the Brief

N°11 - December 2014

Agricultural practices and nitrates in aquatic environments

Agricultural activities impact aquatic environments in terms of not only the quality and quantity of water resources, but biodiversity as well. The shift to increasingly intensive forms of agriculture since the 1960s, including increased use of fertiliser and greater specialisation of farms and regions (livestock farming concentrated in certain areas, reduced diversity of crops, drop in the surface areas of permanent meadows), has resulted in a breakdown in the balance between aquatic environments and agriculture, and specifically in degraded water quality due to nitrates. The European Union reacted by adopting the Nitrates directive[1] in 1991. The directive requires the designation of zones «vulnerable» to nitrate pollution, in which farmers must implement special action programmes. This document presents the situation of nitrate concentrations observed in surface water and groundwater, as well as agricultural practices, at the time of the 4th action program (globally over the period 2010-2011).

Origin and impact of nitrates

Nitrates are chemical compounds found in soil that form during the nitrogen cycle. Nitrogen is essential for plant growth. Nitrates are the natural result of the fixation of atmospheric nitrogen and the decomposition of organic matter by micro-organisms. Low concentrations of nitrates are found naturally in surface waters and in groundwater[2], however the increased quantities of nitrogen now lodged in soil due to human activities contribute to raising concentrations in aquatic environments. The main anthropogenic sources of nitrogen are fertilisers used to improve growth and increase crop yields. Fertilisers are of two types, either mineral (the product of chemical synthesis) or organic (manure or other organic matter, e.g. compost, WWTP sludge).

Farms both produce nitrogen via manure and consume nitrogen in the form of fertiliser for crops. For a general idea on the scale of farming activities in France, in 2011 farms covered approximately 29 million hectares (ha), i.e. 54% of the entire country, and almost 18.3 million hectares (63% of the utilised agricultural area) consisted of arable land, i.e. land available for crops. However, though 91% of the nitrogen inputs in soil and aquatic environments are caused by agriculture[3], other sources also exist, notably industry and household activities.

[1] The 91/676/EEC directive concerning the protection of waters against pollution caused by nitrates from agricultural sources.
[2] PIREN-Seine programme, *La pollution du bassin de la Seine par les nitrates*, 2009.
[3] MEDDE/CGDD, *Coût des principales pollutions agricoles de l'eau*, 2011.

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Nitrates are soluble and the part not assimilated by vegetation (or by the microbial biomass) can be transported by rainwater via:

> infiltration, i.e. penetrate deep into the soil and encounter groundwater;

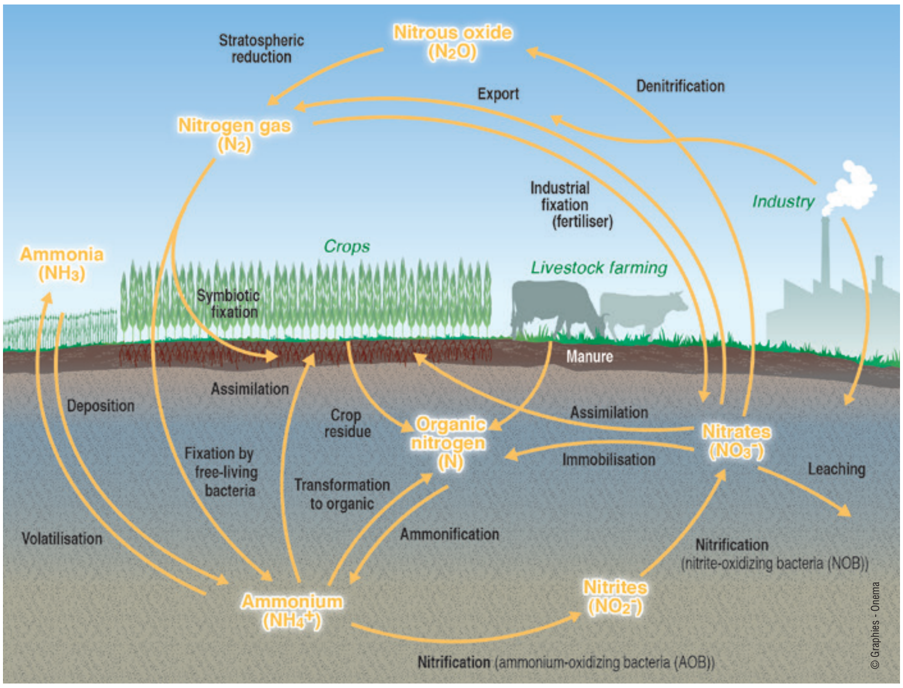
> runoff, i.e. flow over the surface of the ground and end up in rivers, lakes or the ocean;

> drainage, i.e. be removed from the upper layer of soil via drains and ditches.

Transfers to rivers are almost immediate, whereas nitrates stored in soil penetrate slowly down to groundwater. The time required to reach groundwater depends on the type of subsoil and can range from a few hours or months for fractured geological formations such as limestone and granite, to centuries in impermeable zones (clay). However, on average, infiltration, which occurs primarily during wet seasons, proceeds at a speed of approximately one to two metres per year, i.e. it takes ten to twenty years for nitrates to reach groundwater located twenty metres deep[4].

The nitrogen cycle

Source: drawn from Jussieu University, Paris.



Increased concentrations of nitrates in aquatic environments create severe problems.

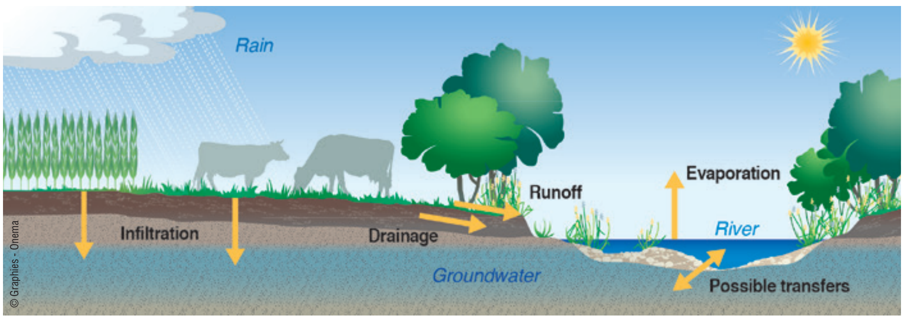
> Health risks. When ingested in very large quantities in drinking water, nitrates can contribute to provoking methemoglobinemia, a disease prevalent notably in babies and characterised by a reduction in the capacity of blood to provide enough oxygen to the cells of the organism[5].

> Environmental imbalances. With phosphates, nitrates contribute to disrupting the ecological balance of aquatic environments by provoking eutrophication. The excess quantities of nutrients result in the development of algae that asphyxiate the environment by consuming the available oxygen.

> Major economic costs. Overruns or the risk of overrunning the maximum level, set at 50 milligrammes per litre (mg/l) in water intended for human consumption, require expensive treatments to restore the necessary quality for drinking water and can even result in shutting down drinking-water abstractions[6]. Algal blooms[7] in water, e.g. the green tides in the Bretagne region, incur both direct costs (removal and treatment of the algae) and indirect costs, for example losses in tourism revenue for the concerned towns.

Nitrate transfer to aquatic environments

Source: drawn from GRAPPE.



[4] MEDDE/CGDD/SOeS, *Les teneurs en nitrates augmentent dans les nappes phréatiques jusqu'en 2004 puis se stabilisent*, 2013.
[5] World Health Organization (WHO). *Guidelines for drinking water quality. Addendum to Volume 1: Recommendations. Addendum to Volume 2: Health Criteria and other Supporting Information*, 1998.
[6] MASS, *Abandons de captages utilisés pour la production d'eau destinée à la consommation humaine*, 2012.
[7] An algal bloom is a relatively rapid increase in the concentration of one (or more) species of phytoplankton in an aquatic system.

Regulations to limit nitrate pollution from agricultural sources

Having observed since the 1970s the drop in water quality caused by nitrates, the EU became aware of the need to regulate agricultural practices and adopted the Nitrates directive[8] in 1991. The purpose of the directive, whose requirements were included in the Water framework directive (WFD)[9] voted in 2000, was to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent any new pollution of the same type. The directive requires that Member States:

> designate «vulnerable» zones, defined as those already polluted or threatened with nitrate pollution from agricultural sources;

> draft guidelines for agricultural good practices concerning the use of nitrogen fertilisers and land management, implemented on a voluntary basis by farmers;

> set up mandatory action programmes for all farmers in vulnerable zones;

> monitor the quality of surface waters and groundwater at least every four years in special monitoring programmes.

In France, implementation of the Nitrates directive started in 1992 with an initial monitoring campaign. Nitrate concentrations were measured on approximately 3 000 sites (called monitoring points) located in or near farming areas in order to characterise and subsequently monitor the zones already polluted or likely to be polluted. This approach logically resulted in detecting higher nitrate concentrations than if the monitoring points were spread randomly over the country. Since 2010, the monitored sites have been part of the network run by the national programme to monitor aquatic environments (a network monitoring much more than simply nitrates) set up in compliance with the WFD.

The results of the monitoring campaign were used to define the initial vulnerable zones in 1997. In France, vulnerable zones are those areas feeding into waters having nitrate concentrations close to or above the 50 mg/l threshold or having nitrate levels resulting in or likely to result in eutrophication in rivers, lakes and littoral waters. Subsequently, four other monitoring campaigns were carried out in 1997-1998, 2000-2001, 2004-2005 and 2010-2011, and the vulnerable zones were revised in 2000, 2003, 2007 and 2012. Since 2000, the surface areas declared as vulnerable zones have steadily increased nationwide, from 214 585 square kilometres in 2000 to 255 955 km^2, i.e. 46% of continental France, in 2012[10].

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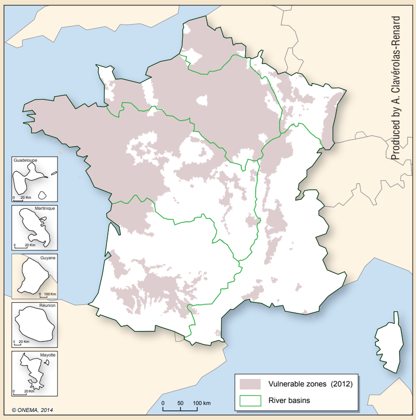
Current vulnerable zones (defined in 2012)

Current vulnerable zones were defined on the basis of the revision in 2012 taking into account the concentrations measured in surface waters and groundwater in 2010-2011. Approximately 55% of the farmland in France is considered vulnerable, mainly in areas where farming activity is highly intensive.



The revision took place during litigation initiated by the European commission against France for incorrect application of the Nitrates directive, notably for the insufficient designation of vulnerable zones. The position of the European commission was that a larger number of townships should be declared vulnerable zones in light of the observed nitrate concentrations and the risks of eutrophication. Following a decision by the EU Court of justice on 13 June 2013 in favour of the commission, a number of rules used for the 2012 revision were again criticised by the commission and may lead to fines. To avoid further litigation, France adopted end of March 2015 a new revision of the zones.

In this document, the information presented pertains to the vulnerable zones defined in 2007 and monitored during the 2010-2011 campaign.

[8] The 91/676/EEC directive concerning the protection of waters against pollution caused by nitrates from agricultural sources.

[9] Directive 2000/60/EC of the European parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Transposed into French law by Law 2004-338 (21 April 2004) and by Law 2006-1772 (30 December 2006) on water and aquatic environments.

[10] MEDDE, www.developpement-durable.gouv.fr/Directive-Nitrates-les-zones.html, 2013.

The first action programmes were prepared in 1996 and implemented on the departmental level from 1997 to 2000. They contained mandatory measures dealing notably with limitations or interdictions on manure spreading and the storage of livestock manure. Three other action programmes were carried out in 2001-2003, 2004-2008 and 2009-2013. The fifth programme was not carried out on the departmental level. It comprised national requirements that entered into force on 1 November 2013 and regional requirements that reinforced and developed the implementation conditions of certain national measures and also adopted additional measures specific to certain areas that entered into force over the year 2014.

The policy against water pollution caused by nitrates from agricultural sources is not the only policy regulating the use of nitrogen fertilisers in agriculture. In the wider framework of efforts to prevent disturbances and pollution of natural environments by nitrogen fertilisers, a number of regulations and economic stipulations apply in France and/or the EU. Below are a number of examples.

The current national action programme (since 2013)

The national action programme against nitrate pollution comprises eight measures[11] that are mandatory for farmers in vulnerable zones:

> periods when the land application of fertiliser is inappropriate;

> special storage conditions for livestock manure;

> conditions limiting the spreading of nitrogen fertilisers for each field, based on a balance between the foreseeable needs of crops and all sources of nitrogen inputs;

> requirements concerning fertiliser plans and the keeping of records on fertilizer use;

> the limitation of the amount of livestock manure applied to the land each year, including by animals themselves, to 170 kilograms per hectare (kg/ha) of utilised agricultural area, for each farm;

> conditions for land application of fertiliser near rivers and on steeply sloping ground, water-saturated, flooded, frozen or snow-covered ground;

> maintenance of a minimum quantity of vegetation cover to limit nitrogen losses during rainy periods;

> creation and maintenance of a year-round plant cover along certain rivers, sections of rivers and lakes larger than ten hectares.

> Regulations on «regulated installations for environmental protection» (ICPE)[11] require that farms likely to create risks or to provoke pollution or disturbances, notably for the safety and health of nearby residents, be subjected to a system of authorisations or declarations depending on the degree of risks or disturbances incurred. Spreading of livestock manure must take place at minimum distances from water and from third parties.

> Sale of fertiliser is subject to national[12] and EU[13] regulations setting rules for their authorisation, labelling and packaging.

> The Common agricultural policy (CAP)[14] subjects the payment of most financial aid to compliance with certain regulations and in particular those contained in the Nitrates directive. It also offers specific financial aid for implementation of farming practices respecting the environment and exceeding legal requirements.

In this document, a number of thresholds set by EU and French[15] regulations are used to determine water quality.

> 50 mg/l. This is the maximum threshold above which water may not be used for drinking-water production and abstractions could be halted.

> 40 mg/l. This is a warning threshold above which preventive measures to restore the environment must be taken.

> 25 mg/l. This is an alert threshold indicating that the technique used to produce drinking water must shift from a simple physical treatment with disinfection to a more demanding chemical or biological treatment.

In order to determine whether the situation is improving, the average concentrations of the period studied (2010-2011) were compared to those of the first monitoring campaign (1992-1993) using the following criteria:

> major increase = rise in concentrations exceeding 5 mg/l;

> moderate increase = rise in concentrations between 1 and 5 mg/l;

> stable = concentrations shift between +1 and -1 mg/l;

> moderate reduction = drop in concentrations between -1 and -5 mg/l;

> major reduction = drop in concentrations exceeding -5 mg/l.

In the EU, comparisons were made between the third (2004-2007) and fourth (2008-2011) monitoring campaigns because no earlier data were available. For that reason, caution is advised in comparing the French and EU results. Another factor making comparisons difficult is the fact that EU data cover only rivers and lakes, whereas for France, the data on surface waters include coastal waters.

Finally, in that weather conditions have a strong influence on the transfer of nitrates from soil to aquatic environments, analysis of trends in concentrations must take into account rainfall and hydrology. Heavy precipitation during a hydrological year[16] will encourage leaching of soil, thus releasing nitrates to aquatic environments, whereas the opposite is true during deficit years. Nitrate release through leaching is also greater when a very wet year occurs after several dry years[17] because the quantity of nitrates stored in the soil is greater. Consequently, any decrease or increase in nitrate concentrations must be analysed in light of the hydrological conditions during the years in question. For example, the hydrological year 1992-1993 was marked by a fairly severe low-flow period interrupted by a few months of heavy precipitation (December and January). Similarly, the year 2010-2011 started with a dry period followed by significantly above-average precipitation.

[11] Environmental code.
[12] Rural and maritime fishing code.
[13] Regulation EC 2003/2003 (13 October 2003) on fertiliser.
[14] Regulations 1305/2013 and 1306/2013 (17 December 2013).
[15] Ordinance (11 January 2007) on quality limits and standards for untreated water and water intended for human consumption. Ordinance (17 December 2008) setting assessment criteria and conditions for determining the status of groundwater and for determining the significant and long-term trends of the degradation of the chemical status of groundwater. Ordinance (25 January 2010) on the assessment criteria and methods for determining the ecological status, chemical status and ecological potential of surface water.
[16] A hydrological year is defined as the 12-month period starting after the month during which the most severe low-flow period generally occurs. Depending on the meteorological situation in different regions, the hydrological year may start at dates diverging from the standard hydrological year, but in France, it generally starts in September.
[17] Compared to seasonal mean values.

Nitrates in surface waters

In 2010-2011, measurements of nitrate concentrations were carried out at 3 352 monitoring points for surface waters (rivers, lakes, littoral waters), in or near farming areas:

> 83.3% reported an average concentration of less than 25 mg/l;

> 13.2% reported an average concentration of 25 to 40 mg/l;

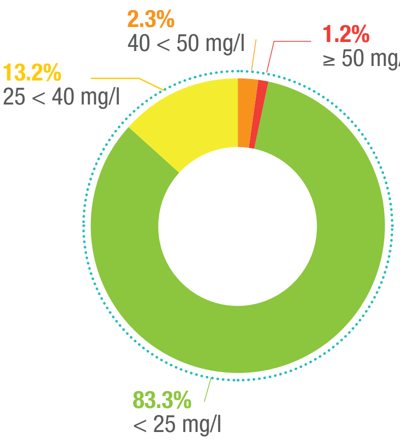
> 2.3 % reported an average concentration of 40 to 50 mg/l;

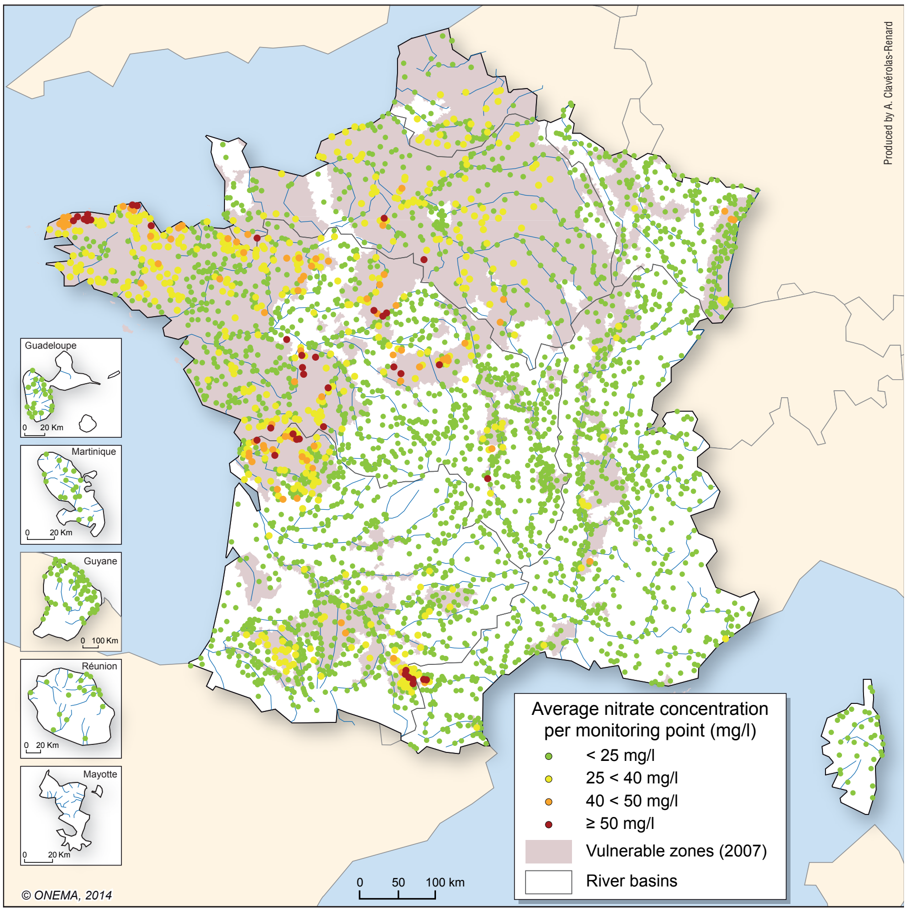
> 1.2% reported an average concentration exceeding the maximum threshold of 50 mg/l.

The average concentrations greater than 40 mg/l (117 monitoring points, i.e. 3.5%) are located primarily in the western section of France (Bretagne, Pays-de-la-Loire, Poitou-Charentes regions), where livestock farming is prevalent, but also in the Haute-Normandie, Ile-de-France, Centre and Languedoc-Roussillon regions where large-scale arable-crop farming is common (grains and high-protein oil seeds).

Distribution of surface-water monitoring points according to average nitrate concentrations in 2010-2011

Source: Nitrates report (Ecology ministry), data transmitted by the Water agencies and offices.





Nitrate concentrations in European rivers and lakes

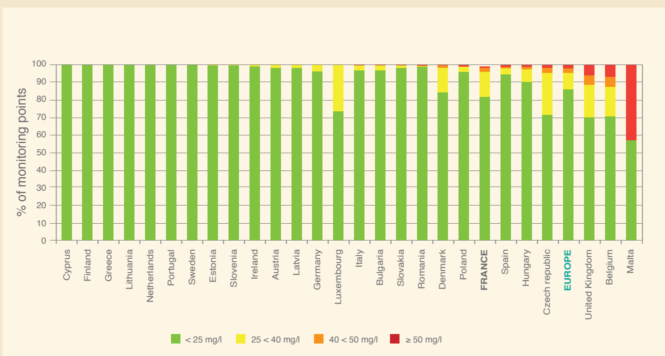
In Europe[18], the average concentration at 86% of monitoring points for continental surface waters was less than 25 mg/l, but 2% exceeded 50 mg/l. The situation in France is close to the European average. The following points should, however, be taken into account:

> monitoring strategy. France selected monitoring points representing areas subject to agricultural pressures and «polluted or likely to be polluted» by nitrates, whereas other countries, e.g. the Netherlands, opted for a wider range of monitoring points, not specifically targeting nitrates from agricultural sources;

> number and density of monitoring points. The United Kingdom comes in first place with 30.6 points per 1 000 square kilometres of territory, France comes in twelfth place with 6.1 points per 1 000 km², just under the European average (6.9). Surface areas of countries vary from 641 185 km² for France (the largest EU country) to 316 km² for Malta.

Distribution of EU river and lake monitoring points according to average nitrate concentrations in 2008-2011

Source: Nitrates report (EU commission), data transmitted by the Member States.

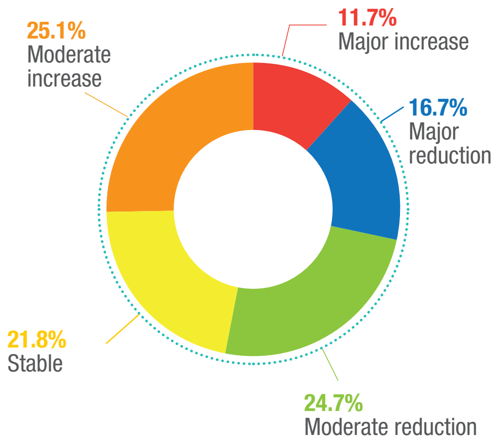


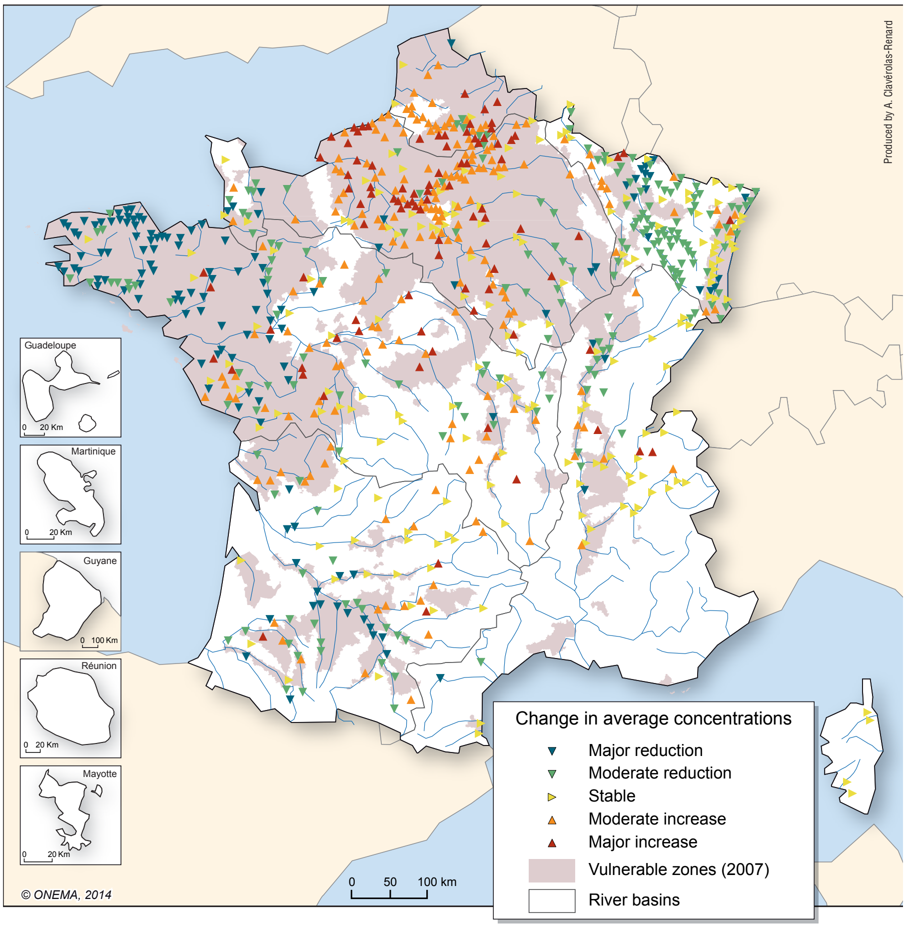
[18] EU commission, working document *Trends in surface-water average concentrations between 2004-2007 and 2008-2011*, 2013.

The average concentrations stabilised or dropped at almost two-thirds (63%) of the 780 monitoring points assessed during both the 1992-1993 and 2010-2011 campaigns. The areas where improvements occurred were located primarily in the western section of France (Bretagne, Pays-de-la-Loire and Midi-Pyrénées regions), whereas those where the situation worsened were found to a large extent in the Paris region.

Distribution of surface-water monitoring points according to trends in average concentrations between 1992-1993 and 2010-2011

Source: Nitrates report (Ecology ministry), data transmitted by the Water agencies and offices.





N.B. In the overseas territories, the monitoring campaigns for the Nitrates directive started in 1997, which explains why they are not mentioned here.

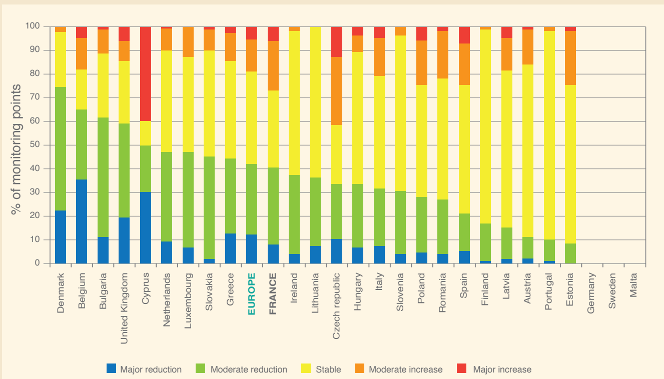
Trends in nitrate concentrations in European rivers and lakes

In Europe[19], the comparison between two more recent periods (2004-2007 and 2008-2011) shows that annual average concentrations dropped at 42% of the monitoring points on rivers and lakes (major reductions occurred at 12%) and increased at 19% of the monitoring points.

France is very close to the EU average with 40% reporting reductions (major reductions at 8%) and 27% reporting increases. However, it is again difficult to interpret these results given the different monitoring strategies of the countries and the impact of meteorological conditions.

Trends in average concentrations at EU river and lake monitoring points between 2004-2007 and 2008-2011

Source: Nitrates report (EU commission), data transmitted by the Member States.



[19] EU commission, working document *Trends in surface-water average concentrations between 2004-2007 and 2008-2011*, 2013.

Nitrates in groundwater

In 2010-2011, measurements of nitrate concentrations were carried out at 2 509 monitoring points for groundwater, in or near farming areas:

> 51 % reported an average concentration of less than 25 mg/l;

> 25.1 % reported an average concentration of 25 to 40 mg/l;

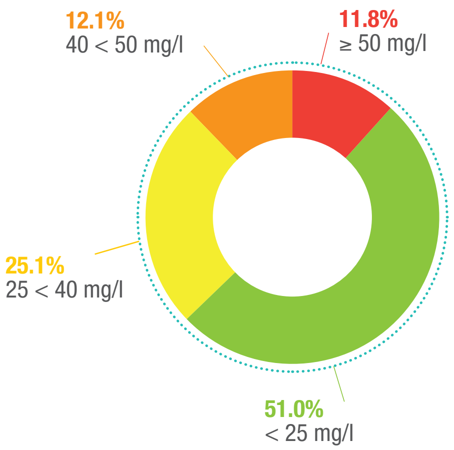
> 12.1 % reported an average concentration of 40 to 50 mg/l;

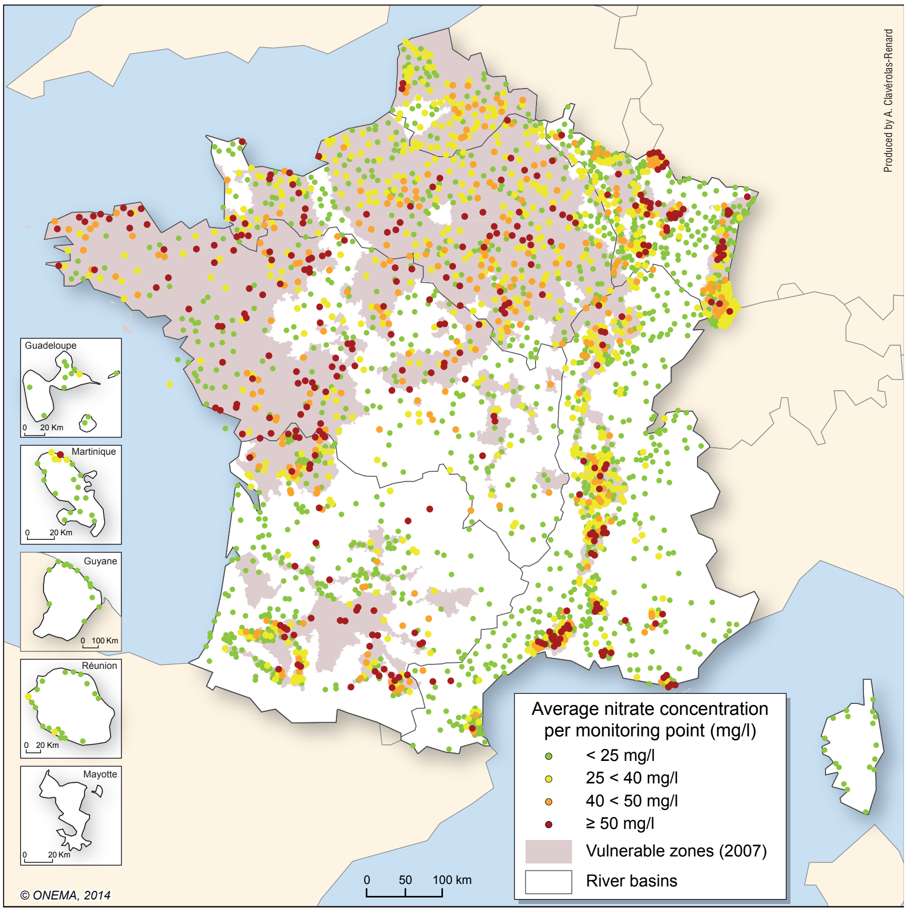
> 11.8% reported an average concentration exceeding the maximum threshold of 50 mg/l.

Monitoring points reporting average concentrations greater than 40 mg/l are spread over the entire country, with the exception of areas where agriculture is a minor activity and those where agriculture is less intensive (Alps and Massif central).

Distribution of groundwater monitoring points according to average nitrate concentrations in 2010-2011

Source: Nitrates report (Ecology ministry), data transmitted by the Water agencies and offices.





Nitrate concentrations in European groundwater

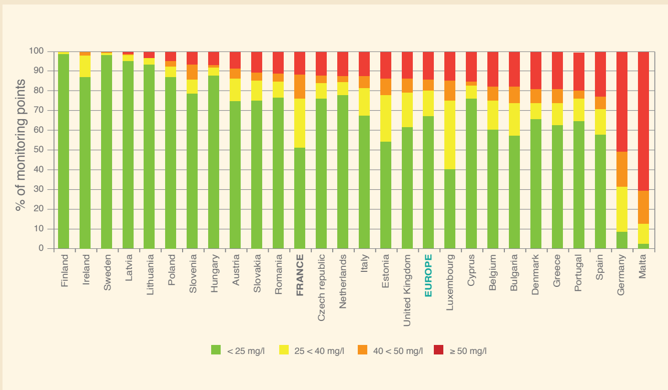
In Europe[20], the average concentration at 67% of monitoring points for groundwater was less than 25 mg/l, but 14% exceeded 50 mg/l.

In France, the proportion of monitoring points reporting concentrations less than 25 mg/l is not as high as the EU average. But the proportion of monitoring points reporting concentrations greater than 50 mg/l is also lower.

Similar to the situation for surface waters, it is important to compare what is comparable, notably in terms of the surface areas of the groundwater bodies, the number of monitoring points and the monitoring strategy. For example, the number of monitoring points varies from 5 331 in Italy to 20 for Luxembourg.

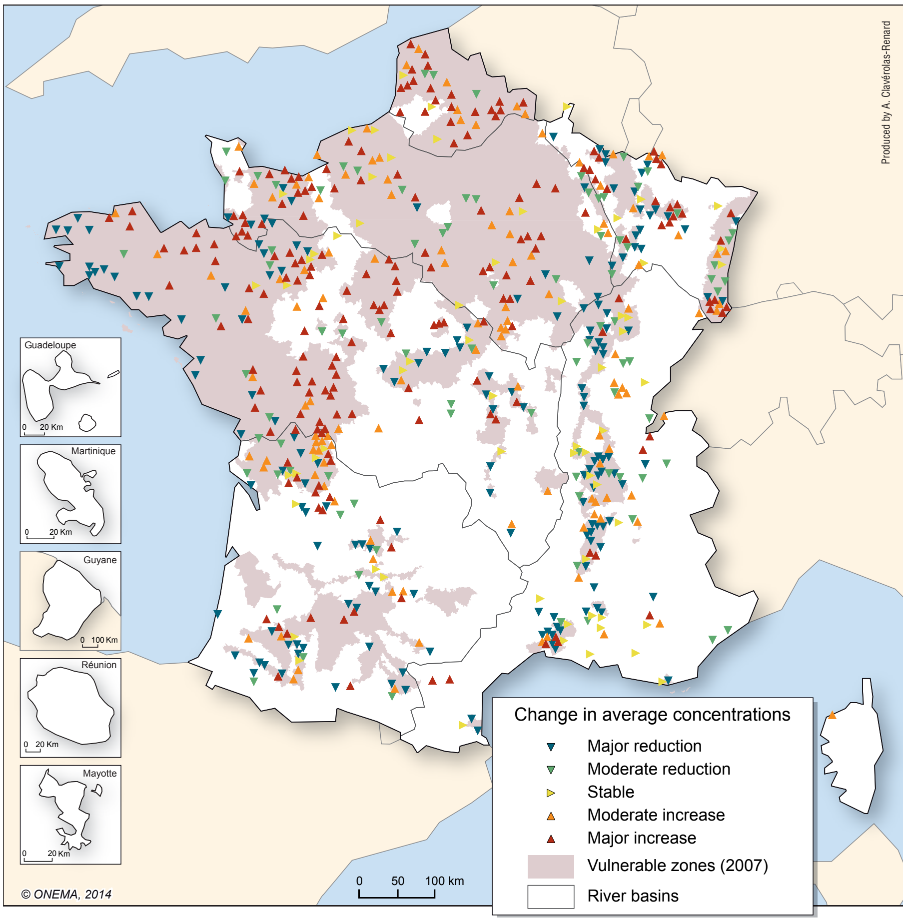
Distribution of EU groundwater monitoring points according to average nitrate concentrations in 2008-2011

Source: Nitrates report (EU commission), data transmitted by the Member States.



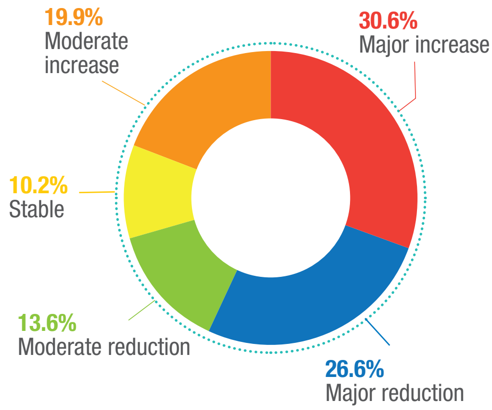
[20] EU commission, working document *Trends in groundwater average concentrations between 2004-2007 and 2008-2011*, 2013.

The average concentrations stabilised or dropped at half of the 625 monitoring points assessed during both the 1992-1993 and 2010-2011 campaigns, but increased sharply at one-third. The monitoring points reporting the most significant increases were located in the western section of France (Poitou-Charentes, Pays-de-la-Loire, Basse-Normandie regions), up to the Nord-Pas-de-Calais region and in the Paris region. Reductions were most commonly noted in the Rhône-Alpes, Bourgogne, Midi-Pyrénées and Bretagne regions.



Distribution of groundwater monitoring points according to trends in average concentrations between 1992-1993 and 2010-2011

Source: Nitrates report (Ecology ministry), data transmitted by the Water agencies and offices.



N.B. In the overseas territories, the monitoring campaigns for the Nitrates directive started in 1997, which explains why they are not mentioned here.

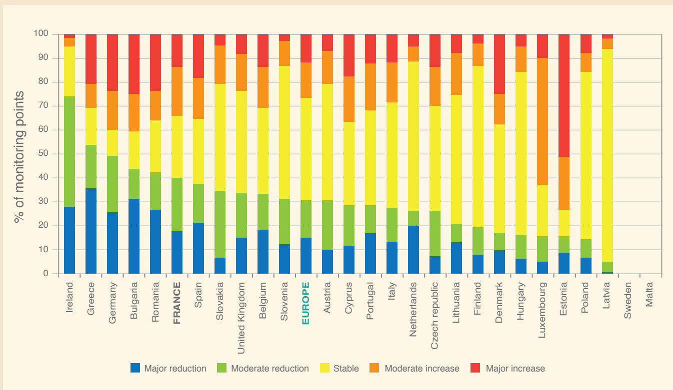
Trends in nitrate concentrations in European groundwater

In Europe[21], between 2004-2007 and 2008-2011, 43% of monitoring points reported stable conditions, 30% a reduction and 27% an increase.

France reported a higher percentage of monitoring points showing reductions (40%) than the EU average, but also a higher percentage of increases (34%). Similar to the situation for surface waters, it is important to remember that these results are influenced by the climate and by the different monitoring strategies of the Member States.

Trends in average concentrations at EU groundwater monitoring points between 2004-2007 and 2008-2011

Source: Nitrates report (EU commission), data transmitted by the Member States.



21 EU commission, working document *Trends in groundwater average concentrations between 2004-2007 and 2008-2011*, 2013.

Nitrogen produced by livestock farming

Agricultural activities use nitrogen in the form of fertiliser for crops, but also produce nitrogen via the manure generated on farms.

For 2010[22], it was estimated that farm animals produced the following quantities of organic nitrogen:

> 1 326 000 metric tons, by 19.5 million head of cattle;

> 143 000 metric tons, by 13.9 million pigs;

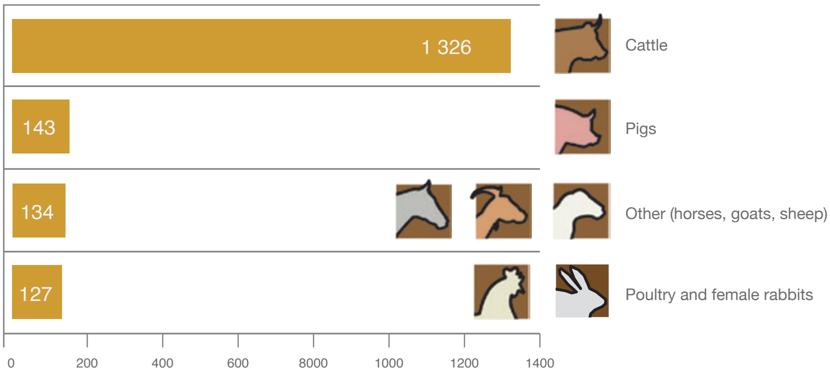
> 127 000 metric tons, by 296.1 million poultry and 855 000 rabbits (female reproducers);

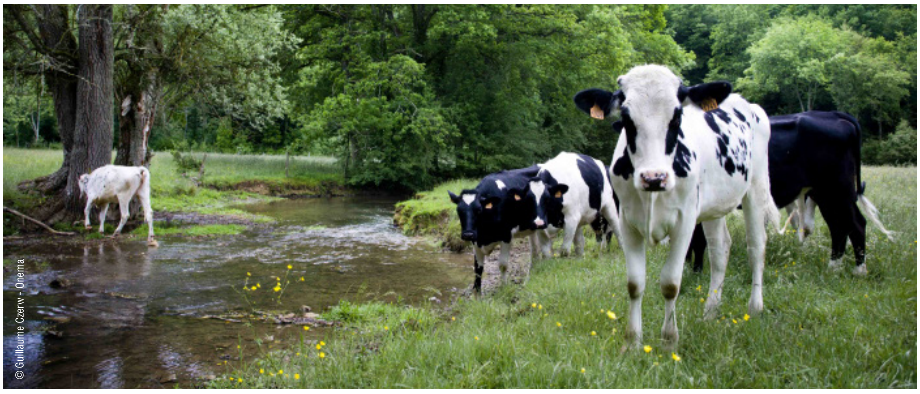
> 134 000 metric tons, by 9.3 million horses, goats and sheep.

A majority of the manure produced by farm animals is used on the farms where it originates, with 55% released directly (essentially by cattle in the meadows where they graze) and 45% spread mechanically[23].

Tons of nitrogen produced by each type of livestock in 2010

Source: CGEDD & CGAAERF[23].





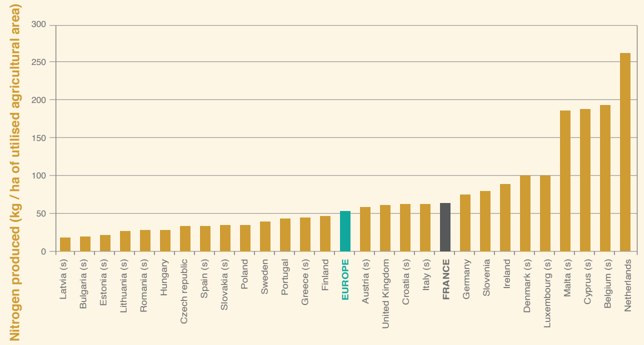
Pressures exerted by organic nitrogen in Europe

In terms of the average quantities of organic nitrogen produced per hectare (ha) of utilised agricultural area, France is positioned slightly above the EU average with 64 kilogrammes, but far behind the Netherlands, Belgium, Cyprus and Malta, countries with high densities of livestock.

The data here indicates the pressure exerted by organic nitrogen per hectare, but it should be noted that a simple average for a country can mask significant disparities between regions, i.e. the pressure in regions where livestock farming is prevalent can be much higher than the national average.

Pressure exerted by organic nitrogen in the EU countries in 2010

Source: Eurostat, data transmitted by the Member States[24].



(s): Eurostat estimate[25]

[22] These results are obtained by multiplying the numbers of livestock by a coefficient specific to each type of livestock, taking into account the type of feed, age of the animals, breeding techniques (indoor or outdoor), etc. The data on livestock numbers were drawn from MAAF/CEP/SSP, *Recensement agricole 2010*, 2011, and the coefficients are those recommended and updated by CORPEN.

[23] CGEDD & CGAAER, *Plan d'action relatif à une meilleure gestion de l'azote en agriculture*, 2013.

[24] In the framework of the survey on farm structures or drawn from annual statistics (for livestock). Nitrogen production by livestock is calculated by multiplying head counts by excreted-nitrogen coefficients. Data extracted from the Eurostat site on 2 December 2014.

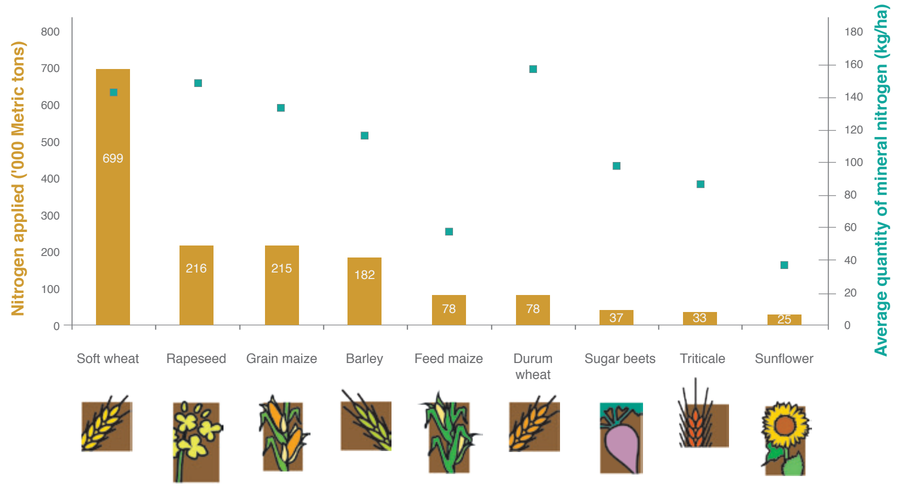
[25] In cases where a country did not provide excreted-nitrogen coefficients, nitrogen values were calculated using head counts and the excreted-nitrogen coefficients indicated in the National inventory submissions under for the U.N. Framework convention on climate change.

Nitrogen spread for crops

Most crops receive nitrogen fertiliser[26], whether organic or mineral, in order to ensure or enhance yields and the quality of the crops. Though nitrogen in mineral form represents approximately two-thirds of the annual inputs for crops[27], certain types of crops receive greater quantities of organic nitrogen. For example, that is the case for feed maize for which over half of the nitrogen fertiliser used is organic. This is because the farmers growing maize are generally engaged in mixed crop-livestock farming, i.e. they produce feed maize for their animals and spread the manure on the maize fields, thus making use of the manure and avoiding the purchase of fertiliser. On the other hand, mineral fertiliser makes up 95% of the nitrogen fertiliser for soft wheat, 99% for durum wheat and 94% for barley.

Tons of mineral nitrogen applied each year to the main crops in continental France in 2010

Source: SOeS[28].



The largest quantities of mineral nitrogen are generally applied to the crops occupying the largest surface areas, for example, in 2010, 699 000 metric tons for soft wheat (17.1% of utilised agricultural area), 216 000 for rapeseed (5.1%), 215 000 for feed maize (5.6%) and 182 000 for barley (5.5%).

However, some plants require larger inputs to ensure their growth. The average quantity of mineral nitrogen, i.e. the total quantity divided by the surface area, differs between crops, e.g. sunflowers occupy 2.4% of the utilised agricultural area, but receive only 36.6 kg/ha, whereas durum wheat occupies 1.7% of the utilised agricultural area and receives 157.6 kg/ha.

Quantities of mineral nitrogen applied and percentages of the utilised agricultural area for the main crops in continental France in 2010

Source : SOeS[28].

	Soft wheat	Rapeseed	Grain maize	Barley	Feed maize	Durum wheat	Sugar beets	Triticale	Sunflower
Net mineral fertilisation ('000 metric tons)	699	216	215	182	78	78	37	33	25
Percentage of mineral fertilisation in total fertilisation	95	90.2	83.8	93.8	42.6	99	84.9	78.4	83.4
Percentage of utilised agricultural area for the crop	17.1	5.1	5.6	5.5	4.8	1.7	1.3	1.3	2.4
Average quantity of mineral nitrogen (kg/ha)	143	149	134	116	57	158	98	86	37

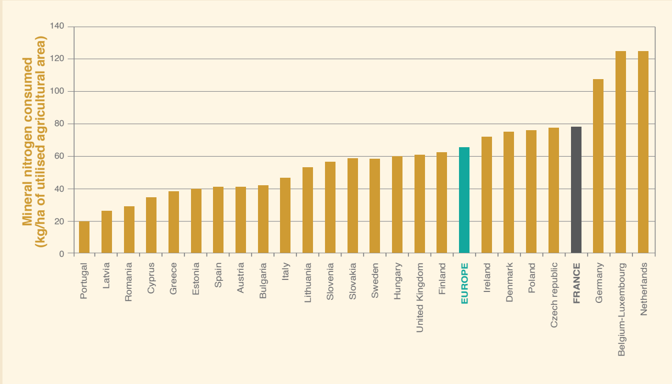
[26] Except for leguminous plants (e.g. peas) that can naturally fix atmospheric nitrogen.
[27] MAAF/CEP/SSP, *Gestion de l'azote*, Data sheets on variables, 2009.
[28] MEDDE/CGDD/SOeS, *Les surplus d'azote et les gaz à effet de serre de l'activité agricole en France métropolitaine en 2010*, 2013.

Nitrogen used for crops in Europe

In Europe, France is among the countries using the most mineral nitrogen per hectare of utilised agricultural area, but trails far behind the Netherlands, Belgium-Luxembourg and Germany. This situation[29] is due in part to the differences in crops, for example the Netherlands with their horticultural production that consumes great quantities of fertiliser and France where a sizeable part of the utilised agricultural area is devoted to crops that receive a high average quantity of mineral nitrogen, such as wheat and rapeseed. Other criteria may come into play, such as the desired yields and quality of production, or the density of livestock making it necessary to intensify the production of feed for the animals.

Consumption of organic nitrogen in the EU countries in 2010

Source: Eurostat, data transmitted by the Member States.



A reduction in the nitrogen balance

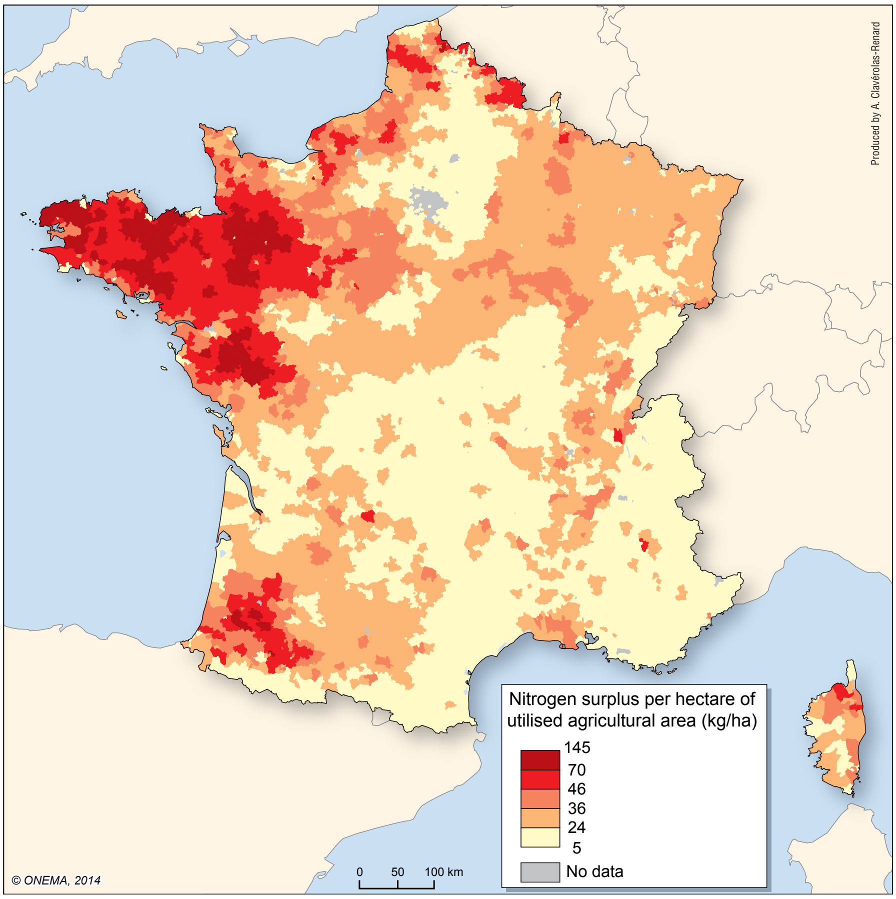
The quantity of nitrogen inputs for crops is not necessarily significant in terms of the quantities transferred to water because the latter depend on the quantities consumed by the crops and on transfer phenomena. The quantity of nitrogen that remains in the soil after harvesting because it could not be assimilated by the crops and that is likely to reach aquatic environments is called the "nitrogen surplus". The nitrogen surplus can be estimated by the nitrogen balance, which essentially corresponds to the difference between:

> nitrogen inputs, which consist of mineral fertiliser, livestock manure, other organic inputs from towns or industry, symbiotic nitrogen fixation by leguminous plants, atmospheric deposition;

> nitrogen outputs, i.e. the nitrogen consumed by crops and meadows, and the losses of nitrogen gas.

Geographic distribution of nitrogen surpluses in 2010

Source: Nopolu (SOeS)[31]



The use of different coefficients (e.g. for the manure produced by dairy cattle) or of different geographic units may explain the differences in the results presented by the Ecology ministry (via Nopolu, a tool developed by IFEN[30]) and the Agriculture ministry (via GraphAgri). However, the overall results for France as a whole are the same.

[29] Bel, F. *et al.*, Efficacité et limites d'une taxe sur les engrais azotés : *éléments d'analyse à partir de 16 pays européens*, 2004.

[30] French environmental institute (IFEN), which subsequently became the Observation and statistics unit (SOeS), the statistical department of the Ecology ministry.

In 2010, agricultural activities in France generated a nitrogen surplus estimated at 902 000 metric tons by the Ecology ministry[31], i.e. 32 kg of nitrogen on average per hectare of utilised agricultural area. The surplus varies depending on:

> the type of livestock farming (intensive or extensive) by a factor of 1 to 4. In the Auvergne and Limousin regions (extensive production), the nitrogen surplus is 15 and 16 kg/ha respectively, whereas in the Pays-de-la-Loire and Bretagne regions (highly prevalent intensive production), the surplus reaches 55 and 69 kg/ha respectively;

> the type of crop by a factor of 1 to 6. Among the main crops, the highest surplus is for durum wheat with 63 kg/ha, followed by rapeseed with 60 kg/ha.

The nitrogen surplus is a good indicator of areas potentially threatened with nitrogen pollution. The trend over time can provide information on changes in nitrogen-management techniques. However, it cannot be directly interpreted as an indicator of nitrogen losses to water given the very complex transfer processes of nitrogen through soil, air and water.

The Agriculture ministry calculated that between 2000 and 2012, the average nitrogen surplus represented 34% of the inputs. Between 2000 and 2008, the average was 36%, but then it dropped to 29% in 2012. This trend should be examined in light of the overall reduction in nitrogen inputs since the beginning of the 2000s (-13% from 2000 to 2012) and of the climate conditions (e.g. the exceptionally dry year 2003).

Percentage of annual agricultural nitrogen inputs left in the soil by crops and agricultural nitrogen inputs (organic and mineral) between 2000 and 2012

Source: GraphAgri France 2014 (SSP)[32].

N.B. The 2003 spike in the nitrogen surplus was due to the exceptionally dry year that reduced crop growth and nitrogen consumption by the crops. The spikes in 2008 and 2011 in nitrogen inputs were due to the high price of grain compared to the cost of nitrogen during the monitoring campaigns 2007/2008 and 2010/2011[33].

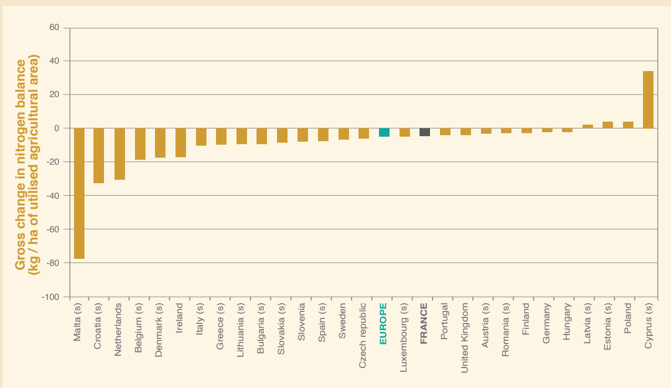
European trends in nitrogen balances

In Europe, France is positioned number 12 among the countries reporting a drop in the average nitrogen balance between 2004-2007 and 2008-2011. The trend in France is close to the average for the EU as a whole.

The countries reporting an upward trend in their nitrogen balance are primarily the new members of the EU where production volumes have increased without any specific nitrogen-management policy.

Trends in the gross nitrogen balance in EU countries between 2004-2007 and 2008-2011

Source: Eurostat, data transmitted by the Member States.



(s): Eurostat estimate

[31] MEDDE/CGDD/SOeS, *Les surplus d'azote et les gaz à effet de serre de l'activité agricole en France métropolitaine en 2010*, 2013.

[32] MAAF/CEP/SSP, *L'agriculture, la forêt et les industries agroalimentaires – Environnement*, 2013.

[33] MAAF/CEP/SSP, *Engrais minéraux azotés : ajustement des apports*, 2012.

Example of changes in agricultural practices

The quantities of nitrogen input and produced on farms have a major influence on the nitrogen surplus and consequently the risk of nitrate transfers to aquatic environments, however a number of other factors, e.g. climate, soil type, type of plant cover, etc., are just as important. That is why efforts to limit water pollution by nitrates from agricultural sources must take the other factors into account as well. The past Nitrate action programmes established good practices for nitrogen management (fertiliser inputs and periods between crop rotations) taking into account all the above factors. They targeted "the right dose, at the right place and at the right time". Other, more ambitious measures targeting more in-depth changes in production systems have also been launched in certain areas to manage local problems, e.g. to protect abstraction supply zones or river basins polluted with green algae. These measures bring a wide array of tools into play, notably farm assessments, advice and training provided to farmers, agri-environmental grants and financial aid for environmentally friendly investments, regulatory measures in some cases, etc.

Though it is difficult to directly link the changes in agricultural practices and drops in nitrate concentrations in water given the complexity and duration of transfers, the examples below, drawn from the current Nitrate action programme, illustrate a number of changes.

> Rational fertilisation

One of the primary measures involves limiting nitrogen inputs for crops. Rational fertilisation is the means to reduce nitrogen losses throughout the crop cycle. A number of different rationalisation techniques exist:

> balanced nitrogen fertilisation, i.e. management of the total quantity of nitrogen. Ever since the first Nitrates action programme in 1996, the quantity of fertiliser spread must be limited according to calculations based on the balance between the foreseeable nitrogen needs of crops and nitrogen inputs from all sources. Management rules were clarified in the fifth Nitrates action programme by creating a complete system of regional reference values used to calculate input quantities for all types of crops and for meadows in each region;

> input splitting, i.e. dividing the total quantity into several applications over the growth cycle of the crop. This technique adapts the inputs to the precise needs of the plants;

> adjustment of the total input during the crop cycle to the nutritional status of the plants which can be estimated by growth measurements, the colour of leaves, chlorophyll content, etc., and using a management tool. The tool runs the various measurements on plants and produces a diagnosis of the nutritional status at the time of the measurement.

Over the past ten years, use of the management tools has made great progress. For example, the percentage of grain crops (surface area) for which nitrogen inputs were adjusted using one of the existing management tools increased between 2005-2006 and 2010-2011 for winter durum wheat, winter soft wheat, winter barley and spring barley. In 2010-2011, the surface areas represented one-quarter of the total surface areas for spring barley and soft wheat, and over one-third for durum wheat.

Trends in percentage of grain-planted surface areas with nitrogen inputs adjusted by a management tool in 2005-2006 and 2010-2011

Source: SSP[34].

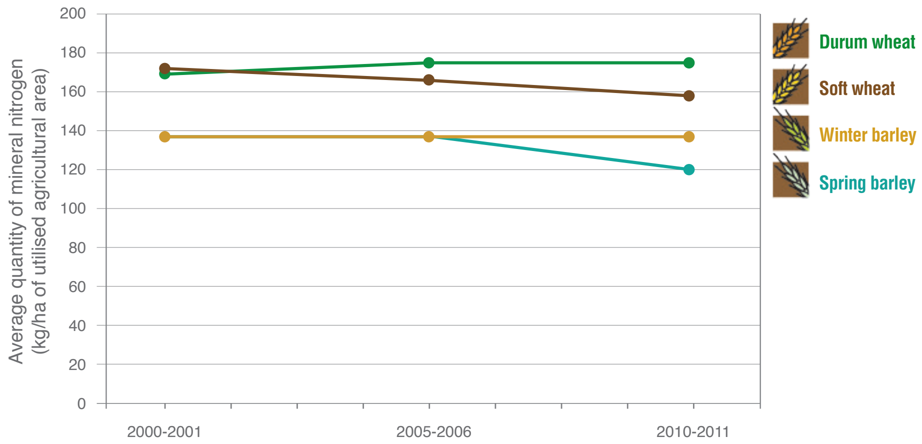
	% surface areas with management tool in 2005-2006	% surface areas with management tool in 2010-2011
Winter durum wheat	9%	36%
Winter soft wheat	11%	25%
Winter barley	4%	15%
Spring barley	3%	27%

[34] MAAF/CEP/SSP, *Enquête Pratiques culturales 2011*, 2013.

Implementation of these rational fertilisation techniques is one of the reasons behind the drop since 2000 in the average quantities of mineral nitrogen applied to the main types of crops, even though other factors also intervene, e.g. climate. The reduction took place between 2000 and 2010, particularly for spring barley (-10%) and soft wheat (-10%).
Rational fertilisation is not, however, in itself sufficient to reduce nitrate losses and must be combined with other measures, such as soil cover between crop rotations.

Trends in average quantities of mineral nitrogen applied to the main types of crops between 2000-2001 and 2010-2011

Source: SSP[35].



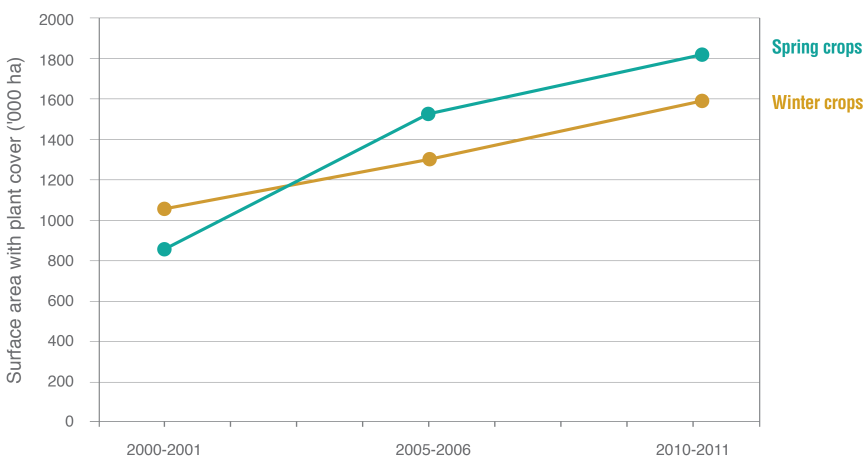
> Soil cover between crop rotations

Between crop rotations, i.e. between the harvest of one crop and planting of the next, soil is often left bare, without any vegetation capable of absorbing the nitrates in the soil. There is a significant risk that the nitrates not absorbed by the harvested crop and those produced by mineralisation of the organic matter in the soil will be transferred to the aquatic environment, particularly if heavy rains occur during the period in question. A plant cover between crop rotations is a means to partially absorb the excess nitrates and to immobilise them temporarily in the plants, thus limiting the risks of water pollution. The plant cover can also supply the next crop with nitrogen that is freed from its residue through mineralisation, which makes it possible to reduce the quantity of nitrogen fertiliser applied to the next crop.

The soil cover can be provided by nitrate-fixing intermediate crops, often a fast-growing fodder crop such as white mustard, radishes, rapeseed, phacelia (*Phacelia tanacetifolia*), vetch (*Vicia sativa*), clover, etc., by volunteers of crops and, in some cases, by harvest residues. Soil cover has been mandatory since 2001 in certain sections of vulnerable zones and the obligation was progressively spread to all vulnerable zones during the fourth Nitrates action programme from 2009 to 2013. The surface areas receiving a nitrate-fixing intermediate crop or crop volunteers have progressed significantly, from 1.9 million hectares in 2001 to 3.4 million in 2011. The trend was even stronger for cover crops prior to spring crops in that it doubled over the ten-year period.

Trends in surface areas with a plant cover (nitrate-fixing intermediate crops and volunteers) before spring crops and winter crops

Source: SSP[35].



[35] MAAF/CEP/SSP, *Enquête Pratiques culturales 2011*, 2013

The positive influence of cover crops on nitrate concentrations in water

A study[36] by the National institute for agricultural research (INRA) demonstrated, in most of the tested situations, the effectiveness of nitrate-fixing intermediate crops in reducing leaching and nitrate concentrations in drainage water, with a reduction rate generally greater than 50%. In most cases, that reduction rate reduces the nitrate concentration in drainage water to less than 50 mg/l, the maximum permissible concentration in drinking water. The effects vary, however, depending on the pedoclimatic context, the weather conditions during the given year and the crop system. For example, there is a greater risk of leaching when rainfall is frequent and the layer of topsoil is thin. In addition, leguminous plants (that can fix atmospheric nitrogen) are generally less effective in reducing the leached quantities of nitrogen than non-leguminous plants.

> Grass buffer strips

The creation of grass or wooded buffer strips along rivers in all vulnerable zones has been mandatory since the fourth Nitrates action programme. Grass or wooded buffer strips limit the direct transfer of nitrogen from farmland to rivers. The strips must be at least five metres wide and run along certain rivers and lakes listed in the applicable regulations[37]. Studies have shown that grass buffer strips can limit the transfer of solid particles by acting as a filter and encouraging sedimentation. For example, a grass buffer strip eight metres wide can reduce the flow of nitrates carried in runoff water by 73%[38].

Outlook

The Council for the environment and sustainable development (CGEDD) assessed French water policy in 2013[39] and, in view of reducing agricultural nonpoint-source pollution, recommended:

> implementing all the various solutions (assistance in fertilisation management, agronomic advice, control over land use, fiscal instruments, etc.) through a combination of incentives, regulations and inspections;

> supporting research projects on priority topics such as agricultural techniques requiring less fertiliser and having less impact on water resources and aquatic environments, ecological engineering, protection of abstraction supply zones, etc.

The fifth Nitrates action programme, comprising both national and regional programmes (launched in 2014), includes measures that have been reinforced compared to those in the previous departmental programmes. The measures extend the periods during which spreading is forbidden, establish for each region a set of reference values used to calculate nitrogen fertiliser volumes based on the balance between crop needs and inputs, set precise rules for spreading on steeply sloping ground, water-saturated, flooded, frozen or snow-covered ground,

[36] INRA. *Réduire les fuites de nitrate au moyen de cultures intermédiaires : conséquences sur les bilans d'eau et d'azote, autres services écosystémiques.* Summary of the study report, 2010.
[37] Ordinance (13 July 2010) on rules to achieve good agricultural and environmental conditions.
[38] Blanco-Canqui *et al.*, *Grass Barrier and Vegetative Filter Strip Effectiveness in Reducing Runoff, Sediment, Nitrogen, and Phosphorus Loss*, 2004.
[39] CGEDD, *Évaluation de la politique de l'eau - Quelles orientations pour faire évoluer la politique de l'eau ?*, 2013.

define conditions for soil covers, etc. Supplementary measures on nitrogen management have also been set up for specific situations such as abstraction supply zones for drinking-water, in compliance with the Grenelle 2 law[40], or river basins confronted with green algae.

Note on methods

The information presented briefly here was prepared using a method implemented jointly by Onema, IOWater, the Ecology ministry, the Agriculture ministry and the members of a national working group (GVI) comprising the Water agencies and offices, the Water and biodiversity directorate of the Ecology ministry, basin DREALs, SOeS and research institutes such as BRGM, Ifremer and Ineris.

The purpose of the nitrogen balance is to calculate the excess quantity of nitrogen in a given area taking into account the inputs (organic and mineral) and the outputs. Various data sources are mentioned in this document:

> the nitrogen surplus, calculated on the basis of spatialised farm-pressure data, is drawn from Nopolu (developed by the Ecology ministry);

> the result of the nitrogen balance, calculated for administrative geographic sectors, is drawn from GraphAgri (developed by the Agriculture ministry);

> the gross nitrogen balance, published by Eurostat, the EU statistical department, based on the data transmitted by the Member States (by the Agriculture ministry for France). It should be noted that the calculation methods for the nitrogen balance are currently being harmonised among the EU Member States.

The Ecology and Agriculture ministries use the same calculation method taking into account the following factors:

> inputs: net nitrogen inputs to plants (mineral and organic volatilisation is deducted from mineral and organic fertiliser volumes), symbiotic fixation and atmospheric deposition;

> outputs: assimilation by crops and fodder, losses of nitrogen gas.

However, there are still a number of differences in the coefficients used for certain factors, e.g. excreted-nitrogen coefficients, notably for dairy cows, and meadow nitrogen-output coefficients, as well as in the spatial units used for calculations.

The data on nitrate concentrations are contained in the reports filed by the Member States to the EU commission every four years in compliance with the Nitrates directive. In France, the nitrate-concentration data are produced by the Water agencies, the Regional environmental, development and housing agencies (DREAL) and the Regional health agencies (ARS).

Finally, the data on livestock and cropping practices are drawn from three main sources:

> the Agriculture ministry and particularly its Agreste site, which provides agricultural statistical data, and GraphAgri;

> the Ecology ministry and its Observation and statistics unit (SOeS);

> Eurostat, which publishes the data transmitted by the Member States via their statistics departments.

For more information

Data on the monitoring programmes for the Nitrates directive may be found at:
www.rapportage.eaufrance.fr/directive-nitrates

Find this document on the internet at:
www.eaufrance.fr/IMG/pdf/nitrates_20102011_201412_EN.pdf
or www.documentation.eaufrance.fr

eaufrance The French water-information portal:
www.eaufrance.fr

[40] Law 2010-788 (12 July 2010) on the national effort for the environment.

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the Brief

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