WAGENINGEN UR
For quality of life

Aan de Minister van LNV
voor deze de Directeur van de Directie Agroketens & Visserij
t.a.v. Ir. C.A.C.J. Oomen
Postbus 20401
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Geachte heer Oomen,

Met genoegen bied ik u hierbij het rapport "Agricultural Nitrogen Use in selected EU-countries" aan. De opdracht tot het uitvoeren van voornoemde studie is door u per brief aan de Commissie Deskundigen Meststoffenwet (CDM) verstrekt (Brief TRCDL/2008/1927 van 29 juli 2008, met als onderwerp 'Benchmark bemestingsadviezen en werkingscoëfficiënten').

In het rapport worden de verschillen in bemestingsadviezen voor grasland, mais, aardappelen, suikerbieten, wintertarwe, zomergerst en uien tussen lidstaten geanalyseerd. Ook worden de werkingscoëfficiënten voor dierlijke mesten zoals toegepast in de lidstaten vergeleken. Uit het rapport blijkt dat er overeenkomsten zijn in bemestingsadviezen en werkingscoëfficiënten, maar ook interessante verschillen.

Ik hoop u hiermee voldoende te hebben geïnformeerd.

Met de meeste hoogachting,

Prof.dr.ir. O. Oenema
Voorzitter Commissie van Deskundigen Meststoffenwet

CC.
Gerard Velthof (secretaris CDM)

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APPLIED PLANT RESEARCH
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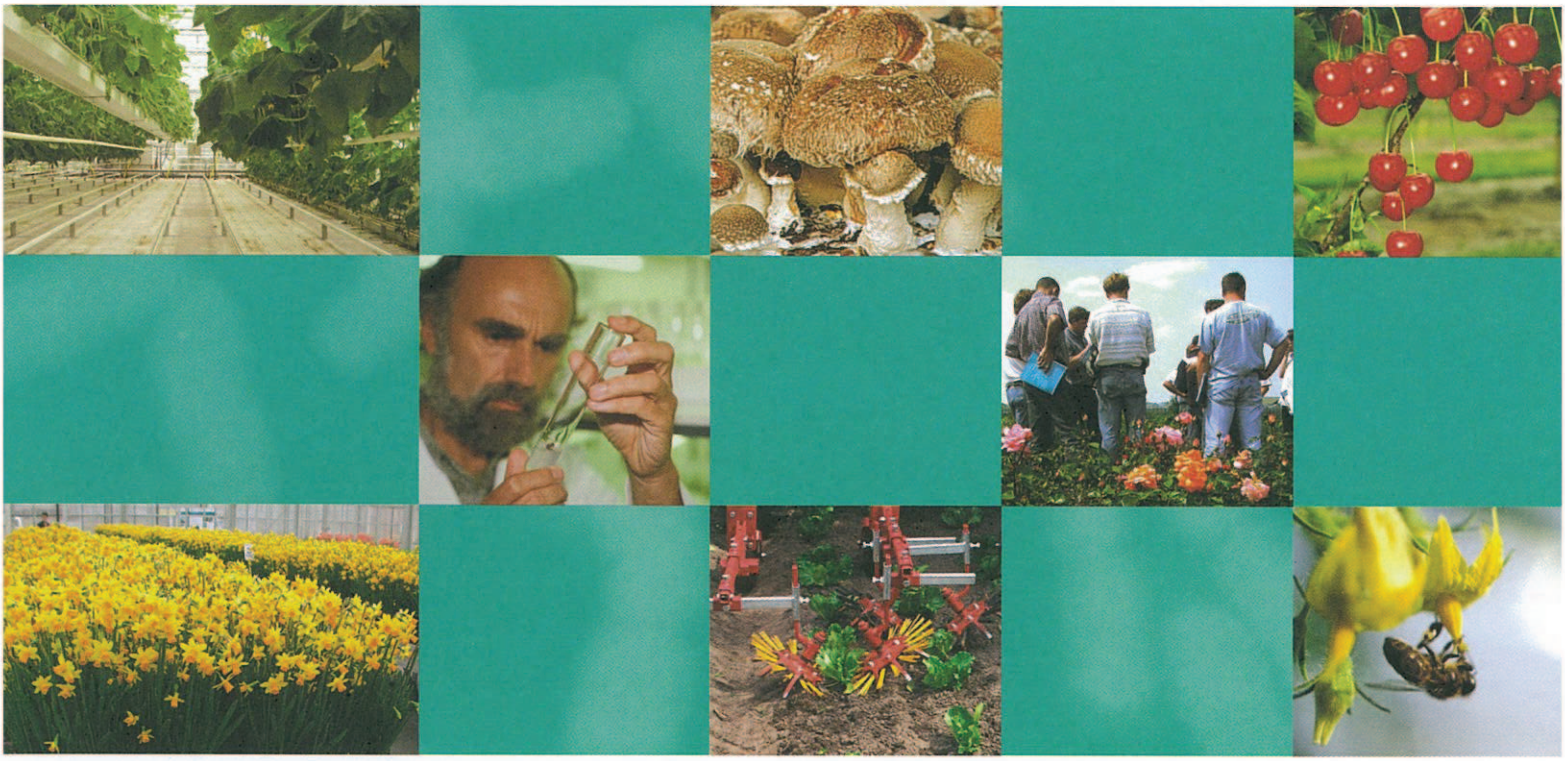
Agricultural nitrogen use in selected EU countries

A comparison of N recommendations, and restrictions in response to the EU Nitrates Directive

Wim van Dijk en Hein ten Berge (Eds)



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Summary

The use of N in EU countries is subject to constraints as given in the Nitrates Directive (ND). Member states must define Codes of Good Agricultural Practice (voluntary measures) for their whole national territory, as well as designate Nitrate Vulnerable Zones (NVZs) where the risk of nitrate pollution would be high if actions prescribed in the ND were not taken.
With specific reference to the designated NVZs, so-called Action Programs (APs) have to be established which contain mandatory measures in order to meet the objectives of the ND. For some countries, APs include N-application standards: explicit limiting values to N inputs.
Central to Good Agricultural Practice (GAP) are the fertilizer recommendation systems, which reflect crop N requirements. Recommendations are the starting point for fertilizer planning – a required element of Codes of GAP as prescribed by the ND. They have also served as a reference in those countries where N-application standards were introduced. Another required element in Codes of GAP is the specification of periods when fertilizer application is inappropriate (closed periods). Finally, the fertilizer value of manures is required both for fertilizer planning (GAP) and to assess room for supplemental fertilizer inputs within set N-application standards.
These elements together (recommendations, application limits, closed periods, and fertilizer equivalents) constitute the core of rules and regulations in the respective APs and Codes of GAP. Details of these elements, including numerical values, differ between countries. This reflects, in part, differences in biophysical and socio-economic production conditions. To provide a broader basis for justifying rules and numbers for adoption in APs and Codes of GAP, the study documented here compares recommendations and the various restrictions on N use among selected 'neighbouring' countries. The study is confined to Flanders, Denmark, Germany, France and The Netherlands. As for major crops, grassland, maize, potatoes, sugar beets, winter wheat, summer barley and onions are addressed. All collected values for N application standards apply to the year 2009.

N legislation in Action Programs

General
Flanders, Denmark, Germany, and The Netherlands have designated their entire territories as NVZ. Comparison of the respective APs shows considerable variation with regard to nitrogen use between the countries. The Action Programs of Flanders, Denmark and The Netherlands contain fixed, crop specific application standards (allowed maximum inputs) for N in manures and mineral fertilizers. The German AP is based on rules for GAP (applies to all states). In addition, on farms with arable crops the German AP does not allow farm N surplus to exceed values of 90 (2008) and 60 kg N per ha (2011). French legislation does not limit total N input in general, nor in the territories designated as NVZs. Only in zones where the ground- and surface water is used for drinking water and where - simultaneously - nitrate concentration is high, total N input is limited to 140-210 kg N per ha (manure + mineral fertilizers). Flanders and some German states (e.g. Baden-Württemberg) have additional rules with regard to maximum allowed amounts of soil mineral N in the autumn.

Application standards (manure + mineral fertilizers)
Between countries with fixed N application standards, definitions of input constraints vary, too. While N application standards in Denmark and The Netherlands regulate allowed N-inputs on the basis of 'effective N' (covering mineral fertilizers as well as fertilizer equivalents in manures), the AP of Flanders includes a standard for total N input (all N in fertilizers and manures), and two extra separate application standards: one for mineral fertilizers and one for 'organic-fertilizers-not-from-animal-origin'.
The degree of differentiation – to crops and soils – also varies between countriess. Flanders distinguishes only six crop groups: grassland, maize, crops with low N demand (including onions and peas and beans), legume crops (excluding peas and beans), sugar beets, and a group of other crops (e.g., potatoes, wheat, barley, most vegetables, etc.). In contrast, systems in Denmark and

the Netherlands specify separate values for a long list of individual crops. Application standards in Denmark and the Netherlands depend on soil type, for all crops. In Flanders this only applies for maize and cereals; these have somewhat lower application standards on sandy soils than on other soils.
The level of application standards also varies between countries. Compared to Denmark, the Dutch values are higher for potatoes, sugar beets and winter wheat; and lower for summer barley and onions. Values for maize are similar to those in Denmark. Compared to Flanders, the Dutch values are higher for potatoes and onions and lower for summer barley and maize. Dutch values for winter wheat and sugar beets are similar to those in Flanders.

Animal manure
Except for France, all countries have a (granted) derogation for application of animal manures, allowing maximum rates between 200 and 250 kg N per ha. Most derogations refer to grassland-dominated farming. Flanders, however, has derogations for 'arable' crops like maize followed by grass; winter wheat followed by a catch crop or green manure crop; and for sugar beets and fodder beets, too. Most derogations apply to cattle manure (including sheep and goats), except in Flanders where the liquid fraction of pig manure is included, too.
All countries have restrictions with regard to the allowed application period of manures. Generally, allowed application periods for manure types with high available N loads (slurries, poultry manure) is shorter than for manure types with lower available N loads. Because application standards in Denmark and The Netherlands refer to 'effective N' (see above), fixed N fertilizer values (NFV) had to be adopted in the respective APs. NFVs are specified per type of manure. NFV-values used in Action Programs do not always correspond to values used in recommendation systems. NFV-values for Denmark are higher than for the Netherlands, and include long term (10 year) effects.

N fertilizer recommendations
Comparison of N fertilizer recommendations is difficult as these depend on many factors. Therefore, only a rough comparison of average levels is possible. N-recommendations in the Netherlands for potatoes and - to a lesser extent - grass and winter wheat are higher than in other countries. Recommended levels for summer barley are lower. Recommendations for maize and sugar beets are quite similar between countries.
The principles of recommendation systems differ between countries. The Danish and Dutch systems employ recommendations derived from dose-response-trials; while in France a balance approach is used. In Germany and Flanders both systems are used.
Recommendation systems of all countries include - to more or lesser extent - corrections for attainable yield; and for variations in N sources like soil mineral N in spring, soil N mineralization, long term effects of manure and N delivery from previous crops.

1 Introduction

The use of N in EU countries is subject to constraints as given in the Nitrates Directive. It aims at reducing water pollution caused or induced by nitrates from agricultural sources and, further, at preventing such pollution. The directive prescribes that member states are to take four major actions to realize this objective:

1. Member states have to define Codes of Good Agricultural Practice (voluntary measures) for the whole country with the aim of providing for all waters a general level of protection against pollution.
2. Member states are obliged to designate areas in their territory (Nitrate Vulnerable Zones or NVZs) that drain into fresh surface waters and/or groundwater that contain, or could contain more than 50 mg/l nitrate if actions prescribed in the Nitrates Directive are not taken.
3. The Nitrates Directive compels member states to establish Action Programs (APs) with respect to NVZs so that the objectives of the Nitrates Directive can be realised.
4. Member states are obliged to implement suitable monitoring programs to establish the extent of nitrate pollution in waters and to assess the effectiveness of the Action Programs.

While the use of animal manures is restricted in all EU countries, some countries in their APs account for other inputs as well, such as mineral fertilizers. In those cases, so-called N-application standards define the maximum allowed amounts of N to be used per ha per year. These are often differentiated according to soil type and crop species. Some countries have used the possibility to request a 'derogation' from generic EU regulation, thereby pointing at particular local conditions. So all in all, rules and regulations are quite diverse, and in part reflect differences among countries with respect to biophysical and socio-economic production conditions.

The aim of this study was to compare crop N-requirements, according to recommendation systems, as well as restrictions to the use of N, among selected 'neighbouring' countries. This comparison is to serve the broader goal of achieving a firmer basis for rules and numbers used in Action Programs.

This report presents the first results of the comparative benchmark study. Particular goals of the study were:

- To compare the base principles of the Action Programs among countries and, where relevant, to compare N application standards for major crops.
- To compare the base principles of N fertilizer recommendation systems (regarded as components of the respective Codes of Good Agricultural Practice) among countries and the actual N recommendations for major crops.
- To compare N fertilizer values (NFV) of animal manures, in recommendations as well as in allowed application standards (where applicable).
- To compare restrictions related to closed periods for manure and fertilizer application.

Different countries refer to their legislative documents by different names. Flanders has its 'Mestdecreet', Germany its 'Düngeverordnung', the Netherlands its 'Meststoffenwet'. To simplify matters and to avoid incorrect terminology, we maintain in this report the original names of documents and plans as used in the respective countries. When referring to all these rules and regulations in general (all countries) we use the term 'Action Programs' (APs).

The study was restricted to Flanders, Denmark, Germany, France and The Netherlands. As for major crops, we focused on grassland, maize, potatoes, sugar beets, winter wheat, summer barley and onions.

All collected values for N application standards apply to the year 2009.

2 N application standards

2.1 N in animal manures

The EU Nitrates Directive N dictates that on agricultural land application of N as animal manures should not exceed 170 kg N per ha. However, for certain situations a higher rate can be allowed, provided that it is made plausible that N demand is high and nitrate levels in groundwater do not exceed 50 mg per liter. Such exceptions are referred to as 'derogations'. Denmark, Flanders, Germany and the Netherlands have been granted a derogation.
Table 1 summarizes some of the conditions included in the respective derogation agreements. Allowable rates of manure-N in Table 1 refer – for all countries - to total N in manure; not to fertilizer equivalents. Most derogations refer to grassland-dominated farming. Flanders, however, has derogations for maize followed by grass , for winter wheat followed by a catch crop or green manure crop, for sugar beets and fodder beets, too. Most derogations apply to cattle manure (and manures from other ruminants such as sheep and goats; and horse manure), except in Flanders where the derogation allows also the liquid fraction of pig manure.

Farms applying manures produced on the farm itself have to base their actual N-rates (in animal manures) on N-excretion by animals (mostly fixed value per animal type) minus the ammonia losses during housing and manure storage. For manure transfers between farms in the Netherlands, the associated amounts of N are assessed from its measured N contents (compulsory sampling). In Denmark, the transfer of N in manures between farms is not assessed on the basis of chemical analysis. It is estimated as part of the total N production in manures at the selling farm. The receiving farm must have the same amount of N received as animal manure in his fertilizer account.

In Flanders, manures from cattle, horses, goats, and sheep, and the liquid fraction (with certificate) of pig manure, are referred to as 'Derogation manures'. Transports of such 'derogation manures' can be executed only by certified agents, and manures in such cases must be analysed before transportation. The analysis should not be older than one year ago. The result of the analysis is available for free to the receiving farmer. Transport of non-derogation manure is comparable with the Danish system.

Table 1. Application standards manure (kg total N per ha).

Country	*Conditions*	*Application standard for manure* (kg total manure N /ha	*Derogation*
Denmark	Farms with > 70% grassland + forage crops	230	- Granted (2009-2012) - Applies to whole farm area - Manures: cattle
	Other situations, for cattle, sheep and goats	170	
	Pigs, poultry	140	
Flanders	Grass; maize followed by grass	250	- Granted (1.1.2007-31.12.2010) - Applies to resp. crop acreages - Manures: cattle (except fattening calves), horses, goats, sheep, liquid fraction of pig slurry (these are called 'derogation manures')
	Winter wheat+green manure crop, sugar and fodder beets	200	
	Legume crops other than peas and beans	0	
	Crops with low N demand[1]	125	
	Other crops	170	
Germany	Grassland (≥ 4 cuts or ≥ 3 cuts + grazing)	230	- Granted (2006-2009) - Applies to resp. crop acreages - Manures: cattle
	Other situations	170	
France	General standard	170[2]	To date, no derogation was requested
Netherlands	Farms with > 70% grassland	250	- Granted (2006-2009) - Applies to whole farm area - Manures: cattle (except fattening calves), horses, goats and sheep
	Other farms	170	

1 Cichory, flax, carrots, shallots, onions, fruit

2 In some regions ('litigation watersheds') N input is restricted to 140 kg N per ha (see also section "Regulations for total N in France")

2.2 N in manures and mineral fertilizers

This section discusses regulations on the maximum amount of N (be this 'total N' or 'fertiliser equivalents') that is allowed by the respective Action Programs. This is the maximum allowed sum of N in manures, mineral fertilizers, and other inputs; and is referred to as 'N application standard'. Only few countries have defined such explicit values for the maximum allowable N-rate. This holds for Denmark, Flanders and The Netherlands. Other countries have other regulations to constrain the application of N (Germany and France). Both situations are discussed below.

It is important to stress that N inputs are always (all three countries) constrained by the legal limits given in paragraphs 2.1 as well as in 2.2, simultaneously. So, N in animal manures may not exceed the constraints listed in paragraph 2.1, but simultaneously the N-application standards discussed in 2.2 may not be violated.

Fixed N application standards
The Action Programs of Denmark, Flanders and The Netherlands contains fixed, crop dependent N applications standards for N inputs in manures and mineral fertilizers.
In each of these three countries, N application standards are valid for the entire territory. Values for some major crops are given in Table 2. Some history and reasoning behind the application standards of the respective countries are given in section 2.4.
The Danish and Dutch values apply to effective N being the sum of N fertilizer value of manure (NFV; see also section 3) and total N from mineral fertilizers. In contrast, values for Flanders refer to total N in manure, other fertilizers (including compost) and mineral fertilizers. To enable direct quantitative comparison, we have transposed the 'total-N' values of Flanders into effective N by assuming a relative N fertilizer value for manure of 60% (as used in the underpinning of the Action Program of Flanders). This we did at two presumed application levels of animal manure (170 and 250 kg N per ha for grassland and 100 and 170 kg N per ha for the other crops), but this can obviously be done at any other level of animal manure input.

The degree of differentiation between crops and soil types varies between countries. Flanders distinguishes only six crop groups: grassland, maize, crops with low N demand (including onions and the legume crops peas and beans), legume crops (excluding peas and beans), sugar beets, and a group of other crops (e.g., potatoes, wheat, barley, most vegetables, etc.); see Table 3). In contrast, the Danish and Dutch systems specify separate values for a long list of individual crops.

Application standards in Denmark and the Netherlands depend on soil type, for all crops. In Flanders, such distinction is only made for maize and cereals, where application standards for sandy soils are lower than for the other soils. In Denmark and the Netherlands, allowed levels on light textured soils are generally lower than on clay soils.

While Denmark and the Netherlands regulated their allowed input levels for mineral fertilizers by overall N application standards, the Flemish Action Program includes an extra separate application standard for mineral fertilizers and for the group 'other fertilizers' (see Table 3).

N application standards in Denmark and the Netherlands were derived from the fertiliser recommendations. However, when environmental goals are not achieved, application standards can be decreased to suboptimal N fertilization levels. For Denmark current levels for all crops are about 15% below recommended levels, for the Netherlands this applies to crops susceptible to leaching (for instance potatoes, maize, vegetables) on sandy and loess soils (now at 5-10% under recommended levels).

Table 2 shows that grassland values (cut grass) in Denmark and the Netherlands are somewhat higher than in Flanders. However, Flanders has higher levels for maize than Denmark and the Netherlands. In the Netherlands – not in Denmark or Flanders - , cut grass and grazed+cut grass

have different application standards.

Danish values for potatoes and sugar beets are lower than Flemish and Dutch values. For winter wheat, Denmark distinguishes between wheat grown for fodder purpose and wheat grown for bread production. The application standards for bread production are comparable with Flemish and Dutch values, while Danish values for fodder production are lower than the general Flemish and Dutch standards for wheat. Summer barley values are higher for Denmark and Flanders than for the Netherlands. For onions, Danish values are higher and Flanders' values lower than the Dutch values.

The Danish system accounts for N delivery from previous crops; so, reference values for such residual effects are to be subtracted from the N application standard, to obtain the allowed input in manures and fertilizers. Furthermore, application standards depend on expected crop yield. Where expected yield (to be documented; see 2.3) exceeds the reference yield, an upward corrections is given. Though the system is symmetrical, downward corrections do not occur in practice, as farmers with lower yields will not file requests. In Denmark, corrections for previous crop and yield are the same as those used in recommendations (see section 2.3 and 4).

Table 3. N application standards for different crop groups, Flanders; from January 1st, 2009 (all values refer to total N).

Crop group	Total N	N in manures	N other fertilisers[5]	N mineral fertilisers
Grass (irrespective of grassland use)	350	250/170[1]	170	250
Maize	275[2]	250/170[1]	170	150
Crops with low N requirement[3]	125	125	125	70
Legumes (excluding peas and beans)	0	0	0	0
Sugar beet	220	200/170[1]	170	150
Other crops	275[4,7]	200[6]/170[1]	170	175[7]

1 with and without derogation
2 on sandy soils 265 kg N per ha; 260 from 2010 onward.
3 low N requirement applies to onion, flax, peas and beans, chalots, chicory and fruit crops
4 cereals on sandy soils 265 kg N per ha
5. including compost
6. derogation for winter wheat with green manure; or fodder beet
7. in most vegetable crops, the full 'total N'-volume may be given as fertilizer-N; in subsequent 'double-cultures' a total of 345 kg N/ha is allowed

Table 2. N application standards for major agricultural crops (effective N for Denmark and the Netherlands, total N for Flanders; levels 2009).

Crop	Netherlands			Denmark[1]					Flanders		
	Sand	Clay	Peat	0-5 % clay (Soil Index 1+3)	5-10 % clay (Soil Index 2+4)	10-15 % clay (Soil Index 1+3)	> 15 % clay (Soil Index 1+3)	0-10 % clay (Soil Index 1-4)	Total N	Effective N[2]	Effective N[2]
				Not irrigated	Not irrigated			Irrigated		With N manure set to 170 grass 100 other crops	With N manure set to 250 grass 170 other crops
Grass											
- Grazing+mowing	260	310	265	310	320	330	330	345	350	230	200
- Mowing	340	350	300	310	320	330	330	345	350	280	250
Maize	150	185		150	140	140	155	165	265/275[3]	210/210[3]	195/205[3]
Potatoes											
- ware	245	250		140	140	135	140	155	275	235	205
- starch	230			175	170	170	180	190	275	235	205
Sugar beets	145	150		110	105	110	120	130	220	180	150
Winter wheat	160	220		150/190[4]	155/195[4]	165/215[4]	180/230[4]	170/215[4]	265/275[3]	235	205
Summer barley	80	80		115	115	120	135	130	265/275[3]	235	205
Onions	120	120		165	150	140	150	165	125	85	not

1 Values apply to situations with no effect of previous crop (0 kg N per ha) and standard yield levels; given range represents different soil types

2 For comparison, FL values in this report were calculated from total N limits using N fertilizer value of manure (60%; except grassland with grazing where 30 (170 kg manure-N/ha) and 40% (250 kg manure-N/ha was used) + 100% of N mineral fertilizer. If besides animal manure also other fertilizers (like compost) with a lower N fertilizer value are applied the effective N input will be lower than the values given in the Table.

3 sandy soils/other soils

4 fodder wheat/wheat for bread production

Regulations for total N in France and Germany

France
While the limit of 170 kg N per ha with animal manure holds for France this does not apply to total N input (manures plus fertilizers) in general, nor in the territory designated as nitrate vulnerable zone (NVZ). Brittany, for example, is entirely classified as NVZ. Within this NVZ, there are restrictions on N use in so-called 'Complementary action areas' or ZAC's (Zones d'Actions Complémentaires). These are zones used for drinking water supply while at the same time facing high actual nitrate values. One third of Brittany's agricultural land was assigned this ZAC status. Total N input is here limited to 210 kg total N/ha. Some watersheds, where nitrate concentration in surface waters exceeds 50 mg/l (so-called 'watersheds en contentieux'), have more restrictive thresholds if used for drinking water ('litigation-watersheds'): 140 kg total N/ha for arable, pig and poultry farms (maximum 40 as mineral fertilizers); and 170 (including excretions on pastures) for cattle farms (maximum 70 as mineral fertilisers). To classify for these higher values, cattle farms must have over 60% grassland.

Germany
Germany has different regulations for the different 'Länder'. Principles outlined here are for the whole country, as given in the Düngerverordnung (DüV). The DüV does not regulate the use of total N with fertilizers by fixed application standards. Instead, the basis of the DüV is good agricultural practice aiming at:

(i) yield stability and product quality,
(ii) conservation of environmental values and
(iii) maintenance of soil fertility.

State or regional authorities need to publish fertilisation recommendations based on the Düngeverordnung and are also responsible to implement control systems to see if farmers comply with the regulations (so here, regulations and recommendations are made to be mutually consistent.)
Recommendations common to the entire German territory do not exist. In general, the recommendation systems of the various states - and other authorities named by the state governments - take account of the following aspects, in expressing fertilizer requirements:

- nutrient requirement of the crop based on yield and quality expected under local conditions and grown plant variety.
- nutrient supply from the soil as influenced by local conditions, particularly climate, soil classes and soil type. The following has to be included:
  - Soil mineral N in spring
  - Additional delivery of nitrogen from the previous crop
  - Utilization of nitrogen from (animal) manure
- lime content (pH) and the humus content of the soil.
- nutrient supply resulting from land management practices – except for fertilizers but including irrigation – during crop growth.
- Crop-growing conditions affecting nutrient supply, particularly grown varieties, previous crops, soil tillage management and irrigation.

Crop N demand can be calculated using the N-base-demand (Sollwert) and adjusting its value according to the yield expectation by deductions or allowances. When the final N-demand is determined the Nmin value, values for N delivered from previous crops (see Appendix 5) and N fertilizer values of manures or other organic fertilizers need to be subtracted to establish the N mineral fertilizer demand.
These values are also used in recommendations (see Chapter 3).
Besides the above nutrient planning, farmers also have to calculate every year a nutrient balance at field level, including inputs with fertilizers (manure and chemical fertilizers) and legume crops and outputs with harvested products. The N-contents of harvested crop products are published in the DüV. On farms with animal husbandry N input with manure is calculated as the N excretion (fixed values given in DüV) minus ammonia losses during housing, manure storage and application

(fixed percentages of N excretion given in DüV, values range from 20% for manure excreted on pastures to 70% for cattle manure).
For vegetables in the nitrogen balance calculation it is allowed to subtract the amounts of 50-120 kg N per ha (annual basis) representing 'inevitable losses' required to achieve adequate yield and quality. These supplements depend on crop type. Three crop groups are distinguished: Group I (plus 50 kg N/ha), Group II (plus 80 kg N/ha) and Group III (plus 120 kg N per ha, or 160 if followed by a green manure crop and other measures).
Calculated N surpluses are averaged over the three most recent years, and may not exceed the following thresholds (for all crops): 90 kg N per ha (2006-2008), 80 kg N per ha (2007-2009), 70 kg N per ha (2008-2010) and 60 kg N per ha (2009-2011). However, there a no penalties when the threshold level is exceeded.

2.3 Additional restrictions

Soil mineral N in autumn
Some countries have supplementary rules with regard to maximum allowed amounts of soil mineral N in the autumn.

Flanders
In Flanders the "Mestdecreet"(fertilization decree) also handles with a maximum allowed amount of residual soil mineral nitrate-N in the autumn. The sampling is done between October 1 and November 15 in the soil layer 0-90 cm. Measured levels may not exceed 90 kg NO_3^--N per ha. Control is done by accredited labs. If the farm is located in a risk area (depends on the surface water quality) then the following rules apply: when the value is between 90 and 150 kg NO_3-N/ha, the Flemish Manure Bank performs a farm audit and provides instructions on proper use of fertilizers. If the value exceeds 150 kg NO_3-N/ha, the farmer gets a fine as well as an audit. The next year he must have at least 3 parcels analyzed on his own expenses.

Germany (Baden-Württemberg*)*
In Germany different states have additional restrictions in water protected areas. As example the situation in Baden-Württemberg is summarized. Since 1988, this state has developed a system to protect water quality in certain areas designated as 'protected' (areas for the winning of drinking water). This system is referred to as SchALVO (Schutzgebiets- und Ausgleichsverordnung), and has known different stages. The system was expanded in 2001 and is again under revision in preparation of policies to address the EU-water Framework Directive. SchALVO aims to achieve further improvements beyond what is commonly viewed as 'good agricultural practice' (GAP) and takes GAP as a prerequisite.
Protected areas occupy some 25% (2007) of land area in the state. Protected areas are subdivided into 'Normal' areas, 'Problem' areas (4.6% of state area), and 'Recovery' areas (Sanierungsgebiete; 1% of state area). This distinction is made on the basis of nitrate concentration in groundwater, its absolute level but also its trend. Roughly, concentrations up to 35 mg nitrate/l (mean of two years) qualify as 'normal' (unless there is a positive trend (increasing nitrate concentrations) over three years); 35-50 mg/l qualifies as 'problem' (if no positive trend); and areas where concentrations exceed 50 mg/l qualify as 'Sanierungsgebiete'. (SchALVO includes also water protection from biocides; not covered here).
Nitrate concentrations have decreased by 6.9% in 'Sanierungsgebiete', 5.1% in problem areas. Also, the size of areas designated as 'Sanierungsgebiete' and 'problem areas' has decreased (figures 2007 relative to 2001).

Protected areas are subject to a range of constraints, some of which are differentiated to the above severity classes and type of water protection zone (I, II or III depending on near presence of springs); Depending on the classification of the area, there are limitations to land use and land cover (grassland with or without grazing; grassland-arable rotation, catch crops and green manures etc.), presence and number of livestock per ha; use of various primary or treated animal

manures; no destruction of grassland older than 5 years; use of fertilizers, and allowable levels of residual inorganic soil N in autumn. Organic manures (from animals) are altogether prohibited in 'Sanierungsgebiete'.

Soils are sampled for residual inorganic N, between October 15th and November 15th. With later harvests, the sampling period is extended to December 15th. Annually, some 20.000 sites are sampled, 16.000 of these are in problem or 'Sanierungsgebiete'. Soils of Type-A (leaching sensitive) are distinguished from Type–B. A-soils include shallow soils (<60 cm), all peat soils, and soils of 'coarse' texture classes. Each farm is designated as A-type or B-type, depending on the dominant soil type. Farmers are entitled to receive on their request a detailed map of soil types on their land, that justifies the classification of their land as A or B type. Soils of Type-A should have less than 45, 30 or 20 kg NO_3-N per ha within respective maximum possible sampling depths of 90, 60 and 30 cm. Type-B soils should have less than 45 kg/ha within 0-60 cm, and peat soils less than 90 kg/ha in 0-60 cm. For B-type and peat soil, there are also separate thresholds for depth intervals. Violation of soil nitrate thresholds may result in various types of penalties.

Cover crops
In The Netherlands growing a cover crop after maize is compulsory on sandy and loess soils.
In France, soils must be covered during winter. This is compulsory on all soil types in the ZAC, and highly recommended in the NVZ's. (For acronyms, see above)
In Denmark farmers must have at least 14 percent catch crops on farms with more than 0,8 livestocks unit per ha, and at least 10 percent on other farms. These fractions are relative to the total area of cereals, oilseed rape, peas, maize on the farm in the preceeding year. Undersown grass in cereals in spring counts as catch crop, as do crucifers established before August 20th. The catch crop must be followed by a crop established in the next spring.

2.4 Backgrounds of N application standards

Of the countries covered in this study, Denmark, the Netherlands and Flanders have more of less fixed N-application standards (maximum allowable N rates) per crop or crop group; the standards include N given as mineral fertilizers. Denmark and the Netherlands have standards expressed as 'effective N'; Flanders has standards for 'total N' and includes additional separate limits for various N-inputs. This paragraph aims to show how the N application standards were derived in these respective countries, and provides further background and details.

The Netherlands (adapted from Schröder and Neeteson, 2007. Geoderma discussion paper)

Surplus as a starting point
Figure 1 shows the procedure leading to allowable N application standards. The soil N surplus plays a central role. Based on allowable nitrate concentration in groundwater, the allowable N load to groundwater is calculated, which serves as input to derive maximum soil N surplus and maximum N rate in manures and mineral fertilizers. Permissible N surpluses, as dependent on soil type and crop species, were derived from observations on N concentrations (in the upper ground and surface water) in relation to N soil surpluses. These are collected annually in an ongoing monitoring program covering 75 commercial farms, referred to as LMM (Netherlands Monitoring Network Effects Fertilizer Policy) (Schröder et al., 2007). The LMM network indicates that the same value of soil N surplus results in more N leaching from arable land than from grassland; and in more leaching from dry soils than from wet soils. Differences in denitrification seem to play the most important role in these contrasts. The leaching fraction is the fraction of N surplus on the soil surface balance (the balance sum after subtraction of ammonia losses during manure application) that is leached as nitrate to groundwater. After assessing permissible soil N surpluses, manure-mineral fertilizer combinations were calculated that just meet the N concentration goals. These calculations involve crop-specific defaults for the N harvest index; for recovery of mineral soil N

and fertilizer N; and N fertilizer values of all relevant organic N sources. The N load lost to groundwater or surface water is calculated as the leaching fraction (varying from 0.04 for peat grassland to 0.73 for arable crops on sandy soils with a deep ground water table) times the soil balance surplus (inputs minus outputs). To arrive at a concentration, as required by the Nitrates Directive, the N load (kg per unit area) is divided by the volume of the precipitation surplus. Following this scheme (Fig. 1), N application standards were calculated for dozens of crops and soil types (Schröder et al., 2004b).

Where calculated allowable standards exceeded current N recommendations, as holds often for clay and peat soils, N application standards were capped by the recommendation. This procedure implies that N recommendations changed from a guideline into a formal instrument used to assess maximum allowable inputs; a significance they never had before. Moreover, recommendations are not fixed values but depend on several factors as N mineralization level of the soil, soil mineral N in spring, previous crop and yield level. This put the N recommendations under fire, even though they had been established under co-responsibility of the agricultural sector. Meanwhile a protocol has been developed by which N recommendations may be adjusted in case of justified doubt (Ten Berge et al., 2005). This protocol specifies minimum requirements of experimental evidence that is needed to demonstrate that an update of the current recommendation is necessary; such as the setup of N-response trials, number of locations and years, etc. The requirements depend on the importance (area, economics) of the crop, and on the availability of documentation with the existing recommendations.

Crop-soil combinations with calculated allowable rates lower than recommended N rates, are referred to as 'susceptible to leaching'. These include vegetables on sandy soils, but also a number of arable crops such as potato. This implies that lowering N leaching to its target level would be associated with a yield penalty. This penalty may be restricted by alternative fertilization techniques (splitting, placement, provisional fertilization on the basis of crop or soil indicator) and additional measures to increase N efficiency (removal of crop residues, cover cropping), but even so the risk of yield reduction would remain. In response to such concerns, the government has met growers quite a long way by imposing higher application standards than those proposed by scientists.

There are three types of application standards: (a) for total P (sum of mineral fertilizer and organic manures); (b) for plant available N (sum of mineral fertilizer and N becoming available during the first season after application of a manure (i.e. the N fertilizer replacement value, NFV); (c) for total N in the form of animal manures. In general, not more than 170 kg animal manure N may be applied per ha per year insofar this is not in conflict with the application standard for total P. Individual dairy farms can, however, submit a request for permission to apply up to 250 kg cattle slurry N per ha ('derogation') (see also section 2.1). In any case, these limitations are used in such manner that none of the various restrictions is violated. So, the use of inputs must fulfill all criteria at the same time.

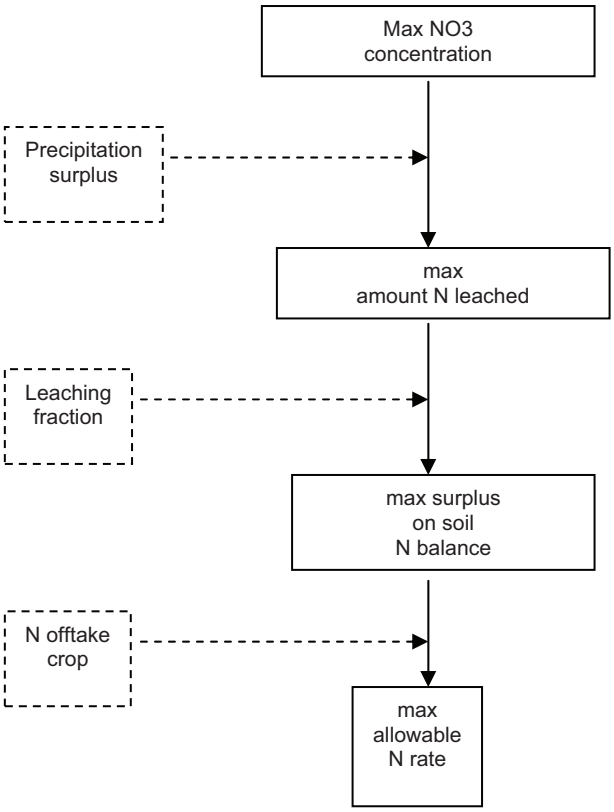

Figure 1. Stepwise procedure leading to allowable maximum N application rate or 'N application standard', as used in scientific documents to prepare the Netherlands' Action Programs.

Derogation

The scientific basis for the derogation request consists of a mix of modelling and experimental validation (Schröder et al., 2005a, 2007). It shows that allowable fertilizer and manure rates should depend on 1) the shares of cut grassland, grazed grassland and maize land in the total land use, 2) soil type, and 3) growing conditions and management qualities of the farmer. Policy makers eventually simplified these scientific nuances, to arrive at enforceable legislation. To obtain a derogation, grassland acreage must exceed 70% of farm acreage; such farms can apply up to 250 kg total N in cattle slurry per ha per year. This amount refers to total N applied in manure including the urine and dung excreted during grazing; gaseous N losses from housing and storage do not contribute to this 250 kg limit (but N emissions during grazing do). As the internal manure flow on livestock farms is difficult to administer, animal numbers along with default excretions per animal type are used. N and P excretion, however, depend on production level and N concentration of the feed ration. For dairy cattle, the N concentration in feed is derived from (registered) urea content in milk delivered (Tamminga et al., 2004). The urea content in milk reflects excess N intake, which is excreted in urine and manure (e.g. Schröder et al., 2005c). All this has led to detailed excretion tables.

Based on the excretion criteria, N fertilizer replacement values of manure N and the proposed application standards for (effective) N on grassland and maize land, the EC agreed to a derogation up to 250 kg slurry N per ha for the period 2006-2009. The derogation will be closely followed by monitoring of groundwater and surface water quality. This has resulted in a substantial extension of the LMM network. Tables are available specifying manure composition (N,P) as function of housing, animal type, milk urea and milk production per animal; and specifying allowable mineral fertilizer N rates depending on soil type and grassland use.

Denmark

Denmark has fulfilled all the demands of the EU Nitrate Directive. Danish regulation on N use in agriculture has been strict since the 1980s, and was induced by concerns about anoxia in surrounding seas. Action Plans I and II aimed to reduce nitrate leaching by 50% in 1985-2003. Action Plan III (2003-2015) aims for a further reduction of 13% (relative to 2003). Monitoring showed that N leaching from the root zone decreased by about 40% between 1989 and 2001 (compared to an average EU-value of 11%). Algal blooms decreased in the estuaries. Incidences of oxygen depletion in the sea, however, have not decreased noticeably; in fact such incidences were common in the summer of 2003.

Legislation on N use is based on N-quota at farm level, utilisation of N from animal manures, fertilizer accounts for all farms, fines for the use of surplus nitrogen and requirements on the (minimum) acreage of cover crops. For farmers the reduction in N use has resulted in lower yields. Effects are mitigated by better utilisation of animal manure, but for some farm types the decrease in income was significant, due to lower yields and particularly lower protein contents in grain.

The Danish legislation is closely linked to the recommendation system. An outline of the approach is given below. Factors from the recommendation system that could not be copied into legislation are: correction for soil fertility per field; actual Nmin spring per field; and farmer experience.

National Cap

A series of multi-location N response trials is organized by the farmers association every year. These are used to assess economic optimum N rates $Nopt_A$ (sub A for 'actual') per year for the main crops. A moving average of $Nopt_A$ over the last 10 years is recalculated every year, taking into account current prices of farm products and fertilizers. $Nopt_A$ is then normalized to assess a typical optimum for that crop and region in that year, by making corrections for achieved yield level and soil type (texture) in the local experiment. For example, if the soil was coarse (causing larger N-losses) or the yield was high (high N demand), the normalized $Nopt_{NORMAL}$ is made to be smaller than the locally observed $Nopt_A$. After normalization, $Nopt_{NORMAL}$ from all experiments (locations) per crop are averaged, to achieve the national optimum for that crop (i) and year (j),

here denoted as $\overline{Nopt^{j}_{i,NORMAL}}$.

The optimum for 2003 plays a central role, as well as the application standard for 2003 derived from it, which was approximately 90% of the optimum value:

$$N^{2003}_{\text{std},i} \approx 0.9 \cdot \overline{Nopt^{2003}_{i,NORMAL}} \qquad \text{Eq 1}$$

The total (national) amount of N use allowed in DK in 2003 is represented by the product of the crop-specific N application standard with the corresponding crop acreage (a_i^{2003}),summed up over all crops:

$$CapN^{2003}_{2003} \equiv \sum_i a_i^{2003} \cdot N^{2003}_{\text{std},i} \qquad \text{Eq 2}$$

The total agricultural area in 2003 is denoted as:

$$A^{2003} \equiv \sum_i a_i^{2003} \qquad \text{Eq 3}$$

Both $CapN^{2003}_{2003}$ and A^{2003} are references. Total area A^{2003} is used in later years j to scale the total (whole country) N quota. This is to ensure that total N use does not increase if total area expands, thus preventing an associated rise in emissions. In the case total area should decrease, the same mechanism avoids unnecessary restrictions on farmers: there would be room for relaxation (increase) of N application standards without increasing the load on the marine environment. In other words, it is only the relative presence of crops that sets the maximum total N input. This approach is expressed in Eq. 4

$$CapN^{2003}_{j} \equiv \sum_i \left[\frac{a_i^j}{A^j} \right] \cdot A^{2003} \cdot N^{2003}_{\text{std},i} \qquad \text{Eq 4}$$

with

$$A^j \equiv \sum_i a_i^j \qquad \text{Eq 5}$$

So this 2003-based 'cap' $CapN^{2003}_{j}$ is recalculated for every new year j, given the relative allocation of land to crops i. This procedure allows for changes in total N requirement for Danish agriculture which arise from shifts in cropping pattern. If more crops with a high N demand are grown in year j, the 'cap' goes up with it, and vv. Obviously, this procedure does not preclude possible enhancement of N losses.

In order to meet the $CapN^{2003}_{j}$ level, every year, a reduction factor R is calculated from Eq. 6. Smaller R means stronger reduction, so lower N application standards. R is equal for all crops including grassland.

$$R^j \cdot \sum_i a_i^j \cdot \overline{\overline{Nopt^{j}_{i,NORMAL}}} = CapN^{2003}_{j} \qquad \text{Eq 6}$$

where the double 'averageing bar' refers to all locations (experiments) and a 10-year period (the

optimum is a 10-year moving average). R is an implicit function of fertilizer price, product prices, N-responses of the crops and total agricultural area in Denmark. Smaller R values are induced by lower fertilizer price and/or higher crop product prices (as both these parameters raise optimum N-rates); R is also reduced by expansion of the total Danish agricultural area. R can be lowered if more restrictive environmental goals are imposed (requires intervention by Parliament). The presence of environmental goals and their balancing against farmer interests makes R into a 'policy factor'.
The basic norm (N applic standard) for a reference soil and reference yield is then given as

$$N^{j}_{\mathrm{std},i} = R^{j} \cdot \overline{\overline{Nopt^{j}_{i,NORMAL}}} \qquad \text{Eq 7}$$

Experiments are repeated every year to expand the data base. Optima shift depending on weather, product and fertilizer prices, new cultivars, crop protection, etc). Optima from 10 most recent years are recalculated every year with updated price ratios, to adjust the 10-year running average. There is a complementarity principle embedded in the above procedures: if the standard is considered too low for a certain crop species, it can be adjusted but only at the expense of another crop's standard.

Site specific corrections
The Action Program contains corrections for soil type, yield level, winter precipitation and N delivery from the previous crop.

Soil type

$N^{j}_{\mathrm{std},i}$ is the starting point for deriving soil specific N application standards. Soil texture is the basis for distinguishing 4 soil classes, a fifth class covers irrigated soils (various sandy texture classes merged). A reference soil has 0-10% clay and is not irrigated. Uptake efficiency on clay soils is presumed to be higher, which reduces the N-requirement. Moreover, Nmin in spring was found to be lower on coarser-textured soils. This results in the corrections as given in Table 4; these corrections were already incorporated in Table 2. The reason why N application standards (Table 2) increase with higher clay content, despite the figures in Table 4, is that the heavier soils have higher reference yields. Each soil class has an expected reference yield $Y_{ref,s}$: lower for more sandy soils without irrigation, higher for more clayey soils and all irrigated soils. For this reason, clay soils and irrigated soils would require more N. Based on expected yield (in addition to above corrections), each of the five soil classes gets a basic norm, $N^{j}_{\mathrm{std},i,soil}$ (see also Table 2 and Appendix 1). This standard is for normal yield, no long term effect of animal or organic manures, normal incorporation of plant residues the years before, no effect of plant residues of the crop the year before, and a normal content of mineral nitrogen in the spring. The soil-bound reference yields are independent of farmer-based individual yield corrections (see below).

Table 4. Soil-texture-based corrections on N application standard (kg N per ha, excluding yield effects).

0-5 percent clay (Soil Index 1+3), not irrigated	5-10 percent clay (Soil Index 2+4), not irrigated	10-15 percent clay (Soil Index 5+6	15 percent clay and more (Soil Index 7-10)	0-10 percent clay (soil Index 1-4), irrigated
+15	0	-10	-5	+15

Winter precipitation
The above mentioned standards are corrected (by region) for winter precipitation; corrections are given just before the new season, and are made on the presumption that very wet winters leave less mineral soil N for the new season. This correction, referred to as N-prognosis, is based on 150 measurements of Nmin in the Square Grid Net for Nitrate Investigation in Denmark, and associated model calculations.

Yield level

All farmers are entitled to use $N^{j}_{\mathrm{std},i,soil}$ for crops i on given soil type, but can claim more if they can document higher than reference yields, based on 5-year records. This factor is e.g. for winter wheat 13 kg N per ton grain yield. It means that a field with a yield level at 9 ton per ha compared to a field with a level at 7 ton per ha has an extra N-demand at 26 kg N per ha. Yield corrections fors some major crops are given in Table 11 (section 4.1) and Appendix 1.

Not many farmers use this facility. It is very difficult to fulfill the requirements for mixed farms where part of the arable produce is used to feed livestock within the same farm.

Previous crop effect

The system accounts for N delivery from previous crops. Fixed values for N delivery are to be subtracted from the standards of following crops (see also Appendix 1). E.g. oilseed rape delivers 35 kg N per ha to the following crop. This means that the application standard of winter wheat grown after oilseed rape is 35 kg N lower than for winter wheat grown after cereals.

Special conditions

Finally, individual farmers can claim higher N application standards due to special events like excessive rain. Such allowances are handled 'per express' because requests may come in full growing season and require immediate action.

Flanders

The first Mestdecreet dates back to 23 january 1991, before the Nitrate Directive was issued. It has been adapted successively in 1995, 1999, 2000, 2003, and 2006 to include progressively restrictive N application standards. The basic approach to the assessment of N application standards was introduced in 1995 for all agricultural land, and still holds as the foundation for today's standards. Meanwhile, the entire Flemish territory had been designated as NVZ (1.1.2007 onward). A new "Mestdecreet" was issued by end of 2006 and came in force January 1st, 2007. It contains the principles of the first Mestdecreet with important adaptations.

The 1995 adaptation already specified N application standards for grass, maize, 'crops-with-low-N-requirement', and 'other crops'. Standards set limits for animal manures as well as mineral fertilizers. Contrary to Denmark and the Netherlands, standards apply to total N from manure and mineral fertilizers instead of effective N from manure and mineral fertilizers (see also section 2.2). The 2005 European Court decision required further refinements, and better demonstration that the Action Program meets the basic balance principle called for in the Nitrates Directive, namely that the sum of N supply sources including soil stocks should meet crop N demand. Scientific underpinning was provided in 2006 (Eindrapport Wetenschappelijke Onderbouwing van de bemestingsnormen van MAP2), and includes detailed balances for a number of crops. Sections below were derived from this 'Eindrapport'.

Central to the Flemish approach in calculating N application standards is the amount of inorganic N required to achieve maximum crop yield (Navail,req). This is calculated as the N uptake requirement (Nup,req; all crop parts (product, straw, roots etc.) multiplied with their respective N-contents) plus a minimum amount of soil mineral N (Nrelikwaat) that is considered necessary throughout the growing season up to harvest:

Navail,req = Nup,req + Nrelikwaat

Nrelikwaat is also referred to as 'N-overschot' (literally 'N-surplus'). We retain here the term Nrelikwaat, because 'N-overschot' or 'N-surplus' are defined (in other countries) as the difference between N-input and N-output. Nrelikwaat has values of 30 (grass, cereals, sugar beet), 40 (maize) and 50 (potato) kg N/ha. It plays no explicit role in legislation.
The requirement Navail,req is to be matched by the sum of all sources of mineral N: deposition,

soil mineralization, Nmin,spring, and N released from manures and fertilizers. All these terms are quantified as defaults in the 'Eindrapport'. Nup,req values are 500 (grass), 305 (maize), 280 (winter wheat), 275 (potato), 275 (sugar beet) kg N/ha. N-export values are 450 (grass, cut), 390 (grass, grazed), 420 (grass, cut+grazed), 275 (silage maize), 160 (maize, grain), 240 (winter wheat, grain+straw), 225 (potato) and 130 (sugar beet) kg N/ha.

The Flemish system currently recognizes six crop groups (see par. 2.1 and 2.2) The 'Eindrapport' stresses that maximum N-application standards are not identical with N-recommendations. N requirements used in deriving standards relate to maximum achievable yields and so allow optimum production under all conditions.
Potential leaching losses are 'relatively high' under sugar beet, potato and monoculture maize; while production is suboptimal for grassland (all types) and 'single-cut-grass-followed by monoculture maize'.

The 'Eindrapport' specifies percentages of 'leaching losses' ('uitspoelingsverliezen' or PMNV) of 50% (sand) and 30% (other soils). These represent the fraction of mineral soil N in autumn that is lost overwinter, as found from the overwinter decrease in Nmin. They are used to argue that residual Nmin in autumn should not exceed 90 kg NO_3-N per ha, as in current legislation. It is noted here that the percentage 'leaching losses' in Flanders is not identical with the 'leaching fraction' as used in the Netherlands. Whereas in Flanders this fraction is with reference to soil mineral N (autumn observation), in the Netherlands it is with reference to the N surplus on the soil balance. The latter is – in general – quite different from Nmin. This difference requires further discussion.

3 N fertilizer value of manures and allowed application periods

3.1 N fertilizer value

The N fertilizer value (NFV) of manure is defined as the amount of N in the manure having the same effectiveness as carefully applied mineral N fertilizers expressed as a percentage of total N in the manure. Table 5 summarizes N fertilizer values of most frequently used manure types. We have distinguished three crop types differing in growing period, and have used different manure application techniques:

- Application on arable land just before sowing/planting (maize, potatoes and beets)
- Application on arable land in standing crops (winter wheat)
- Application on grassland, before the first cut

The values apply to the first year of application.

Recommended values
NFV-values for cattle slurry are quite comparable among countries. For pig slurry values in The Netherlands and Denmark are somewhat higher than in the other countries. For solid cattle manure NFV value in Denmark is 15-20% (percent points) higher than in the other countries. NFV values for solid poultry manure are comparable for The Netherlands, Flanders, Denmark and France, while Germany works with lower values.
In Denmark, France and the Netherlands, NFV varies between (some) crops (for example arable land versus grassland). Flanders and Germany have one value for all crops. For Denmark and the Netherlands, the ranges in NFV for liquid manures (slurries and liquid fractions) given in Table 5 represent different application techniques (for Denmark see also Appendix 2). Highest NFV values correspond with injection, while more superficial application techniques result in lower NFV values, due to increased ammonia losses. In Denmark cattle slurry has a larger contrast in NFV between application methods (wider range), than pig slurry. This is related with the fluidity of the slurry (easier penetration of soil by pig slurries).

Values used in the Action programs
Only in Denmark and The Netherlands fixed NFV-values are directly used in the Action Programs. Generally, NFV values used in Action Programs do not always agree with values used in recommendations (Table 5). This is especially so for slurries applied in winter wheat and grassland and for solid cattle manure where legal values are higher than the recommended ones. Dutch values apply to the short term fertilizer value (first year after application), but Danish legal values (not values used in recommendations) refer to a supposed 10-year application history. Danish NFV values are higher than Dutch values, for all manure types covered here. In Denmark as well as the Netherlands, NFV values are independent of application technique.

The German Action Program also states NFV-values for different types of manure. Though Germany has no application standards, NFV-values must be used for calculating the supplementary need for mineral fertilizers.

The Flemish Action Program does not state NFV values, but values were used in the underpinning of the application standards for total N (manure + mineral fertilizers) (Table 5). France does not prescribe NFV values in its Action Program.

The Dutch Action Program accounts for lower NFV-values if cattle manure is excreted on the pasture (20%). The lower value is, however, not used directly but is implied in the ‘average’ NFV of 45%, to be used for cattle manure on farms with grazing (all cattle manures applied within the own

farm). The value of 45% aims to represent the NFV of excretions on pasture (20%) and stored slurry (60%).

Table 5. Recommended (as in advisory systems) and legal (as in Action Program) N fertilizer value of manure (% of total N in manure) as affected by manure type.

		Recommendations						Legal (Action Programme)				
		NL	FL	GE[3]	DK	FR		NL	FL[1]	GE	DK	FR
Cattle slurry	Arable land, spring, maize/potatoes/beets	50-55	55	70	55-70	55		60	60	50	70	
	Arable land, spring, winter wheat	40	55	70	45-55			60	60	50	70	
	Grassland, before 1st cut	45-50	55	70	45-50	50-60		60	60	50	70	
	Excreted on pasture[1]			25				20[2]	20		70	
Pig slurry	Arable land, spring, maize/potatoes/beets	70-75	65	60	70-75	60-75		60-65	60	60	75	
	Arable land, spring, winter wheat	55	65	60	65-70	60-70		60-65	60	60	75	
	Grassland, before 1st cut	45-55	65	60	60	50-65		60	60	60	75	
Solid cattle manure	Arable land, spring, maize/potatoes/beets	30	30	60	45	15-30		40	30	25	65	
Solid chicken manure	Arable land, spring, maize/potatoes/beets	50-55	55	50	65	45-65		55	30	30	65	
Liquid fraction after separation	Arable land, spring, maize/potatoes/beets	85-90	80-90		90			80		90	85	
	Arable land, spring, winter wheat	70	80-90		85-90			80		90	85	
	Grassland, before 1st cut	65-75	80-90		75-80			80		90	85	
Solid fraction after separation, cattle	Arable land, spring, maize/potatoes/beets	25	25		55			40			65	
Solid fraction after separation, pigs	Arable land, spring, maize/potatoes/beets	50	35		55			50			65	
Compost	Arable land, spring, maize/potatoes/beets	10	10			10-15		10				

1 values as used in underpinning of Action Program (Mestdecreet), not explicit in Action Programme
2 used for deriving a fixed NFV value for situations of grazing (45% in 2009)
3 Values based on the recommendation of Thüringen for manures produced on the farm. Different values apply for manures imported to the farm.

3.2 Allowed periods for manure application

All Action Programs contain restrictions with regard to the allowed application period of manures. Generally, allowed application periods for manure types with high available N loads (slurries, poultry manure) is shorter than for manure types with lower available N loads. The starting date after which application of N rich manure types is allowed varies from 16/1 (France) till 15/2 (Flanders). The end of the allowed period differs more between countries (1/9 for the Netherlands and Flanders, till 1/12 for Denmark).

France

In France two manure groups and five crop types are distinguished (Table 6). For solid manure (excluding poultry) and compost allowed periods are longer than for manure types with higher content of available N (slurries, chicken manure).

Table 6. Periods when application of manures and chemical fertilizers is allowed in France[1].

Manure type	Winter crop (wheat…)	Spring crop (maize…)	Summer crop (winter rape…)	Grassland	Vegetables
Compost, Farmyard manure (cattle or pig)	All year	1/11 to 30/6	All year	1/11 to 31/8	16/1 to 30/9[2]
Slurries (cattle, pig, chicken), solid poultry manure	16/1 to 30/6	16/1 to 30/6	16/1 to 30/9	16/1 to 30/9[3]	16/1 to 30/9
Chemical fertilizers	16/1 to 30/6	16/1 to 30/6	16/1 to 30/9	16/1 to 30/9[3]	Depending on growth period

1 Small variation in dates may occur between regions
2 limit varying from 30/6 to 30/9 according to growth period of vegetables
3 except for young grasslands established after September 1st

Denmark

Denmark, too, distinguishes between liquid and solid manures (Table 7). The Danish restriction on liquid manure are very tight.

Table 7. Periods when application of manures and chemical fertilizers is allowed in Denmark.

	Bare soils winter	Winter crop general	Winter Oil seed rape and grass
Liquid manures	1/2-1/6[1]	1/2 – 1/6[1]	1/2-1/10
Solid manures	1/11-1/6[1]	No restrictions	No restrictions
Chemical fertilizers	No restrictions	No restrictions	No restrictions

[1]Actually untill harvest; in practice this means no later than 1/6 because manures cannot be applied later in most crops (besides grass).

Germany

Germany distinguishes arable land and grassland (Table 8). The allowed application periods apply to fertilizers with significant loads of available N like slurries, liquid fractions and solid poultry manure. Solid manures other than poultry manure are excluded and are allowed to be applied the whole year.

The authorities are allowed to select different periods from those given in Table 8, as long as the closed period is at least 12 weeks for arable land, and 10 weeks for grassland (these minimum periods are to be without interruption). Approved criteria include regional conditions (weather, start and end of growing season, objectives of soil and water protection). The competent authorities are also allowed to impose additional requirements concerning application of fertilizers and can grant authorisation for a limited period only.

Manure application on arable land in the period between harvest of the main crop and 31 October

is only allowed when the following main crop is planted in the autumn, when a green manure crop is grown, or when cereal straw is incorporated. Maximum rates, however, may not exceed 40 kg ammonium-N per ha or 80 kg total N per ha.
Further, the application of fertilizers, soil improvers, growing media and plant strengtheners with significant nutrient loadings of nitrogen or phosphate is prohibited if the soil is flooded, water-saturated, frozen or covered by an even layer of snow measuring more than 5 cm in height.

Table 8. Periods when application of manures and chemical fertilizers is allowed in Germany.

Land use	Allowed application period	
	Manures	Chemical fertilizers[1]
Arable land	1/2 – 31/10	1/2 – 31/10
Grassland	1/2 – 14/11	1/2 – 14/11

1 applies to fertilizers with > 1.5% N

Netherlands

In the Netherlands, the period when manures may be applied depends on manure type (slurries, solid manure and compost), crop type (arable land versus grassland) and soil (sand/loess versus clay/peat) (Table 9). Allowed periods for slurries are quite comparable for the different situations. No restrictions exist for solid manures on arable clay land. For arable land on sandy/loess soils, however, and for grassland (all soils), application is restricted to the period February till September. The reason for the restriction on arable sand/loess land is the higher susceptibility for nitrate leaching, compared with clay land.

Table 9. Periods when application of manures and chemical fertilizers is allowed in The Netherlands.

	Sand/loess	Clay/peat	
	Arable + grassland	Arable land	Grassland
Slurries	1/2 - 1/9	1/2 - 15/9	1/2 - 15/9
Solid manures	1/2 - 1/9	No restrictions	1/2 - 15/9
Compost	No restrictions	No restrictions	No restrictions
Chemical fertilizers	1/2 - 1/9	1/2 - 1/9	1/2 - 1/9

Flanders

In Flanders the application of animal manures (excluding farmyard) is allowed between 15/2 and 1/9. On heavy clay soils the allowed period is longer. The same applies to farmyard manure and compost.

Table 10. Periods when application of manures and chemical fertilizers is allowed in Flanders.

Animal manures (excluding farmyard manure)[1]	15/2 – 1/9[1]
Farmyard manure and compost	15/1 – 15/11
Chemical fertilizers	15/2 – 1/9
Other fertilizers and products made from animal manures both with low available N load	No restrictions

1 on heavy clay soils allowed application period 15/2 - 15/10

Comments to Table 10:

- An exception is made for 'other fertilizers and products made from animal manures', to be specified by authorities, all of which may be applied at any time. Such exceptions fulfill the conditions that either N content is low, or only a small fraction of N is released in the first year.
- Excepted are also crops with substantial N uptake in the above closed period* (Sept 1 – Feb 15) which cannot be covered by soil N supply. Within this group: in case of autumn crops no inputs may be applied after Nov 14; in case of spring crops no input may be applied before Jan 16 (these crops are named, 25 crops, mostly vegetable crops).

3.3 Other limitations to the use of manure

France
Some restrictions have to be taken in account, according to manure type and topography, to protect :
- surface water, springs : 35 to 50 m for type 1, 1b, 100 m for type 2 if slope > 7%,
- wells : 35 m
- beaches : 200 m for animal manures,
- shell production zones on sea coasts : 500m

Other restrictions concern the minimal distance to houses (or sport campus…): 10 to 50 m depending on delay of incorporation and manure type (lower distances for composted manures).

The minimum distance for chemical fertilizers is 5 m.

The restrictions given here for France exists also in most of the other countries, with some variations with respect to distances.

4 Nitrogen fertilizer recommendation systems

4.1 Principles recommendation system

The main principles of the fertilizer recommendation systems are given in Table 11.

Table 11. Main principles of fertilizer recommendations systems.

	FL[1]	GE	FR	DK	NL
Basis	Based on dose effect trials	Balance approach	Balance approach	Based on dose effect trials	Based on dose effect trials
Corrections for Yield level	Yes	Yes	Yes	Yes	No, only in wheat Yes
Corrections for N sources					
- Initial soil mineral N	Yes	Yes	Yes	Yes	Yes
- Soil N minera-lization level	Yes	Yes	Yes	Yes	No, only grassland Yes
- Long term effects manure	Yes	Yes	Yes	Yes	No
- Previous crop	Yes	Yes	Yes	Yes	Yes

1 various N-recommendation systems are used in FL; listed are common elements.

Basis

In DK and NL recommendations are mainly based on dose-response trials that have been executed in the past. Based on prices for fertilizers and harvested products, response curves from such trials are used to derive the economically optimal N rate (Nopt). DK conducts a new series of multilocation trials every year; and updates its Nopt values as a running average over 10 years, with new-set price levels. In NL no routine response trials are carried out anymore, but N-responses of specific crops or crop-soil combinations are addressed on project basis.

FR is using a balance system. The balance is written as (Eq 1):

$$N_{eff,fert} = N_{crop} - (\Delta N_{min} + N_{minsoil} + N_{ltman} + N_{prevcrop} + N_{irr}) \quad [1]$$

With:

$N_{eff,fert}$ Effective N input with fertilization (manure + mineral fertilizers)
N_{crop} Crop N uptake
ΔN_{min} Difference between soil mineral N at start and closure of crop growing period
$N_{minsoil}$ Soil N mineralization
N_{ltman} Long term N effect manure
$N_{prevcrop}$ N delivery from previous (catch) crop
N_{irr} N in irrigation water

The crop N uptake is based on production level and the N concentration in the harvested product (fixed levels per crop). The chosen production must be attainable in three out of five years. For corrections for soil N mineralization level, long term N effects of manure, N delivery from previous crops see the section 'N sources'.

In situations where it is difficult to estimate the different N sources also Eq [2] is used:

$$N_{eff,fert} = (N_{crop,fert} - N_{crop,unfert}) / ANR \quad [2]$$

With:

$N_{eff,fert}$ Effective N input with fertilization (manure + mineral fertilizers)
$N_{crop,fert}$ N uptake fertilized crop
$N_{crop,unfert}$ N uptake unfertilized crop
ANR Apparent nitrogen recovery

The values for $N_{crop,unfert}$ and ANR are derived form local field networks. This method is especially used for grassland fertilization. For grassland an ANR-value of 0.7 is used.

In FL dose-response trials as well as balance systems are used to derive recommendations. The balance approach in FL is comparable with that from France. FL however accounts for the so-called 'necessary residual Nmin'. This is based on the fact that available N from different N sources including fertilization must be higher than the expected crop N uptake as the uptake efficiency is < 100%. This extra N is the necessary residual Nmin. For sugarbeets this is around 20-30 kg N/ha (deep roots, good rooting system), whereas for potatoes this is between 50-75 kg N per ha. In fact it can be compared with the use of the apparent N recovery.

GE also uses different approaches depending on the authorities or state publishing the recommendations. While some states (e.g. Niedersachsen, Thüringen) follow the balance approach, other states (e.g. Brandenburg, Mecklenburg-Vorpommern, Sachen-Anhalt) use for example the SBA system (Stickstoff Bedarfs Analyse) which is based on dose-response trials. For the balance approach, no correction is made for apparent N recovery. In the values for crop N base demand (N-Sollwerte) in most cases a certain average value for soil N mineralization is already accounted for. In situations with a low or high mineralization level an upward or downward correction is used (see also section N sources).

Correction for yield level
In most countries a correction is made for yield level. In balance based systems yield level is automatically accounted for. But also in systems based on dose-respons trials yield-corrections are used in situations where actual yields differ from standard levels on which recommendations are based (Denmark). Table 12 gives some corrections used in the different countries.
In France, N requirement is directly based on the expected yield level and fixed levels for N content of the product, and so yield corrections are implicit. In Denmark, standard recommended levels correspond to standard yield levels (see also Appendix 1). For higher or lower yields, upward or downward corrections are made, based on N contents given in Table 12. For winter wheat values depend on the target protein content of the grains. Variation in used N content values is quite great for this crop. No corrections are used for silage maize and grass.

In Germany, upward or downward corrections are applied in cases where expected yield level deviates from a set reference. Such corrections are in the order of 10-20 kg N per ha. The Dutch recommendation system includes such corrections only for winter wheat, using thresholds of 11 (clay) and 9.5 ton per ha (sand). Standard recommendations are based on high expected yield; for yields below these thresholds, recommended levels are decreased with 20 kg N per ha.
For Flanders yield levels are different between agricultural regions and are taken into account in the recommendation system.

Table 12. Yield correction in N fertilizer recommendations (kg N per ton fresh weight (FW) main product or kg N per ha).

	DK	FR	GE[1]	NL
	Kg N/ton FW	Kg N/ton FW	Kg N/ha	Kg N/ha
Grass			-10	
Silage maize		14[2]	-20/+20	
Potatoes	2		-10/+20	
Sugar beets	1		-20/+20	
Winter wheat	13/17[3]	30	-20/+10	-20[4]
Summer barley	15	22	-10	

1 values are based on the recommendations of the state of Thüringen and can vary between states. The first value is a deduction for lower yield expectations and the second value an upward correction for higher yield expectations
2 kg N per ton dry weight
3 fodder wheat/wheat for bread production
4 downward correction for low yield expectations, standard recommendations are based on high yield expectations

N sources

Initial soil mineral N

In all countries initial soil mineral N before sowing/planting is accounted for and is mostly based on the amount measured in the rooted zone. Table 13 gives default depths used in recommendations.

Table 13. Default depths (cm) for measuring soil mineral N in spring as used in N recommendations.

Crop	DK[1]	FL	FR	GE[2]	NL
Maize	50/75/100	0-90	0-90	0-60	0-30
Winter wheat	50/75/100	0-90	0-90	0-90	0-90
Summer barley	50/75/100	0-60	0-90	0-60	0-60
Potatoes	50/75/100	0-60	0-90	0-60	0-30/60[3]
Sugar beets	50/75/100	0-90	0-90	0-90	0-60
Onions	50	0-60		0-60[4]	0-30

1 coarse sand: 50 cm; 5-10% clay: 75 cm, > 10% clay: 100 cm
2 based on the recommendations of the state of Niedersachsen
3 Sandy/clay soils
4 based on recommendations of IGZ Grossbeeren and the state Baden-Württemberg

Soil N mineralization

Most recommendation systems account for soil N mineralization. In Flanders it is based on the frequency of use of organic materials or on an estimation based on soil organic matter. In the latter case, it is mostly a fixed percentage of the amount of soil organic matter not taking into account the degradability of the organic matter. In the underpinning of the Action Program the following levels are used: grassland: 125 kg N/ha, maize: 90 kg N per ha, cereals: 55-65 kg N per ha, potatoes: 85 kg N per ha and sugar beets (110 kg N per ha). Differences between crops result from varying length of the growing period.

In France fixed values are used. For grassland they depend on the age of the grass, growth rate and organic input level (see Table 14). For arable crops soil N mineralization is estimated at a level of 100-120 kg N per ha of which 40-80% is assumed to be available for crop uptake, depending on crop type.

Table 14. Used references for soil N supply by mineralization (kg N per ha) for grassland in western France.

	Summer growth low		Summer growth medium		Summer growth high	
Grassland age	*Young 2-5 years*	*Old > 5 years*	*Young 2-5 years*	*Old > 5 years*	*Young 2-5 years*	*Old > 5 years*
Organic inputs[1]						
High	90	120	140	170	160	190
Medium	70	90	110	30	120	160
Low	50	70	80	100	90	120

1 The definition of previous organic inputs is: High : slurry or manure inputs >= 3 years/5

In Germany generally fixed corrections are used. For example in the state of Niedersachsen, for soils with low organic matter content (< 1.5 %) recommended levels are increased with 20 kg N per ha. Comparable increments are applied for cold soils.
In The Netherlands soil N mineralization is only accounted for in grassland recommendations. The mineralization is estimated by measuring total N content of the soil (0-10 or 0-20 cm). This value is transposed to a N mineralization level by using empirical relationships between soil N content and N uptake of unfertilized grassplots. Subsequently, N mineralization is calculated by the quotient of N uptake of unfertilized grass plots and apparent N recovery of the grass. For arable land no correction is made for N mineralization as up to now no appropriate indicator is available.
In Denmark soil N mineralization is accounted for by fixed values based on the long term manure and cropping history, and on soil total N-content of the field (see Table 15).

Table 15. Correction of standard N demand for total N content of the soil and cropping/manure history in Denmark.

Total - N in soil (%, plow layer)	**Cropping history**	**Correction of N-demand from the standard, kg N per ha**
<0,11	Cereals, straw removed	+10
0,11-0,14	Mixed crops, only little animal manure	0
0,15-0,17	Mixed crops, animal manure from pigs each year in the rotation	-10
0,18-0.22	Mixed crops, animal manure from cattle in the rotation	-20
>0,22	Rotations with clover grass, alfalfa. High amount of animal manure in the rotation.	-40

It must be emphasized that the corrections mentioned for DK en GE do not apply to the absolute N mineralization level, but to the difference with respect to reference which defined the basic recommendation level.

Long term effects of manure
For Flanders the long term effect of organic manure is integrated in the recommendation system in the calculation of soil N mineralization (based on soil organic matter content or based on the frequency of the use of organic materials).

In France the long term effect of organic manure is also integrated in the recommended levels for soil N mineralization as far as grassland is concerned. These levels do depend on the organic inputs (see Table 14). Corrections for long term N effects in arable crops range from 10 to 90 kg N per ha, depending on type and frequency of manure inputs. For long term annual applications, extra N release is set at 70-90 (compost), 40-60 (cattle manure) and 10-15 (pig manure) kg N per ha.

For Denmark no separate corrections for long term effects of manure are used, but they are combined with the long term cropping history and the total N-content of the of the field (see Table 15).

In Germany the long term manure effects are based on historical manure production/use. In Niedersachsen and Nordrhein-Westfalen for example, recommended levels are decreased with about 10 kg N per ha per livestock unit.

For The Netherlands the long term effect of applied manure is accounted for in different ways. Recommendations for arable crops give long term NFV-values for cases where manure has been applied regularly (see Table 16). For maize the long term effect is taken into account by a decreased N fertilizer recommendation for situations where manure is applied regularly (205 – Nmin in situations with no manure, 180 – Nmin in situations with regular manure applications). The long term N effect of manure on grassland is accounted for by an estimate of total soil mineralization, derived from (sampled) total N-content (see also section soil mineralization).

Table 16. First year and long term N fertilizer value (NFV, % of total N) of some manure types in the Netherlands.

Manure type	1st year NFV	Long term NFV
Pig slurry	75	85
Cattle slurry	55	75
Solid poultry manure	55	70
Solid cattle manure	30	55

Comment to soil N mineralization and long term effects of manure
When recommendations are based on dose-response trials,long term manure effects may be already implied in the recommendation, if the latter was based on trials executed on fields with a 'manure-history'. In such cases, the subtraction of a correction for long term manure effects can lead to suboptimal N recommendations. The same applies to corrections for soil mineralization.

Previous crops
Adjustments for N from previous crops are part of the recommendations in all countries. Table 17 gives values for some crops. Corrections are mostly restricted to previous crops with a relatively high amount of N in the crop residues (e.g. sugar beets, grass, green manure crops). More detailed information per country is given in Appendix 1 (DK) and Appendix 3 (GE, FR, NL).

Table 17. Corrections for previous crops (kg N per ha).

Crop	NL	FL	DK	GE[1]	FR
Sugar beet	30	20-30	15	30	20
Grass	100/30/0[2]		30-100[3]	20-40	110-140/20-35/0[2]
Rape			30	10	
Catch crops	30-40	30		20-30	

1 for further details see Appendix 3, Table 1
2 3-10 year old grassland, N-correction in 1st/2nd/3rd year after destruction, following crop is maize
3 30 kg N/ha for grass and 100 kg N/ha for grass-clover

4.2 Recommended levels for major crops

As mentioned before, N-recommendations depend on many factors, such as previous crop, yield level, soil N supply and initial soil mineral N. This makes a direct comparison between countries or states difficult. Nevertheless, we have tried to make a comparison assuming average growing conditions. The results are given in Table 18. If soil N supply by mineralization was part of the recommendation system a medium level was assumed. Effects of previous crops were not taken into account. The values given in Table 18 apply to effective N fertilizer requirement (so after subtraction of soil mineral N in spring; for used Nmin-values see head Table 18).
For GE recommendations differ between the states. Recommendations from four states are shown here: Nordrhein-Westfalen, Niedersachsen, Thüringen and Schleswig-Holstein. The basic recommendations (Sollwerte) on which the N fertilizer requirement is based are given in Appendix 4.
For cut grassland recommended levels for Denmark and the Netherlands are comparable while for Flanders, Germany and France values are lower. For maize and sugar beets no great differences are observed between the countries. Recommended levels for potatoes and to a lesser extent winter wheat are higher in the Netherlands than in the other countries. For summer barley, however, recommendations in the Netherlands are lower. For potatoes the yield levels on which the Recommendations in Denmark and Germany correspond to lower yield levels (30-40 tons per ha) than those found in the Netherlands (50-55 tons per ha). Recommended levels for onions are higher in Denmark than in the Netherlands, Germany and France.
For winter wheat in most countries a distinction is made between fodder wheat and wheat used for bread production. A higher protein content is required for baking quality. N recommendations then are higher (by 20-60 kg N/ha) than those for fodder wheat.
In Germany and The Netherlands a distinction is made between summer barley used for breweries and fodder barley. Too high protein contents are unfavorable for the brewing process. Therefore, recommendations for brew quality are lower by 20-40kg N/ha.

Table 18. Recommended nitrogen fertilization levels (effective N, kg per ha) for some main crops in situations with no effects of previous crops and, if applicable, a medium level for soil mineralization (for arable crops we assumed the next values for soil mineral N (Nmin): silage maize, potatoes, sugar beets, summer barley and onions: 30 kg N/ha; winter wheat: 40 kg N/ha),

	NL			DK					FL	GE				FR[1]
	Sand	Clay	Peat	0-5 % clay (Soil Index 1+3)	5-10 % clay (Soil Index 2+4)	0-10 % clay (Soil Index 1-4)	10-15 % clay (Soil Index 1+3)	> 15 % clay (Soil Index 1+3)		Nordrhein- Westfalen	Niedersachsen	Thüringen	Schleswig-Holstein	
				Not irrigated	Not irrigated	Irrigated								
Grass														
- Grazing+cutting	285-325	345	295						200-225			230	200-240	230
- Cutting	325-365	385	330	365	375	405	385	385	250-300	300		300	240-280	185
Silage maize	150/175[2]	150/175[2]		175	160	190	165	185	150-175	160	150	160	150	110
Potatoes														
- ware	245	250		160	160	180	155	165	200-225	130	130	130	70-140	120
- starch	220			205	200	225	200	210	-		130			150
Sugar beets	150	150		130	125	150	150	125	125-150	150	130	110	90-110	120
Winter wheat[3] - Fodder wheat - Bread production	190	 230 270		 180 220	 180 230	 200 250	 195 250	 210 270	175-225	180	 170 190	130	 130-220 140-230	170
Summer barley[4]	90/90	60/80		135	130	155	140	155	100	90/110	90/110	60/100	70-140	40
Onions		120		165	150	165	140	150				100-170		60

1 available N from soil mineralization 40 kg N per ha for arable crops
2 regular manure applications/no manure history
3 when two values are given: fodder wheat/wheat for bread production
4 when two values are given: barley used for breweries/fodder barley

5 Conclusions

5.1 N legislation in Action Programs

General

- The comparison of the different Action Programs shows considerable variation in legislation with regard to nitrogen use between the countries.
- The Action Programs of Flanders, Denmark and The Netherlands contain fixed, crop specific N application standards for N inputs in manures and mineral fertilizers.
- The German Action Program is based on rules for Good Agricultural Practice. In addition, on farms with arable crops farm N surplus is not allowed to exceed values of 90 (2008) and 60 kg N per ha (2011).
- French legislation does not limit total N input in general, nor in the territories designated as nitrate vulnerable zones. Only in zones where the ground- and surface water is used for drinking water and where - simultaneously - nitrate concentration is high, total N input is limited to 140-210 kg N per ha (manure + mineral fertilizers).
- Flanders and some German states (e.g. Baden Württemberg) have supplementary rules with regard to maximum allowed amounts of soil mineral N in the autumn.

Application standards (manure + mineral fertilizers)

- Considerable variation in rules and regulations also exists between countries with fixed N application standards:
  - While Denmark and The Netherlands regulate their allowed input levels for mineral fertilizers by overall N application standards (for effective N), the Action Program of Flanders includes an extra separate application standard for mineral fertilizers and for organic fertilizers not from animal origin.
  - In Denmark and The Netherlands the values apply to effective N being the sum of N fertilizer value of manure and total N from mineral fertilizers, while the values for Flanders refer to total N in manure and mineral fertilizers.
  - The degree of differentiation varies between countries, for crops as well as soil types. Flanders distinguishes only six crop groups: grassland, maize, crops with low N demand (including onions, peas and beans), legume crops (excluding peas and beans), sugar beets, and a group of other crops (e.g., potatoes, wheat, barley, most vegetables, etc.). In contrast, the systems in Denmark and the Netherlands specify separate values for a long list of individual crops.
  - Application standards in Denmark and the Netherlands depend on soil type, for all crops. In Flanders this only applies for maize and cereals, where application standards for sandy soils are somewhat lower than for the other soils.
- The level of application standards also varies between countries:
  - Compared to Denmark, the Dutch values are higher for potatoes, sugar beets and winter wheat; and lower for summer barley and onions. Values for maize are similar to those in Denmark.
  - Compared to Flanders, the Dutch values are higher for potatoes and onions and lower for summer barley and maize. Values for winter wheat and sugar beets are similar to those in Flanders.

Animal manure

- Except for France, all countries have a derogation (granted) for application of animal manure ranging from 200-250 kg N per ha. Most derogations refer to grassland-dominated farming. Flanders, however, has derogations for ‘arable’ crops like maize followed by grass; winter

wheat followed by a catch crop or green manure crop; and for sugar beets and fodder beets, too. Most derogations apply to cattle manure (including sheep and goats), except in Flanders where the liquid fractions of pig manure is allowed, too.
- All Action Programs contain restrictions with regard to the allowed application period of manures. Generally, allowed application periods for manure types with high available N loads (slurries, poultry manure) is shorter than for manure types with lower available N loads.
- Fixed N fertilizer values (NFV) for different types of manures are explicit in the legislations of Denmark and The Netherlands; this is required because application standards refer to effective N input. NFV-values used in the Action Programs do not always agree with values used in recommendation systems. NFV-values for Denmark are higher than for the Netherlands, and include long term (10 year) effects.

5.2 N fertilizer recommendations

- Comparison of N fertilizer recommendations is difficult as these depend on many factors. Therefore, only a rough comparison of average levels is possible.
- Recommended levels in the Netherlands for potatoes and - to a lesser extent - grass and winter wheat are higher than in the other countries. Recommended levels for summer barley are lower. For maize and sugar beets recommended levels are quite similar between countries.
- The principles of recommendation systems differ between countries. The Danish and Dutch systems employ recommendations derived from dose-response-trials; while in France a balance system is used. In Germany and Flanders both systems are used.
- Recommendation systems of all countries include - to more or lesser extent -corrections for attainable yield; and for variations in N sources like soil mineral N in spring, soil N mineralization, long term effects of manure and N delivery from previous crops.

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Appendix 1A Recommended nitrogen standards 2008-2009 Denmark

Crop	Effect on next crop	Must the effect of previous crop be included	Coarse sand (below 5 percent clay), Soil index 1 or 3, not irrigated		5-10 percent clay, not irrigated, Soil Index 2 or 4		Below 10 percent clay, irrigated. Soil index 1-4		Loamy Sand (10-15 percent clay), soil index 5-6		Sandy loam, more than 15 percent clay, soil index 7-10		Correction for yield
			UN	KN	UN	KN	UN	KN	UN	KN	UN	KN	
	kg N/ha	yes/no	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	kg N/dt
Spring barley	0	Yes	41	136	48	132	53	154	60	140	64	156	1.5
Winterwheat	0	Yes	54	178	68	181	72	201	86	195	91	211	1.3
Winterwheat for bread	0	Yes	54	220	68	228	72	250	86	249	91	268	1.7
Winter Oil Seed Rape	32	Yes	27	197	35	209	35	209	40	217	42	220	1.5
Peas	22	No	45	0	45	0	45	0	45	0	45	0	0
Potatoes for starch	7	Yes	430	204	480	199	530	224	530	199	530	209	0.2
Potatoes, fresh	7	Yes	302	161	377	161	402	181	402	156	402	166	0.2
Sugar beets	17	Yes	386	129	486	124	614	151	614	126	650	140	0.1
			Feeding units pr. ha		**Feeding units pr. ha**		**Feeding units pr. ha**		**Feeding units pr. ha**		**Feeding units pr. ha**		
Maize for silage	0	Yes	9595	177	9595	162	10595	192	10495	165	10995	183	
Permanent græs med lavt udbytte4	22	No	1800	80	1800	80	1800	80	1800	80	1800	80	
Permanent grass	22	No	3000	155	3000	155	3000	155	3000	155	3000	155	
Clover grass (below 50 percent clover)	102	No	6847	273	7047	275	8347	288	7347	278	7347	278	
Grass without clover	22	No	7501	365	8001	375	9501	405	8501	385	8501	385	
Onion	0	Yes	-	165	-	150	-	165	-	140	-	150	-

Appendix 1B Application standards 2008-2009 Denmark

Crop	Effect on next crop	Must the effect of previous crop be included	Coarse sand (below 5 percent clay), Soil index 1 or 3, not irrigated		5-10 percent clay, not irrigated, Soil Index 2 or 4		Below 10 percent clay, irrigated. Soil index 1-4		Loamy Sand (10-15 percent clay), soil index 5-6		Sandy loam, more than 15 percent clay, soil index 7-10		Correction for yield
			UN	KN	UN	KN	UN	KN	UN	KN	UN	KN	
	kg N/ha	yes/no	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	dt/ha	kg N/ha	kg N/dt
Spring barley	0	Yes	38	116	45	113	50	132	57	119	61	133	1.5
Winterwheat	0	Yes	48	152	62	155	66	172	80	166	85	180	1.3
Winterwheat for bread	0	Yes	48	188	62	195	66	214	80	213	85	229	1.7
Winter Oil Seed Rape	32	Yes	25	169	31	179	31	179	36	185	38	188	1.5
Peas	22	No	45	0	45	0	45	0	45	0	45	0	0
Potatoes for starch	7	Yes	390	174	440	170	490	192	490	170	490	179	0.2
Potatoes, fresh	7	Yes	285	138	360	138	385	155	385	134	385	142	0.2
Sugar beets	17	Yes	338	110	438	106	566	129	566	108	602	120	0.1
			Feeding units pr. ha		**Feeding units pr. ha**		**Feeding units pr. ha**		**Feeding units pr. ha**		**Feeding units pr. ha**		
Maize for silage	0	Yes	9300	151	9300	138	10300	164	10200	141	10700	156	
Permanent græs med lavt udbytte4	22	No	1800	68	1800	68	1800	68	1800	68	1800	68	
Permanent grass	22	No	3000	133	3000	133	3000	133	3000	133	3000	133	
Clover grass (below 50 percent clover)	102	No	6100	234	6900	236	8200	247	7200	238	7200	238	
Grass without clover	22	No	6600	312	7800	321	9300	346	8300	329	8300	329	
Onion	0	Yes	-	165	-	150	-	165	-	140	-	150	-

Appendix 2 Fertilizer equivalents for animal manure in Denmark

Source: http://www.lr.dk/planteavl/informationsserier/dyrkningsvejledninger/markeffekt_hus.htm

Background for setting the values for fertilizer equivalents
In sheets 1 to 8 recommended values for fertilizer equivalents are given for the most common types of solid and liquid animal manure. Besides this the values are given for the liquid fraction and the fiberfraction after separation in a decanter centrifuge.

The figures are given as the amount of nitrogen in mineral fertilizer that 100 kg total-nitrogen in animal manure can replace.

The background for the values are:

- Trials with animal manure at Danish Agricultural Advisory Center since medio 1980th
- Trials with animal manure at The State Research Center (Foulum)
- Trials with determination of emission of ammonia at The State Research Center (Foulum)

Specification of the application time

Liquid animal manure	**Spring**	**Summer**	**Autumn**
Spring sown cereals	Before sowing	About tillering	-
Beets and maize	Before sowing	June	-
Winter cereals	Before 1th of May	1th-15th of May	-
Winter oil seed raps	Befor 1th of May	-	Before sowing or 3-4 leaves
Grass for seed	Before 1th of april	-	Ultimo Sept. To 15th of Oct.
Grass	Before 1 cut	After 1 and 2 cult	Ultimo Aug. to beg. of Sept..

Solid manure	**Spring**	**Late autumn**	**Winter**
Spring sown cereals	Before sowing	20th of Oct. tol 1th of Dec.	1th. of Dec..to1th of Feb.
Beets and maize	Before sowing	20. Oct. to 1th of Dec.	1th. of Dec..to1th of Feb.
Winter cereals	Before 1th of May	-	-
Winter oil seed raps	Befor 1th of May	-	-

Sheet 1. Fertilizer equivalent for Nitrogen in slurry from pigs with an ammonia content about. 70 pct. of total Nitrogen in slurry

Slurry from pigs	Spring		Summer		Autumn	
	Injection	Trailing hoses	Injection	Trailing hoses	Before sowing	In growing corp
Spring sown cereals	75	70	-	45	-	-
Beets and maize	75	70	70	40	-	-
Winter cereals	70	65	-	65	-	-
Winter oil seed rape	-	65	-	-	65	55
Grass for seed	-	60	-	-	-	60
Grass	60	60	55	45	-	55

Sheet 2. Fertilizer equivalent for Nitrogen in slurry from cattle with an ammonia content about. 60 pct. of total Nitrogen in slurry

Slurry form cattle	Spring		Summer		Autumn	
	Injection	Trailing hoses	Injection	Injection	Before sowing	In growing crops
Spring sown cereals	70	50	-	35	-	-
Beets and maize	70	55	60	35	-	-
Winter cereals	55	45	-	40	-	-
Winter oil seed rape	-	45	-	-	50	35
Grass for seed	-	45	-	-	-	45
Grass	50	45	45	35	-	40

Sheet 3. Fertilizer equivalent for Nitrogen in degassed slurry with an ammonia content about. 80 pct. of total Nitrogen in slurry

Degassed slurry	Spring		Summer		Autumn	
	Injection	Trailing hoses	Injection	Injection	Before sowing	In growing crops
Spring sown cereals	75	70	-	50	-	-
Beets and maize	75	70	70	45	-	-
Winter cereals	75	75	-	65	-	-
Winter oil seed rape	-	75	-	-	65	55
Grass for seed	-	70	-	-	-	60
Grass	70	65	60	45	-	60

Sheet 4. Fertilizer equivalent for Nitrogen in the liquid fraction after separation of slurry with decanter with an ammonia content about. 90 pct. of total Nitrogen in slurry

Liquid fraction from decanter centrifuge or urine	Spring		Summer		Autumn	
	Injection	Trailing hoses	Injection	Injection	Before sowing	In growing crops
Spring sown cereals	90	90	-	70	-	-
Beets and maize	90	90	90	70	-	-
Winter cereals	90	85	-	85	-	-
Winter oil seed rape	-	85	-	-	85	70
Grass for seed	-	85	-	-	-	75
Grass	80	75	75	65	-	70

Sheet 5. Fertilizer equivalent for Nitrogen in solid manure from cattle with an ammonia content about 25 pct. of total Nitrogen in the manure

Solid manure	Spring	Before sowing	Late autumn	Winter
Spring sown cereals	40	-	30	35
Beets and maize	45	-	35	40
Winter cereals	25	20	-	-
Winter oil seed rape	25	30	-	-

Sheet 6. Fertilizer equivalent for Nitrogen in deep litter from cattle, pigs, horses and sheep's with an ammonia content about 25 pct. of total Nitrogen in the manure

Deep litter	Spring	Before sowing	Late autumn	Winter
Spring sown cereals	30	-	25	30
Beets and maize	35	-	30	35
Winter cereals	25	20	-	-
Winter oil seed raps	25	30	-	-

Sheet 7. Fertilizer equivalent for Nitrogen in solid manure from poultry with an ammonia content about 30 pct. of total Nitrogen in the manure

Solid manure from poultry	Spring	Before sowing	Late autumn	Winter
Spring sown cereals	60	-	30	35
Beets and maize	65	-	35	40
Winter cereals	50	20	-	-
Winter oil seed rape	50	50	-	-

Sheet 8. Fertilizer equivalent for Nitrogen in the fiber fraction from separation of slurry with decanter centifuge with an ammonia content about 50 pct. of total Nitrogen in the manure

Fiber fraction	Spring	Before sowing	Late autumn	Winter
Spring sown cereals	50	-	30	35
Beets and maize	55	-	35	40
Winter cereals	30	20	-	-
Winter oil seed rape	30	25	-	-

Appendix 3 Values for N delivery from previous crops as used in recommendations

Germany

Table 1: Plant available N supply from preculture in Germany

Preculture	N supply in kg N / ha
Cereal, potatoes, flax, sunflowers, silage maize	0
Grain maize, rape seed, annual ryegrass, fallow without legumes	10
Turnip rape, mustard, fodder beet, field grass and perennial ryegrass	20
Grain legumes, sugar beet, alfalfa, clover, clover grass, fallow with legumes, vegetables	30
Perennial fallow	40

Table 2: Plant available N supply from intermediate crops as well as from organic and mineral N supply from main crops of the previous year (Germany).

	N supply in kg / ha		
Management	No fertilizer application	Mineral fertilizer application or liquid manure	Solid manure or other organic fertilizer
Without intermediate crops:			
- Winter-planted crop fertilization in fall	0	20	30
- Fertilization to mineralize straw	0	20	20
Intermediate crops not legumes			
- Removed from field	0	10	20
- Incorporated in fall	10	20	30
- Incorporated in spring	20	30	40
Intermediate crops legumes			
Removed from field	20	(20)	(20)
- Incorporated in fall	30	(30)	(30)
- Incorporated in spring	40	(40)	(40)

France

Table 1: N delivery from supply from previous crops in France

Previous crop	N supply in kg N / ha
Cereals (straw removed), silage maize	0
Cereals (straw incorporated in soil)	-20
Grain maize	-10
Peas, beans, beet, potatoes, rape	20
Alfalfa, horse bean	30
Vegetables (carrot, chicory …etc)	10
Catch crops (Nitrate Directive)	10-15

Netherlands

Table 1: N delivery from supply from previous crops in The Netherlands

Previous crop	N supply in kg N / ha
Cereals	0
Grain maize	10
Sugar beets, cabbages, Brussels sprouts	30
Grass	100/30/0[1]

1 N-correction in 1st/2nd/3rd after destruction

Appendix 4 N recommendations (N Sollwerte) in the Netherlands and Germany (Nordrhein-Westfalen, Niedersachsen, Thüringen and Schleswig-Holstein)

Crop	Netherlands Sand	Netherlands Clay	Nordrhein-Westfalen	Niedersachsen	Thüringen	Schleswig-Holstein
Silage maize[1]	180/205 - Nmin	205 – Nmin	190 - Nmin	180 - Nmin	190 – Nmin	180 – Nmin
Potatoes, ware	300 – 1.8*Nmin		160 - Nmin	160 - Nmin	160 - Nmin	100-170 – Nmin
Potatoes, starch	275 – 1.8*Nmin	285 – 1.1*Nmin				
Sugar beets	200 – 1.7 * Nmin		180 – Nmin	160 – Nmin	140 - Nmin	120-140 – Nmin
Winterwheat[2]	230 - Nmin	270/300 - Nmin	210/230 – Nmin	210-230 – Nmin	170 – Nmin	170-270 – Nmin
Summer barley[3]	120 - Nmin	90/110 - Nmin	120/140 – Nmin	120/140 – Nmin	90/130 – Nmin	100-170 – Nmin
Onions					130 – Nmin	

1 regular manure applications/no manure history
2 fodder wheat/wheat used for bread production
3 barley used for breweries/fodder barley

Appendix 5 Values for N content in harvested product as given in the German Action Program (Düngerverordnung)

Crop	Harvested product	Kg N per ton fresh weight
Grass, 4 ton dry matter per ha	Whole plant	13[1]
Grass, 5.5 ton dry matter per ha	Whole plant	18[1]
Grass, 7.5 ton dry matter per ha	Whole plant	22[1]
Grass, 9 ton dry matter per ha	Whole plant	27[1]
Grass, 11 ton dry matter per ha	Whole plant	28[1]
Silage maize	Whole plant	3.80
Potatoes	Tubers	3.5
	Leaves	2.0
Sugar beets	Roots	1.8
	Leaves	4.0
Winter wheat, 12% protein	Grains	18.1
	Straw	5.0
Winter wheat, 14% protein	Grains	21.1
	Straw	5.0
Winter wheat, 16% protein	Grains	24.1
	Straw	5.0
Summer barley, fodder, 12% protein	Grains	16.5
	Straw	5.0
Summer barley, fodder, 13% protein	Grains	17.9
	Straw	5.0
Summer barley, brew, 10% protein	Grains	13.8
	Straw	5.0
Summer barley, brew, 11% protein	Grains	15.1
	Straw	5.0

1 kg N per ton dry matter