive will probably accepted by the end of April 2014 and implemented in the current 'Meststoffenwet' (Anon., 2014c) and the 'Uitvoeringsregeling Meststoffenwet' (Anon., 2014d). Phosphorus and nitrogen application are both addressed in this legislation.

3.25.2 General application limits

The maximum phosphorus application standards are different for grassland (85-120 kg P_2O_5/ha/y) and for arable land (55-120 kg P_2O_5/ha/y). The crop cultivated at the start of the calendar year (15th of May) determines which set of maximum application standards should be used. Phosphorus can be given by manure, organic materials or chemical fertilisers. The maximum application standard depends upon the phosphorus status of the soil: 'high', 'neutral', 'low' or 'needing reparation' (very low P status) as determined by soil analysis (Tables 12 and 13). The limits in 2015 for soils with a neutral phosphorus status approximate the average phosphorus export of the harvest. On soils with a phosphorus content lower or higher than the neutral status, more or less phosphorus, respectively, can be applied than the maximum P application rate for soils with neutral P status. The phosphorus status is voluntarily measured at least every four years by ammonium lactate extraction (grassland) or water extraction (arable land). Non-analysed soils are assumed to have a high phosphorus status (lowest P application standards). In 2013, 56% of the Dutch grassland area was categorized as 'high' (80% assumed by lack of analysis), 30% as 'neutral' and 14% as 'low'. For arable land this was 63% high (93% assumed), 23% neutral and 14% low (Willems & Schröder, 2013).

Table 12. Maximum phosphorus application standards for grasslands in the Netherlands, depending on the soil phosphorus status (ammonium lactate extraction).

Phosphorus status	P-AL (mg P_2O_5/100 g)	Limit (kg P_2O_5/ha/y)	
		2014	2015-2017
High	> 50	85	80*
Neutral	27 – 50	95	90*
Low	< 27	100	100
Needing reparation	< 16	120$^{\$}$	120$^{\$}$

* To be confirmed by general administrative order.

$^{\$}$ For a maximum of 4 years

Table 13. Maximum phosphorus application standards for arable crops in the Netherlands, depending on the soil phosphorus status (water extraction).

Phosphorus status	Pw (mg P_2O_5/l)	Limit (kg P_2O_5/ha/y)	
		2014	2015-2017
High	> 55	55	50*
Neutral	36 – 55	65	60*
Low	< 36	80	75
Needing reparation	< 25	120$^{\$}$	120$^{\$}$

* To be confirmed by general administrative order.

$^{\$}$ For a maximum of 4 years

The limits for soils needing reparation (grassland P-AL < 16 mg P_2O_5/100 g or arable land Pw < 25) are 120 kg P_2O_5/ha/y during a period of 4 years maximum). The limits for grasslands with phosphorus status 'low' are fixed for 2014-2017 (100 kg P_2O_5/ha/y; Table 12). The limits for arable soils (all categories of soil P status) and grassland soils (phosphorus status high and neutral) will decrease by 5 kg P_2O_5/ha/y in 2015 (Table 13).

3.25.3 Deviations from the general limits

A farmer can apply a maximum of 20 kg P_2O_5/ha/y above the stated limits, providing that this surplus is compensated by lower phosphate application(s) in the next year.

Only 50% of phosphorus applied via compost is taken into account by Dutch legislation because compost has a considerable soil fraction. This exemption is limited to 3.5 kg P_2O_5/1000 kg.

3.25.4 Other

Part of the farm phosphorus surplus (manure) must be processed or exported. The percentage of the farm phosphorus surplus that has to be processed or exported varies per region (these are related to the manure concentration areas). For 2014 the values are 30% (South), 15% (East) and 5% (other). The values are defined annually by the ministry of Economic Affairs.

No subsidies are given to farmers that voluntarily apply less phosphorus than legally allowed.

4 Discussion

4.1 General

Limiting the P application by maximum application rates is one of the ways to reduce the direct risk of P losses to surface waters. General legislation concerning the use of manure or fertilisers can also indirectly limit the P use in agriculture. In Nitrate Vulnerable Zones (NVZ) the application of manure is restricted to 170 kg N/ha/y or a higher value in case of derogation. This tends to limit the P application by manure, depending on the N/P ratio of the applied manure. The implementations of the Nitrates Directive also contain periods when (see also Figure 2 and Appendix 3), places where farmers may not apply fertilisers, and restrictions to the manner in which fertiliser is applied in NVZs. Other regulations can limit land application of waste water treatment sludge, impose measures for limiting erosion losses, etc. which all indirectly contribute to less P losses from agriculture towards surface waters.

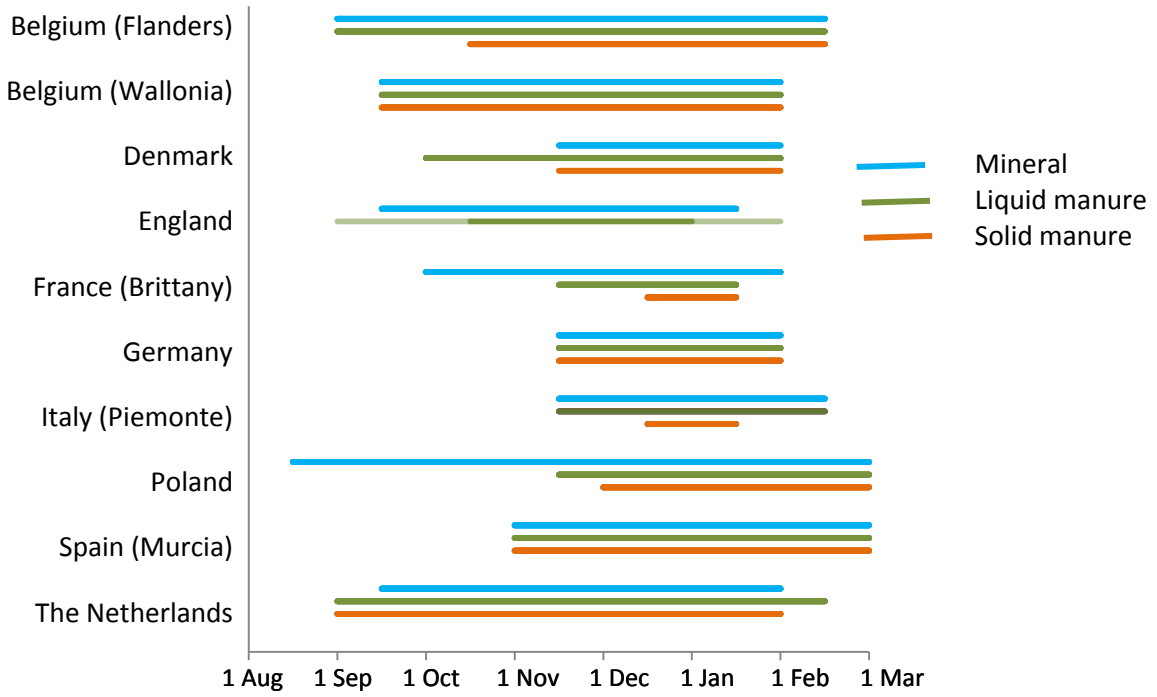

Figure 2. General overview of periods within no mineral (blue), liquid manure (green) and solid manure (orange) can be applied on grasslands in Nitrate Vulnerable Zones (adapted from Hofman et al., 2013)

Direct regulations for phosphorus applications on agricultural land differ widely across European countries and regions. Some countries have no explicitly-stated regulations concerning phosphorus while others have detailed maximum application standards depending upon the crop and/or the soil phosphorus status. The various systems used, e.g. maximum application standards, balance system, etc., complicate the efforts to compare regulations across nations/regions. Even within the system of maximum application standards there are different subjects of regulation: total P, only manure P or

only chemical fertiliser P (see 4.2). Table 14 presents an overview of the different systems and limits. All application rates are reported in kg P_2O_5/ha/y units. To switch from kg P/ha/y to P_2O_5/ha/y units, rates have to be multiplied by 2.29. Within the system of maximum application standards for total phosphorus, Flanders and Brittany have the lowest maximum limits (95 kg P_2O_5/ha/y). Ireland has the lowest minimum limit: for certain crops planted on soils with the highest phosphorus status, the phosphorus application limit is zero.

The extent of the phosphorus legislation and the severity of the application limits is largely related to the ecological condition of the national or regional water bodies. Countries with no (or limited) phosphorus legislation often argue that there are no phosphorus problems in their country. Countries or regions with strict application limits have a history of large phosphorus applications, resulting in large soil phosphorus contents (Figure 3) and a majority of the water bodies with a less than good ecological status or potential (Figure 1). This is especially the case in NW European countries. Nevertheless, some of the countries and regions in Europe with high phosphorus contents in soil and high P concentrations in surface waters do not have an extensive phosphorus legislation, e.g. parts of England, Wales, Poland, France, etc.

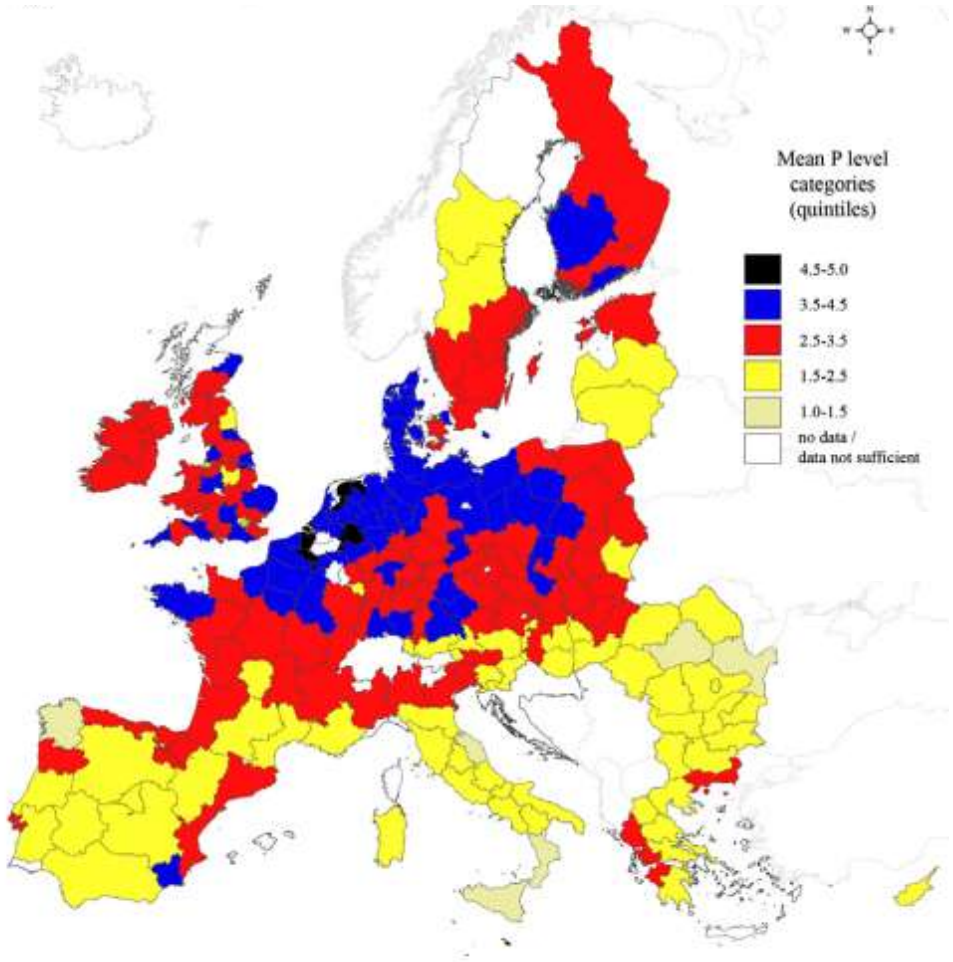

Figure 3. Olsen P concentration categories of cropland soils in the EU 2009-2012, based on the LUCAS topsoil survey (Tóth et al., 2014).White: no data; light yellow: very low; yellow: low; red: medium; blue: high; black: very high.

Table 14. Overview of phosphorus legislation per country/region (limits in kg P_2O_5/ha/y; divide by 2.29 to get units in kg P/ha/y)

Country/region	P application limits?	Regulation system	P type regulated	Limits (kg P_2O_5/ha/y)	Limits depend upon
Austria	No[b]	-	-	-	-
Belgium – Flanders	Yes	Max. rates	Total P	40–95	Crop type, phosphate saturated soil or not
Belgium – Wallonia	No[b]	-	-	-	-
Czech Republic	No[b]	-	-	-	-
Denmark	No[bc]	-	-	-	-
England, Scotland and Wales	No[bg]	-	-	-	-
Estonia	Yes	Max. rates	Manure P Extra chemical P	57 5–224	- Crop type, yield and soil P
Finland	AEP[a]	Max. rates[a]	Total P[a]	0–252[ad]	Soil P, crop type and yield[a]
France – Brittany	Yes	Max. rates or balance	Total P	80–95 or export + 10%	Farm type and water basin, or crop export
Germany	Yes	Balance	Total P	export + 20	Balance (crop yield and export) and soil P
Greece	No[b]	-	-	-	-
Hungary	No[b]	-	-	-	-
Ireland	Yes	Max. rates	Total P	0–286	Crop type and soil P (and yield for cereals)
Israel	No	-	-	-	-
Latvia	No[b]	-	-	-	-
Luxembourg	AEP[a]	Max. rates[a]	Total P[af]	0–186[ad]	Soil P, crop type and yield[a]
Northern Ireland	Yes	Max. rates	Chemical fertiliser P[f]	0–250[d]	Advice (soil P, crop type and yield)
Norway	Yes	Max. rates	Manure P	80	-
Poland	No[b]	-	-	-	-
Spain	No[be]	-	-	-	-
Sweden	Yes	Max. rates	Manure P	50	-
The Netherlands	Yes	Max. rates	Total P	55–120	Soil P (and crop: grass or arable crop)

[a] AEP: No strict regulations but requested in Agri-Environmental Programme (95% participation in Finland and Luxembourg)

[b] Only indirect limitation of phosphorus in manure applied in Nitrate Vulnerable Zones (or whole territory for some countries) by the limit of 170 kg N/ha/y (140 kg N/ha/y for most animals in Denmark)

[c] Restrictions on manure P surplus; only for animal farms that want to expand or change and that drain into Nature 2000 areas that are overloaded with P *and* that fall under class 1, 2 or 3 (see details in Denmark section)

[d] Higher limits possible for higher than average crop yields

[e] Except for the Extremadura region: limit of 80 kg P_2O_5/ha/y for olive, rice, tobacco and deciduous fruit trees.

[f] Manure P (Luxemburg) and organic P fertiliser (Northern Ireland) only restricted if combined with chemical P fertiliser

[g] Scotland: fertilisers must not be applied to land in excess of the nutrient needs of the crop.

In addition to the differences in legislation, the control systems embedded in these regulations differ widely among European countries. Some regulations lack specificity and real enforcement (Ekardt et al., 2011). As an example, not all European countries require mandatory submission of information about nutrient management to the authorities. This affects the degree of compliance with the regulations. In the context of implementation of the Nitrates Directive, penalties, inspection rates (1% to more than 5%) and annual updates of the control action plans differ widely among Member States (Schils & Velthof, 2011).

4.2 Type of restricted phosphorus application

Not all types of phosphorus applications to agricultural land are limited by the various regulations (Table 15). Most of the countries or regions with phosphorus application standards limit all types of phosphorus fertilisation, but this is not the case for Northern Ireland (only chemical fertilisers and other applications in combination with chemical P fertiliser), Luxembourg (manure P is only taken into account when applied in combination with other fertilisation), Sweden (only P in organic fertilisers), Norway (only manure P), Denmark (only organic fertilisers consisting of less than 75% manure) and Latvia (only WWTP sludge). In Ireland, only 50% of P in organic fertilisers must be taken into account for application on soils with low P content (index 1 and 2). In the Netherlands and Flanders (Belgium), only 50% of compost P must be taken into account. In Finland, not all P from manure, sludge and compost has to be taken into account (see Table 15).

4.3 Limits for different crops

Some countries or regions have general phosphorus application standards, while in other countries the phosphorus application standards depend upon the crop cultivated (see last column of Table 14). Phosphorus application standards for the main crops are compared for the different countries and regions (Table 16). The standards presented in Table 16 are valid for soils with moderate P content, which is of course not exactly the same for all countries and regions (for legislation with standards that depend upon soil P status, see 4.4). Maximum phosphorus application standards are generally more strict in northwestern Europe, where a large fraction of the surface waters is not in good ecological condition (see left map in Figure 1). However, not all countries with large phosphorus concentrations in surface waters limit phosphorus fertilisation. Another important factor that determines the extent of the limits is the average national crop yield. The allowed phosphorus inputs increase along with the increasing phosphorus export by the crop, and therefore the increasing crop yield, in cases where the goal is equilibrium fertilisation. This can explain the higher phosphorus application limits for countries or regions with intensive agriculture.

Many European countries do not have any maximum phosphorus application standards. For the countries and regions that do have standards, the maximum application standard for grassland are highest for Flanders (Belgium), Brittany (France) and the Netherlands, all intensive agriculture areas (Table 16). Differences between countries and regions are smaller for maize, cereals and sugar beets. Potatoes, a phosphorus-sensitive crop, have much higher maximum application standards than other crops in Estonia, Finland, Ireland and Northern Ireland.

Table 15. Types of phosphorus application limited by the various countries and regions (x: included in restrictions, -: not included; limits in kg P_2O_5/ha/y, divide by 2.29 to get units in kg P/ha/y)

Country/region	Limits (kg P_2O_5/ha/y)	Limits refer to P in			
		Chemical fertiliser	Manure	WWTP sludge	Compost
Austria	-	-	-[b]	-	-
Belgium – Flanders	40–95	x	x	x[*]	x (50%)
Belgium – Wallonia	-	-	-[b]	-	-
Czech Republic	-	-	-[b]	-	-
Denmark	69	-	-[be]	x	-
England, Scotland and Wales	-[g]	-	-[b]	-	-
Estonia	57 5–224	- x	x x	- -	- -
Finland	0–252[cf]	x[c]	x (40-85%)[cd]	x (40%)[cd]	x (40-100%)[cd]
France – Brittany	80–95 or export + 10%	x	x	x	x
Germany	export + 20	x	x	x	x
Greece	-	-	-[b]	-	-
Hungary	-	-	-[b]	-	-
Ireland	0–286	x	x (50 or 100%[$])	x (50 or 100%[$])	x (50 or 100%[$])
Israel	-	-	-	-	-
Latvia	92	-	-[b]	x	-
Luxembourg	0–186[cf]	x[c]	(x)[abc]	x[c]	x[c]
Northern Ireland	0–250	x	(x)[ab]	(x)[a]	(x)[a]
Norway	80	-	x	-	-
Poland	-	-	-[b]	-	-
Spain	-[h]	-	-[b]	-	-
Sweden	50	-	x	x	x
The Netherlands	55–120	x	x	x	x (50%)

[*] Less than 10% of WWTP sludge has acceptable levels of metals and organic pollutants

[$] 50% for low soil P content (index 1 and 2), 100% for high soil P content (index 3 and 4)

[a] Only restricted if this type of fertilisation is combined with chemical P fertiliser

[b] Indirect limitation of phosphorus in manure applied in Nitrate Vulnerable Zones (or the entire territory for some countries) by the limit of 170 kg N/ha/y (140 kg N/ha/y in some cases in Denmark)

[c] AEP: No strict regulations but requested in the Agri-Environmental Programme (95% participation in Finland and Luxembourg)

[d] 85% for manure, 40% for fur-animal manure (foxes, minks, finnraccoons and fitchets), compost: depending on starting material. Will probably increase to 100% (manure) and 60% (fur-animal manure and sludge) from 2015 on.

[e] Restrictions on manure phosphorus surplus; only for animal farms that want to expand or change and that drain into Nature 2000 areas that are overloaded with P *and* that fall under class 1, 2 or 3 (see details in Denmark section)

[f] Higher limits possible for higher than average crop yields

[g] Scotland: fertilisers must not be applied to land in excess of the nutrient needs of the crop.

[h] Except for the Extremadura region: limit of 80 kg P_2O_5/ha/y for olive, rice, tobacco and deciduous fruit trees.

Table 16. Phosphorus application standards for various crops at a moderate soil P status (limits in kg P_2O_5/ha/y; divide by 2.29 to get units in kg P/ha/y)

Country/region	Grassland	Maize	Cereals	Potatoes	Sugar beet
Austria	-	-	-	-	-
Belgium – Flanders	95	80	70–75	65	65
Belgium –Wallonia	-	-	-	-	-
Czech Republic	-	-	-	-	-
Denmark[f]	-	-	-	-	-
England, Scotland[e] and Wales	-	-	-	-	-
Estonia	57 (manure) 46–60 (+ch)*	57 (manure) 69 (+ ch)*	57 (manure) 34–66[d] (+ch)*	57 (manure) 126–149[d](+ch)	57 (manure)
Finland	18–55[c]	69[c]	18–32[cd]	126[c]	98[c]
France – Brittany	80–95 or export + 10%	80–95 or export + 10%	80–95 or export + 10%	80–95 or export + 10%	80–95 or export +10%
Germany	export + 20	export + 20	export + 20	export + 20	export + 20
Greece	-	-	-	-	-
Hungary	-	-	-	-	-
Ireland	25–71	92	57[d]	172	92
Israel	-	-	-	-	-
Latvia	-	-	-	-	-
Luxembourg	40–88[acd]	120–126[acd]	60–65[acd]	102[acd]	-
Northern Ireland	20–90[ad]	55[ad]	45–65[ad]	170[a]	50[ad]
Norway	80[b]	80[b]	80[b]	80[b]	80[b]
Poland	-	-	-	-	-
Spain	-	-	-	-	-
Sweden	50[b]	50[b]	50[b]	50[b]	50[b]
The Netherlands	95	65	65	65	65

* Crop requirement, can be given on top of manure P by chemical fertiliser

[a] Manure P (Luxemburg) and organic P fertiliser (Northern Ireland) only restricted by these limits if combined with chemical P fertiliser

[b] Only manure P (Norway) or P from organic fertilisers (Sweden), for total area

[c] AEP: No strict regulations but requested in Agri-Environmental Programme (95% participation in Finland and Luxembourg).

[d] Limits are higher for higher yields in Estonia, Finland, Ireland, Luxembourg and Northern Ireland. In Estonia, Luxembourg and Northern Ireland: also lower limits for lower yields.

[e] Scotland: fertilisers must not be applied to land in excess of the nutrient needs of the crop.

[f] Restrictions on manure phosphorus surplus; only for animal farms that want to expand or change and that drain into Nature 2000 areas that are overloaded with P *and* that fall under class 1, 2 or 3 (see details in Denmark section)

4.4 Taking the phosphorus status of soils into account

The risk for phosphorus losses from agricultural soils towards surface waters and groundwaters varies strongly from field to field. The main goal of agricultural phosphorus legislation is to reduce phosphorus losses towards water bodies. Therefore, one can argue that limiting phosphorus

application should be linked to the risk for phosphorus losses. Targeting phosphorus fertilisation in the high-risk areas will probably give the best or fastest improvement in water quality. Phosphorus losses depend upon the availability of P (soil P status and P fertilisation), transport possibilities (slope, soil texture, subsurface drainage, etc.) and connectivity to the receiving waters. These factors are all considered in the Phosphorus Index (Heathwaite et al., 2003), although some doubts have been expressed about the suitability of the index for areas where P transport mainly occurs through leaching (Schoumans et al., 2013). There are no European countries or regions where the maximum P application standards depend upon the P Index or another combination of the abovementioned factors. The connectivity and erosion losses can be addressed by installing a buffer zone (no P fertilisation) along waterways, as many countries have already implemented (Table 17). As an alternative for the P Index, maximum phosphorus application standards can depend upon the soil phosphorus content, which is an important factor in phosphorus loss (Sharpley & Rekolainen, 1997; Tunney, 2002; Rubaek et al., 2010). Many methods are used to measure the soil phosphorus concentration, from mild extractions (by water) to relatively harsh extractions (e.g. oxalate extraction). Most of the methods for soil P measurement are developed for agricultural purposes, i.e. estimation of the availability of P for the crop, and not for environmental goals, i.e. risk for P losses.

The countries or regions with stricter P application regulations for soils with a higher soil P status are the Netherlands, Ireland, Finland (AEP), Luxembourg (AEP), Northern Ireland (only chemical P fertiliser) and Estonia (only chemical P fertiliser in addition to manure P). In Denmark, stricter regulations for manure surplus are applicable at larger soil Olsen-P content for farms that want to expand or change and that drain into Natura 2000 areas overloaded with P. In the Netherlands, 3 (4) soil P classes are defined based upon ammonium lactate extraction (grasslands) or water extraction (arable land). Extraction by ammonium lactate is an agricultural method; water extraction is used both for agricultural and environmental purposes. Ireland has 4 classes defined by Morgan's extraction (weakly acidic, agricultural method). In Northern Ireland, the agricultural Olsen P method is used. In Finland, which uses an acid ammonium acetate extraction (pH 4.65), the fertility class also depends upon the soil texture and the organic matter content. In Estonia, an agricultural method (Mehlich 3 extraction) is used. In Luxembourg, the agricultural calcium acetate lactate extraction is applied. Comparison of the different limits of soil P classes is not possible given the differences in extraction methods and soil sampling depth. Factors for converting the result of one method to another method depend highly upon soil characteristics and are therefore not generally valid (Schoumans, 1997; Sibbesen & Sharpley, 1997; Otabbong et al., 2009).

Flanders (Belgium) has a reduced maximum fertilisation standard (40 kg P_2O_5/ha/y) for a small phosphate-saturated area (0.6–1% of agricultural area). The method for measuring the phosphate saturation degree (PSD) was developed for environmental purposes. It is based on the relationship between the phosphate saturation degree of a soil and the molybdate reactive phosphorus (MRP) concentration in the leachate. Based on a generally acceptable concentration of 0.1 mg MRP/l for surface waters, a limit of 25% PSD was derived (van der Zee et al., 1990b). In Flanders, the PSD limit is set at 35%. Measurements of drainage water in 19 Flemish fields revealed that none exceeded the 0.1 mg MRP/l limit at PSD < 35% (Brookes et al., 1997). However, possible increases in phosphorus drainage concentrations over time were not taken into account. The phosphate-saturated area in Flanders is small because of the higher limit of 35% (compared to 25%), the necessity of 95% probability of exceeding the 35% threshold, and the fact that the protocol for PSD measurement is only valid for non-calcareous light-textured soils (only half of Flanders' agricultural area). In the

Netherlands, 56% of the agricultural area is phosphate-saturated (>25%) (Schoumans, 2004), but this has no legislative implications.

Standard application rates depending upon the soil phosphorus status have as a result that soils with high phosphorus contents will accumulate less P or that the phosphorus content will diminish over time. Consequently, efforts aimed at the highest-risk soils will result in reduced P risks while equilibrium fertilisation on soils with acceptable P levels will assure optimal crop yields. In the Netherlands, Ireland, Northern Ireland, Germany, Finland, Luxembourg and Estonia, more phosphorus can be applied to soils with low phosphorus status. This enables farmers to gradually increase the soil phosphorus content in order to obtain optimal yields. Of course the rate of the transition of soils with low and high P levels towards an optimal P level will depend upon the extent of the difference between the maximum P application standard and the crop P export. Large differences (large net P inputs for low P soils or large net P outputs for high P soils) will induce faster changes in the soil P content. These net inputs and outputs are rather small in the Netherlands, as reflected by the small range of maximum P application rates, i.e. 55–120 kg P_2O_5/ha/y for arable crops and 85-120 kg P_2O_5/ha/y for grasslands. In contrast, the net P inputs and outputs in Ireland are large, as for some crops no P application is allowed for index 4 soils (net output equals P export by the crop) and the maximum P application rate for index 1 soils is very high (see Tables 7 and 8). However, given the importance of hydrology and connectivity between field and water body, there is no 1:1 relationship between the soil phosphorus content of a field and phosphorus losses from the field to surface water. Currently, no national or regional legislation takes the latter two factors into account, but they should be part of an effective P risk approach. Legislative measures based on a more environmental approach to phosphorus fertilisation restrictions would be more effective when attempting to influence the phosphorus concentrations in surface waters.

4.5 Constraints for farmers

Countries or regions with detailed legislation generally have large agricultural phosphorus losses and a large fraction of soils with high phosphorus status. More phosphorus than required for crop production was or is applied because of uncertainty about soil phosphorus status, insurance for optimal crop yields and/or a farm manure surplus. Manure generally has a N/P ratio between 2 and 8, in contrast to the N/P ratio of 7 – 11 required by crops. When the crop's N requirement is applied by using solely manure, this results in an excess of P.

Crops do not suffer from high soil P contents. Apart from the economic cost of chemical fertiliser, a farmer has no incentive to limit the P application. In regions without manure surplus, the availability of good fertilisation advice (Jordan-Meille et al., 2012) and encouragement to measure the soil P status can already limit the P application. But for farms with manure surpluses, fertilisation restrictions affect farmers' practices and income. Moreover, manure is considered a main contributor to organic matter build-up in the soil and substantial restrictions on manure application can therefore limit the maintenance of the organic matter content which can influence the soil properties.

Maximum phosphorus application rates are often set by general crop requirements or crop P exports. Crop requirements are often higher than the export of P by harvest for crops with a low root density (e.g. endive, spinach, potatoes, onions, etc). Higher yields and P exports are often established

by very intensive farming. This is taken into account using balance systems, where phosphorus limits vary according to the crop yield (and in some cases also the crop P content). Balance systems are used in Germany and in some cases in Brittany (France). In Ireland the maximum application standard for cereals increases at higher yields. This is also the case in the Agri-Environmental Programmes of Finland (cereals, rye and oil plants) and Luxembourg. In Northern Ireland, maximum P application rates by chemical fertiliser increase or decrease at higher or lower yields, except for potatoes. In Estonia, the chemical P fertiliser dose that can be applied depends upon the predicted yield. Balance systems also take multiple crops in one year into account since the P export by all crops is calculated. In Ireland and Northern Ireland, the maximum P application standard of one year is the sum of the maximum P application standards of all crops cultivated in that year. In Belgium (Flanders) and the Netherlands, maximum standards do not increase if more than one crop is cultivated in one year, with the exception of one cut of grass or rye followed by maize in Flanders.

4.6 Additional legislation

In addition to general fertiliser restrictions (see above), other regulations also address phosphorus application. In the Netherlands and Flanders (Belgium), part of the farm manure surplus must be processed or exported. In Flanders, this farm manure surplus is based on N production, but in the Netherlands it is based on the phosphorus farm balance.

The main risk related to phosphorus fertilisation is the eutrophication of surface waters. Most European countries have buffer zones along waterways or sources where no fertilisation is allowed. The width of this buffer zone differs widely among the Member States, i.e. from 0.5 m to 500 m (Table 17). Buffer zone width varies with fertilisation type: some countries or regions require a larger width for manures than for chemical fertiliser. The buffer zone width can also vary depending upon the water body type: larger water bodies require wider buffer zones. Larger widths are sometimes requested for more vulnerable areas and sloping land. Wider buffer zones are installed around abstraction points for human water consumption. Some Member States have no restrictions outside the NVZs except under Agri-Environmental Programmes or Cross Compliance. In almost all countries and regions the buffer zone area can be included in the total area for fertilisation calculations of the field, except in Denmark.

Table 17. Buffer zone regulations in the European countries/regions

Country/ Region	**No-fertilisation buffer zone from a water body**			
	Fertiliser type restricted	distance (m)	Where/What kind of waterways	Grazing allowed?
Austria	All types	5	Permanent waterway	Yes
Belgium – Flanders	All types	5	Waterways of all categories, smaller ditches usually not included	Yes
		10	Waterways located in Flemish Ecological Network or next to a slope of >8%	Yes
Belgium – Wallonia	Manure	6	Waterways	Yes
Czech Republic	All types	3	Any surface water in NVZs and for farmers under the agri-environmental programme	No
	Liquid fertilisers with fast N release (liquid manure, ammonia)	25	Any surface water with land slope > 7° in NVZs and for farmers under the agri-environmental programme	Yes
Denmark (cont p 33)	All types	10	Streams and lakes with surface area > 100 m². The buffer zone area can be reduced to 5% of the total farm area if the 10 m buffer zone area is > 5%.	Yes

Denmark (cont p 32)	All types	20	Streams and lakes with surface area > 100 m² if slope >6°. If the slope is between 6° and 12°, it is allowed to use liquid mineral fertilisers and manure injected parallel with the stream/lake between 10 and 20 m distance of the stream/lake.	
England and Wales	Inorganic fertiliser	2	Any controlled water (includes freshwater streams, rivers, ditches, lakes) within a NVZ, and outside a NVZ for Single Farm Payment or Agri-Environment Subsidies	Yes
	Organic manure	10 (6)	Any controlled water (includes freshwater streams, rivers, ditches, lakes) within a NVZ, and outside a NVZ for Single Farm Payment or Agri-Environment Subsidies. Limit of 6 m for precision spraying equipment.	
Estonia	All types	1	Drainage systems with catchment area < 10 km²	Yes
		10	Other lakes, rivers, streams, springs and channels	
		20	Baltic Sea and two largest lakes (Peipsi and Võrtsjärv)	
Finland	N fertiliser	5 (10)	Waterways (10 m if slope > 2%)	Yes
	All types[b]	1[b]	Main ditches[b]	
		3[b]	Brooks, water courses, rivers, lakes, sea and household wells[b]	
France – Brittany[a]	Mineral fertiliser	5	All waterways and conditions	Yes, except if the buffer zone is registered as fallow land
	Solid and composted manure	35 (10)	Waterways (10 meter if a grass strip is present)	
	Liquid manure	35 (10)	Waterways (10 meter if a grass strip is present)	
		100	Waterways when slope > 5% (except if slope <15% + hedgerows present: 35 m)	
		500	Fish farming	
	All manures	50	Water abstraction point for human consumption	
		200	Bathing, beaches	
		500	Shell production areas (coast)	
Germany	All types	3 (1)[c]	All waterways. Reduction to 1 m in the case of exact application techniques and slope <10%.	Yes
Greece	All types	0.5	Irrigation canals, ditches, wells and boreholes	Yes
		5	Rivers, streams, lakes	Yes
Hungary	Chemical fertilisers	2	Surface waters in NVZs	Yes
	Manure	20	Lakes in NVZs	
		5	Other surface waters in NVZs (3 if the plot width ≤ 50 m and plot area ≤ 1 ha)	
		25	Springs, wells used for drinking water supply in NVZs	

Ireland	Chemical P fertiliser	2	Any surface water	Yes
	Organic fertiliser or soiled water	100/200	Abstraction point of any surface water for human consumption in a water scheme supplying 10/100 m³/day or more, or serving 50/500 or more persons/day	
		25	Any borehole, spring or well used for abstraction of water for human consumption other than mentioned above	
		20	Lake shoreline	
		15	Exposed cavernous or karstified limestone features	
		5	Other surface waters than mentioned above	
		10	Other surface waters, where the land has an average incline > 10%	
		10	Other surface waters, two weeks before and after periods closed for fertiliser application	
Latvia	Fertilisers and PPP	10 and more	All rivers with length > 10 km, lakes with surface area > 10 ha. Exact width of buffer zone depends upon the importance of the surface water (e.g. Daugava river: 500 m). Width of buffer zones for groundwater abstraction points can be designated according to local conditions.	Yes
Northern Ireland	Chemical P fertiliser	1.5	Any waterway through which water flows	Yes
	Manure	20	Lakes	Yes
		50	Borehole, spring or well	
		250	Borehole for a public water supply	
		15	Exposed, cavernous or karstified, limestone features	
		10	Any waterway through which water flows, other than lakes, including open areas of water, open field drains or any drain which has been backfilled to the surface with permeable material such as stone/aggregate, except in cases below	
		3	Waterways where the land has an average incline < 10%, organic manure is spread by band spreader, trailing hose, trailing shoe or soil injection, or the adjoining area is < 1 ha in size and not > 50 m in width	
Norway	All types	2	Any waterway. Two metres is mandatory; subsidies (depending on the region and year) are given for 8-10 metres.	Yes

Poland	Fertilisers excluding slurry	5	Lakes and reservoirs < 50 ha, water courses, ditches (< 5 m width), channels. Connected with direct support schemes for farmers.	Yes
	Slurry	10		
	All types	20	Lakes and reservoirs > 50 ha, water intake protection zones, coast (Baltic Sea). Connected with direct support schemes for farmers.	
	All types	2–5	Subsidy for buffer zones along streams	Yes
Spain	All types	–	Most of the regional implementations of agro-environmental measures considers the "maintenance of uncropped borders and zones" in some cases around watercourses to "promote biological diversity"[d]	–
Scotland	Inorganic fertiliser	2	Any river, burn, ditch, wetland, loch, transitional water or coastal water	Significant erosion or poaching must be prevented (5 m)
	Organic fertiliser	10	Any river, burn, ditch, wetland, loch, transitional water or coastal water	
		50	Spring that supplies water for human consumption or any well or borehole that is not capped to prevent water ingress	
	Livestock access	5	Spring that supplies water for human consumption or any well or borehole that is not capped to prevent water ingress	No
Sweden	All types	2	Brooks, streams, rivers, canals or weirs (small dams) within a NVZ, and outside a NVZ for Cross Compliance	Yes
The Netherlands	All types	5	Designated brooks in the uplands of the sandy districts of the Netherlands	Yes

[a] Similar distances in other NVZs of France

[b] AEP: No strict regulations but requested in Agri-Environmental Programme (95% participation)

[c] German regions (Laender) can have stricter regional standards, e.g. 5 m buffer strip in Baden-Württemberg according to the regional Water Act

[d] These types of buffer zones are usually promoted in areas of special ecological interest: borders of natural reserves, in some cases in watercourses, in areas of special interest for birds, etc.

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Appendix 1: Questionnaire for COST action 869

Question 1: Legislation on P application standards

Every country has its own advisory system to farmers, often based on the P status of the soil or on direct P response of crops. This advice is voluntary. The question we are interested in: are these P application rates also regulated in your national legislation ("by law"), e.g. via a maximum set for annual P application rates? And if so, is the P status of the soil taken into account?

Question 2: Other regulations implemented?

Furthermore, are there any other types of official regulations implemented in legislation in your country specifically to reduce P losses from agricultural land?

Question 3: Future expectations

Can such legislation be expected in the near future (or are there any developments in this area in your government) regarding this subject, e.g. based on the discussions regarding the implementation of the WFD?

Appendix 2: Questions for update of phosphorus legislation (2013-2014)

- *Is the use of phosphorus regulated in the national legislation related to the European Nitrate Directive? What is the name of, and reference to, the legislation?*
- *In which years is the legislation applicable? When is new legislation expected?*
- *Are there standard application rates for phosphorus use on agricultural fields?*
    - *If no: is there an alternative (mandatory balance, tax on use,…)?*
    - *If yes:*
        - *What are the maximum application rates? Are these expressed in kg P_2O_5/ha/y? Will these application rates change in the near future?*
        - *Is there a 'philosophy' or scientific basis for the maximum application rates (e.g. standard = average crop P export, or is the standard related to the maximum allowable P loss from an agricultural field,…)*
        - *Do the standard application rates take both manure and fertilisers into account?*
        - *Can the farmer choose whether he/she uses manure or fertiliser?*
        - *Is there only one standard application rate or are the standards differentiated? If differentiation: to crop, to soil P or to something else?*
        - *Are the standard application rates flat or are there exceptions? For example, is there an exception for very intensive farms with crops that export more phosphorus from the soil?*
        - *Is the standard application rate larger if two crops are grown in one year?*
        - *Can part of the standard application rate be transferred to the next year? If so, what are the conditions?*
        - *Are there adapted standard rates for*
            - *soils that are sensitive to P loss? If yes: what are these rates? How are these soils defined?*
            - *vulnerable areas? If yes: what are these rates? How are these areas defined?*
            - *permanently covered soils*
            - *other kind of soils?*
            - *Certain types of manure, organic materials, etc. (e.g. compost in Flanders)?*
- *Are there subsidies for farmers that voluntary apply limited amounts of phosphorus? If yes: what are the conditions?*

Appendix 3: Fertilisation prohibition periods

Prohibition periods of nutrient applications in European countries and regions (Adapted from Hofman et al., 2013)

Country or region	General prohibition period
Belgium	
- Flanders	1 Sept. - 15 Feb. On heavy clay soils 15 Oct. - 15 Feb. Champost and FYM[1] 15 Nov. - 15 Jan.
- Wallonia	<u>Mineral N</u> Grassland: 15 Sept. - 31 Jan. Other crops: 15 Oct. - 15 Feb. <u>Organic N</u> Grassland: 15 Sept. - 31 Jan Other crops: 1 July - 15 Feb. Exception: Catch crop or winter crop (limited till 80 kg N/ha): 15 Sept. – 15 Feb.
Denmark	<u>Mineral N, solid manure and silage effluent</u> 15 Nov. – 1 Feb. No solid manure after harvest unless before winter crops Silage effluent (unless it is on areas without green cover or if no crops the following winter): harvest – 1 Nov. <u>Liquid manures, degassed organic mass</u> Harvest (at the latest 1 Oct.) – 1 Feb. Grass seed: 15 Oct. – 1 Feb. Established winter persistent feed grass areas, areas where winter rape seeds are to be cultivated the following period, catch crops and yellow mustard: 1 Oct. – 1 Feb. Specific weather conditions: 15 Oct. – 1 Feb. Perennial crops (no harvest): 1 Sep – 1 March
France - Brittany	<u>Mineral fertilisers</u>: Grassland 1 Oct. - 31 Jan. Crops sown in autumn or at the end of the summer: 1 Sept. - 31 Jan. Crops sown in spring: 1 July - 15 Feb. <u>Liquid manure, poultry manure</u>: Grassland: 15 Nov. - 15 Jan. Crops sown in autumn or at the end of the summer: 1 Oct. - 31 Jan. Crops sown in spring: 1 July - 31 Jan. Crops sown in spring, preceded by green manure: from 1 July until 15 days before sowing green manure, and from 20 days before destruction or harvest of green manure until 31 Jan.

	<u>Solid manure</u>: Grassland: 15 Dec. - 15 Jan. Crops sown in autumn or at the end of the summer: 15 Nov. - 15 Jan. Crops sown in spring: 1 July - 31 Aug. and 15 Nov. - 15 Jan. Crops sown in spring, preceded by green manure: from 20 days before destruction or harvest of green manure until 15 Jan.
England	<u>Mineral fertilisers</u> Grassland: 15 Sept. - 15 Jan. Other crops: 1 Sept. - 15 Jan. <u>Liquid manure</u> Grassland: 1 Sept. - 31 Dec. on shallow or sandy soils, 15 Oct. - 31 Jan. on other soils Other crops: 1 Aug. - 31 Dec. on shallow or sandy soils, 1 Oct. - 28 Feb. on other soils <u>Solid manure</u> No prohibition period
Germany	Grassland: 15 Nov. - 31 Jan. Other crops: 1 Nov. - 31 Jan. After harvest of the main crop, no N fertilisation except when there is a catch crop or a winter crop or straw will be incorporated (maximum 80 kg total N/ha or 40 kg NH_4^+ N/ha) FYM all year round
Italy - Piemonte	<u>Mineral fertilisers</u> 15 Nov. - 15 Feb. <u>Liquid manure</u> Grassland + winter crops: 15 Nov - 15 Feb. Other crops: 1 Nov. - 28 Feb. <u>Solid manure</u> Grassland: 15 Dec. - 15 Jan. Other crops: 15 Nov. - 15 Feb.
The Netherlands	<u>Mineral fertilisers</u> 16 Sept. – 31 Jan. <u>Liquid manure</u> 1 Sept. - 15 Feb. <u>Solid manure</u> 1 Sept. - 31 Jan. Arable land on clay and peat: no restrictions

Poland	<u>Mineral N fertilisers</u> Grassland: 15 Aug. - 1 March Arable land: 15 Nov. – 1 March <u>Liquid manure and urea</u> Grassland: 15 Nov. – 1 March Arable land: 15 Nov. – 1 March <u>Solid manure</u> Grassland: 30 Nov. – 1 March Arable land: 15 Nov. – 1 March
Spain	
- Andalusia	Not in fallow period unless cover crop is present. Not before 15 days before planting or sowing.
- Murcia	Perennial crops: from 1 Nov. - 29 Feb.
Switzerland	In one region, between 15 Dec. and 15 Feb.

[1] Champost = composted substrate from mushroom production; FYM = farm yard manure





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