Closing the mineral cycles at farm level

Good practices to reduce nutrient loss in the Lombardy region (Italy)
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Nutrient loss – Why does it matter?

Nitrogen, phosphorus and potassium are essential for agricultural production as they nourish the crops and support soil productivity. However, if these nutrients are not taken up by plants, they run the risk of being lost in various ways (e.g., leaching, run-off, emissions) and causing unnecessary costs for the farming business. Finding the right amount required by the plants and optimising the timing and application of the nutrients to match these needs can result in an economic gain and a positive effect on human health and the environment, including soil health and fertility.

This leaflet was developed in the framework of the project “Resource Efficiency in Practice – Closing Mineral Cycles”. It aims at providing practical information to farmers on how the risk of nutrient loss can best be minimised or prevented. In particular, the leaflet addresses the effects of nutrient loss in Italy, with a specific focus on the Lombardy region. The leaflet also provides practical information to farmers on how resource use efficiency can be maximised through good practices at farm level.
Agricultural structure in Lombardy

Lombardy is one of the leading agricultural regions in Italy with 39% of the regional land used for agricultural production in 2014. Lombardy accounted for around 14% of the national agriculture production value in 2013. Livestock production in the region is significant. In 2013, pig, beef, dairy cattle and poultry production represented 40%, 37%, 26% and 19%, respectively, of the national production (in tonnes). Regarding crops, arable land represented 77% of Lombardy’s Utilised Agricultural Area (UAA) in 2012, which was mostly cultivated with maize (used for grain and silage), rice and wheat. Permanent crops and grassland, which are primarily concentrated in hilly areas, represented 23% of the region’s agricultural land use.

Figure 1 - Map of Europe (Italy in green) and map of Italy showing the Lombardy region (dark green)
How does nutrient loss affect farming business?

Nutrients are valuable and vital resources, which can nourish productive grazing lands and crops. From an economical point of view, it therefore makes sense to match the nutrient application to the grassland and crop requirements, thus limiting nutrient loss as much as possible. This in turn could limit the additional costs (e.g., tractor fuel, spreading equipment, labour, etc.) incurred when nutrients are applied beyond the crop and grass requirements. In addition, nutrient loss can create other costs for the farmer; for instance, more mineral fertiliser may need to be purchased and used to supplement for lost nutrients and reach the level of the plants’ needs. Avoiding the impacts that may result from nutrient loss provides benefits to farming businesses, such as maintaining soil health and fertility and crop yields.

How does nutrient loss affect the Lombardy region and what are the causes?

The main regional pressures faced in Lombardy arise from nitrogen losses resulting from agricultural production and sewage water from industrial activities and urban settlements. Organic and mineral fertiliser application which is not fine-tuned in terms of timing, amount, equipment, and/or technology is a significant cause. Eutrophication of freshwater occurs in Lombardy and nitrate levels occasionally exceed the drinking water threshold. Marine water is also indirectly affected by nutrient losses in the region, with 43% of the nitrogen load carried by the Po River to the Adriatic Sea originating in Lombardy. Nitrate contamination of groundwater also occurs frequently in the upper plains, impacting drinking water and posing risks to human health.

In spite of high nitrogen and phosphorus levels in the Po River basin, however, the impacts in the Lombardy territory are limited to some freshwater eutrophication particularly affecting northern lakes. However, the nutrient load does affect the Adriatic Sea, where the North-West coastal areas experience growth of harmful algae blooms that cause economic damage to the fishing industry and decrease the attractiveness of the area for tourists.
What has already been done to address the problem in the region?

In Lombardy, actions to reduce the pollution and negative impacts caused by excessive nitrogen loads in water bodies have been taken through several regional plans and programmes. The “Programme for the protection and use of water” (in Italian – PTUA) was approved in 2006 pursuant to the River Basin Management Plan (under the Water Framework Directive). Various measures under the Programme aimed at restoring the good quality status of water bodies in the Lombardy Region.

With respect to nitrate pollution, numerous Nitrates Directive measures and corresponding good farming practices have been implemented in the nitrate vulnerable zones (NVZs) located in Lombardy under the Nitrates Action Programme and some of them have been extended throughout the region. These actions, like a minimum storage capacity requirement and a limitation on the maximum amount of nitrogen which can be applied to crops, were targeted at preserving and restoring the quality of water bodies contaminated by nitrates from agricultural activities. The regional Rural Development Programme developed under the Common Agricultural Policy has also promoted actions to decrease nutrient losses on-farm and increase resource efficiency. Specific measures have provided financial support to adopt new technology, update equipment, change crop rotations, plough using different methods, etc.
Set of region-specific good practices

Several examples of ‘good practice’ measures to reduce nutrient loss and increase resource efficiency in the Lombardy region have been identified (see Figure 2) and will be described in more detail in the following tables.

The measures were selected based on their impacts on the agro-ecosystem in terms of reduced losses through improved nutrient utilisation. Thus, the selected measures provide some economic advantages for the farmer and at the same time reduce nutrient loss from the farming system, benefitting both the environment and society. Emphasis was placed on measures that have not yet been exploited to their full potential within the Lombardy region. Further selection criteria were whether the measure might be feasibly implemented and whether the measure offers benefits which balance (or outweigh) the costs.

The graphic below highlights various drivers of nutrient loss which exist in the Lombardy region and problems related to those drivers. The final column presents the good practices that were identified as ways to potentially solve the problems associated with nutrient loss.

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### Improving manure cover

**Definition of the measure**
Reducing nutrient losses from manure storage by covering manure. Manure coverage decreases the surface area from which emissions (ammonia and methane) can occur and avoids an increase of the volume of manure that needs to be stored and applied due to rainwater dilution. Manure storage coverage is not compulsory, but is often required to obtain a permit for the construction of biogas or other manure processing plants.

**Technical implementation**
To decide on the type of cover, the percentage of dry matter that the manure contains needs to be considered as well as the amount of precipitation received. Fixed covers are more efficient in achieving emission reductions and diverting rainwater collection. Flexible covers can be implemented in different ways, e.g., straw, clay, fleece, and foils are some possible covers. Cattle manure forms a natural crust, which lowers the amount of ammonia emissions. Pig manure requires the addition of straw or other materials (clay or plastic elements).

**Technical requirements**
High initial investments are needed for fixed covers. Flexible covers have lower associated costs. Fixed coverage may be impractical for solid manure, as the regular addition of manure to the storage structure (daily, twice weekly) requires removal of the cover. Nevertheless, solid manure emits a higher amount of greenhouse gases than separated slurry. Thus, since the emission reduction potential is high, adoption of this measure should be considered where feasible.

### Effects, benefits and costs

#### Benefits for farming business
Cost-savings from reduced mineral fertiliser purchase and application due to higher nutrient content of stored manure (obtained by covering with a semi-permeable or impermeable cover). Cost-savings from reduced storage capacity requirements and transport volumes if impermeable covers are used, which reduces rainwater dilution.

#### Costs for farming business
Construction and increased operating costs for maintenance and handling of the covered manure storage facilities. Fixed covers are more expensive than flexible covers, especially if not foreseen in the storage design. On cattle farms, a solid cover on the storage facility will cause additional costs for removal of sediments that accumulate at the bottom of the tank.

#### Co-benefits and trade-offs
Manure nutrient levels need to be calculated to match the crop needs; otherwise, application of the same quantity of manure would result in higher nutrient levels and potential losses.

#### Environmental effects
Decreased ammonia emissions leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g., aggravated asthma and respiratory problems); decreased ammonia emissions will also result in benefits to water and natural ecosystems.
Reduced greenhouse gas emissions (methane), thereby decreasing the impact on climate.
Improving fertilisation management plans for all agricultural sites

**Definition of the measure**
Basing organic and inorganic fertiliser application rates on a calculated nutrient balance can considerably reduce nutrient losses. More effective nutrient management plans (considering additional factors in the nutrient balance) could be devised beyond the basic requirements of the Nitrates Action Programme and the PUA (Piano di Utilizzazione Agronomica) for manure utilisation. Specific tools (e.g., soil analysis) and technical advisory support could be used to match the amount of nutrients applied to the conditions of the land (soil type, crop demand, and remaining nutrients). (1)

**Technical implementation**
Calculate and interpret the site-specific nutrient balance:  
Analyze the parcel-specific remaining nutrient content in the soil considering the soil type and mineralised crop residues;  
Determine the crop nutrient requirements for the desired yield under the given environmental circumstances;  
Analyze the nutrient content of organic fertilisers, establish the ratio to mineral fertilisers to fully satisfy crop needs, and consider the time lapse between the application and the assimilation of nutrients by crops.

**Technical requirements**
The measure involves the calculation of N, P and K leftover in the soil and adjustment of the amount of fertiliser to be applied in the next growth period. This is based on soil samples taken in the spring and autumn (N_min), which also serve as a monitoring element of this measure. Nutrient application is fine-tuned according to the crop type and the local conditions.

**Effects, benefits and costs**

**Benefits for farming business**  
Cost-savings from reduced purchase and less application of additional fertiliser.

**Costs for farming business**  
Soil analyses, increased management efforts when applied to all sites, and potentially additional technical support to balance the N, P and K budget (e.g., consideration of remaining nutrient content).

**Co-benefits and trade-offs**  
The reduction of applied nutrients positively affects nutrient loss provided that the application takes place under suitable conditions (including weather conditions). A further benefit is the reduction of greenhouse gas emissions during the production of fertilisers if less additional inorganic fertiliser is applied.

**Environmental effects**  
**Water**: Reduced leaching and run-off of nutrients (N, P, and K), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.  
**Soil**: Improved soil fertility and health through reduced potential for acidification.  
**Air**: Decreased ammonia emissions leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g., aggravated asthma and respiratory problems); Reduced greenhouse gas emissions (nitrous oxide and carbon dioxide), thereby decreasing the impact on climate.  
**Biodiversity**: Positive effects from reduced N deposition in natural ecosystems.
## Improving manure processing

### Definition of the measure
Nitrogen removal from liquid manure/slurry can be effective in reducing N losses in intensive livestock areas. The nitrogen removal can be up to 70% of the initial manure content. In Lombardy, several treatment plants are operating on farms and centralised facilities. Most of them are linked to biogas production.

### Technical implementation
Nitrogen removal involves a process using nitrification/denitrification, stripping, or reverse osmosis. According to the technology identified, the treatment plant has to be designed in order to fit the needs of the farm, with careful consideration of the manure's characteristics and the energy requirements of the installation. Collective (centralised) solutions might be implemented.

### Technical requirements
High financial investments and adequate skills are necessary to properly manage treatment plants, as well as energy (electricity, heat) costs (which can be partially supplied by an anaerobic digestion plant).

### Effects, benefits and costs

#### Benefits for farming business
Supports compliance with legislation and provides a way to reduce N surplus on farms while also potentially providing energy (biogas combustion for heat and electricity), creating long-term positive economic impacts. The treated manure is also generally more efficient when applied as a fertiliser and is more easily transported than raw manure.

#### Costs for farming business
High implementation and maintenance costs for machinery. Renting or collectively purchasing the machinery can help reduce costs for individual farmers. The treatment costs should be assessed in a comprehensive business plan due to high investment costs, e.g., combining the nitrogen removal with a biogas production plant (anaerobic digester) for energy cost-savings or sales.

#### Co-benefits and trade-offs
Positive effects where there is a surplus of nutrients generated by livestock activity. However, if the focus of the measure’s implementation is solely limited to nitrogen, there is a possibility that phosphorus levels are not properly considered and could be over-applied to the soil, leading to adverse effects.

#### Environmental effects
- **Air:** Decreased ammonia emissions leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g., aggravates asthma and respiratory problems); Reduced greenhouse gas emissions (nitrous oxide – and methane if biogas is installed too), thereby decreasing the impact on climate.
- **Soil:** Improved soil fertility and health through reduced potential for acidification.
- **Water:** Reduced leaching and run-off of nutrients (N), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
- **Biodiversity:** Positive effects from reduced N deposition in natural ecosystems.
**Using appropriate application techniques**

### Definition of the measure

The use of an appropriate manure application technique, such as band application or injection, can reduce the volatilisation of ammonia by decreasing the surface area of manure in contact with the air. Thereby, the potential for ammonia emissions is decreased by up to 90% and consequently, the amount of nitrogen utilised by the crops is improved. Even distribution of manure can also improve the utilisation of nutrients. New spreading techniques have been tested and have demonstrated efficient incorporation of manure, such as top dressing fertilisation of crops like maize. When manure is incorporated immediately after spreading or directly through injection, nutrient run-off can also be decreased. In Lombardy these spreading techniques are also used for precision farming, which matches the manure application dose to the soil and crop conditions in each particular field.

### Technical implementation

- Immediately incorporate manure (e.g. via injection of slurry, ploughing in solids), which significantly reduces ammonia emissions;
- Calibrate fertiliser spreaders to reduce N losses;
- Broadcast spreading techniques should be replaced by more accurate ones, e.g., trailing hoses/shoes. (2)

### Technical requirements

The appropriate application technique may vary according to soil type and crop. When the manure is applied before seeding, band spreaders (followed by incorporation) or injectors (open or closed slot) can be used. Band spreaders drag perforated hoses behind them, from which slurry is applied close to the ground. Injection systems slit the soil open and inject the fertiliser at different depths. On grassland, using a trailing shoe spreader helps provide uniformity of spreading and lowers emissions. Some band spreading or closed slot slurry injection machines for top dressing applications are also available. Distribution of slurries mixed with irrigation water can also be a suitable technique provided that the irrigation water does not leave the fields. Some of these types of equipment, like a band spreader or an injector connected to an umbilical system, can also improve the timing of application as well as lead to more efficient use of nutrients.

### Effects, benefits and costs

#### Benefits for farming business

Cost-savings from reduced purchase and application of additional fertilisers. Consistent and even application promotes better yields as all crops are fertilised.

#### Costs for farming business

Purchase or rental costs of specific equipment and potential costs from reduced field capacity of the machinery (use of contractors could be a possible solution to reduce expenses); higher labour intensity. Collective action could be a way for smaller farms to invest in such techniques.

#### Co-benefits and trade-offs

Accurate application avoids fertiliser waste, which in turn reduces the use of supplemental manufactured N fertilisers. Through application close to the soil, odour emissions are reduced, but in order to avoid an increase in the nitrate leaching potential, injection must be timed appropriately in terms of crop needs and climate conditions. Furthermore, shallow injection may increase the potential for nitrous oxide emissions; thus, deep injection is preferable. By incorporating or injecting manure, nutrient run-off is reduced. Trailing shoe equipment may increase the potential for soil compaction due to the weight of the attachment. Slurry is best applied in spring when soils are often wetter, thereby threatening compaction damage. Umbilical slurry handling systems can be used to alleviate this, but they are expensive.

#### Environmental effects

- **Air**: Decreased ammonia emissions leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g., aggravated asthma and respiratory problems);
- Reduced greenhouse gas emissions (carbon dioxide – reduced production of mineral fertiliser), thereby decreasing the impact on climate.

- **Water**: Reduced run-off of nutrients (N and P), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.

- **Soil**: Improved soil fertility and health through reduced potential for acidification.

- **Biodiversity**: Positive effects from reduced N deposition in natural ecosystems.
### Using catch/cover crops

**Definition of the measure**
Increasing the area planted with catch/cover crops could significantly decrease the nutrient loss by leaching or run-off. In NVZs, nitrogen leaching risk must be reduced by using catch/cover crops or other suitable measures included in the Code of Good Agricultural Practice. (3)

**Technical implementation**
Catch crops can be grown following the early harvest of main summer crops, such as cereals or horticultural crops (typically in June/July), as well as in the autumn during the break between a summer/autumn harvested crop and the following spring crop. An alternative is to under-sow spring crops with a catch crop that will be in place to take up nutrients and provide vegetative cover once the spring crop has been harvested. The establishment of a temporary cover or catch crop can provide green cover during the winter, using crops such as grass, winter rye, winter barley, or mustard. In the region, farmers either harvest catch crops or use them as green manure to improve the soil organic matter.

**Technical requirements**
The farmer should integrate catch/cover crops into the crop rotation in order to avoid bare soil during the winter period when there is a high risk of leaching. For catch crops, consideration of the appropriate time for seeding and ploughing under is required, but low technical and knowledge requirements are necessary. The choice of the catch crops should be adapted to the territory and the other crops of the rotation to optimise their nutrient catching function.

### Effects, benefits and costs

**Benefits for farming business**
Improved soil fertility and availability of nutrients after the crop has been ploughed in as the residues release nutrients which are available to nourish the following crop, thus reducing the need for additional fertiliser purchase and application costs.

**Costs for farming business**
Additional seeding and ploughing costs but overall, low implementation/running costs.

**Co-benefits and trade-offs**
Catch/cover crops are a means to combat weeds. In some areas of Lombardy, mainly in the South East, the soil type (clay) might not be favourable to the application of this technique due to climate conditions (e.g., humidity) and the difficulties with preparing suitable seedbeds for spring crops.

**Environmental effects**
- **Soil**: Improved soil fertility and structure through increased soil organic matter and reduced risk of soil erosion, contributing to carbon sequestration and storage in the soil.
- **Water**: Reduced risk of leaching and run-off of nutrients during fallow crop periods, decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.
- **Air**: Reduced greenhouse gas emissions (nitrous oxide), thereby decreasing the impact on climate.
- **Biodiversity**: Positive effects due to the catch/cover crops providing additional wildlife and pollinator habitats.
### Definition of the measure

The input of too much water can flush nutrients in the soil to water bodies as run-off or leaching. Systems like drip irrigation or sub-irrigation are able to control the amount of water provided and limit the losses of both water and nutrients. In Lombardy, sub-surface drip irrigation has been adopted not only for fruits and vegetables, but also for other crops like maize. Trials suggest this technique is feasible and sustainable, also for manure spreading (after separation and filtration) when the distance between the storage location and the fields is less than 10 km.

### Technical implementation

A drip irrigation system requires a:

- Water pressurisation system;
- Filter station;
- Distribution system;
- Drip line (usually installed when plants have 5-10 leaves at a depth of 0-15 cm by using special machinery).

### Technical requirements

A change in crop management and special equipment for more accurate input of water to the crops are necessary. Distribution of manure with the irrigation water is possible ("fertigation"), but it requires specific equipment for filtration and dosage optimisation.

### Effects, benefits and costs

#### Benefits for farming business

Reduction of additional fertiliser purchase and application as well as soil compaction and erosion. Often the use of drip irrigation increases crop yields and improves the quality of the harvested products (e.g., less mycotoxins).

#### Costs for farming business

Purchase of equipment and distribution systems, which are partially compensated for by the lower labour requirements to irrigate.

#### Co-benefits and trade-offs

Some devices may limit tillage operation and some herbicides and top-dressed fertilisers require distribution on the soil (and thus cannot use the drip irrigation system). Additionally, the water distribution network (delivered on fixed days) might not be suitable to continuous low-flow-rate systems.

#### Environmental effects

**Water**: Reduced leaching and run-off of nutrients (N and P), decreasing eutrophication and improving surface and groundwater quality, thereby lowering risks to human health and biodiversity.

**Soil**: Reduced potential for soil salinisation (due to lower water flows) and improved soil structure through less soil management.

**Air**: Decreased ammonia emissions (when liquid manure is applied using the fertigation technique) leading to less particulate matter, odour, and ozone formation, which lowers risks to human health (e.g., aggravated asthma and respiratory problems);

Reduced greenhouse gas emissions (nitrous oxide – due to less soil anaerobic conditions), thereby decreasing the impact on climate.

**Biodiversity**: Positive effects from reduced N deposition in natural ecosystems.
Further good practices to reduce nutrient losses

Reducing the amount of nutrients excreted through feeding strategies

In Lombardy, intensive livestock rearing systems are sources of high quantities of manure, exceeding the needs of the crops in the region. Adjusting the quantity of animal feed to match the animals' needs and using feeding practices to increase the assimilation of nutrients contained in the feed by the animals would reduce the nutrient content in their manure. Thus, more of the available manure could be used to reach the same nutrient content in terms of fertilisation. Adjusting the amount of feed provided requires that farmers calculate the nutritional needs of their animals, with the help of external advisers if necessary, and have information on the nutrient composition of the feed. In order to facilitate the provision of feed, animals can be grouped by gender and age or production stage. In Lombardy, this practice is generally well implemented in pig farms while some improvements are possible for cattle farms. An increasing number of farmers have contracts with feed suppliers that limit the possibility of varying their feeding strategies. However, these strategies typically include phase feeding and good nutrient efficiency, so there is no need for variation.

Manure transfer

Reducing the excessive fertilisation of soils in Lombardy at the farm level can be achieved not only through the reduction of organic and inorganic fertiliser use, but also by the transfer of manure. Where there is a nutrient surplus, manure can be exported to neighbouring farmland containing spare arable land or grassland with the capacity to accept more spreading of manure (if available). This allows for the optimisation of manure use, as well as the substitution of chemical fertilisers and decreased environmental problems by preventing excessive manure use on farms with a manure surplus. However, greenhouse gas emissions would result from transport. The success of this measure depends on the availability of land close to where the manure was produced for application of the surplus manure. The possibility to transfer manure also depends on the type of crops in the surrounding area and biosecurity concerns. The price of the manure transferred and the transport costs also impact the implementation of this measure since these factors can directly affect the farmers’ income. Transporting liquid manure farther than 20–30 km may impact the economic sustainability of the activity.

Using digested manure from biogas production

In addition to the production of energy, anaerobic digestion results in digested manure that can be applied to fields as fertiliser. Digested manure is generally easily assimilated by crops due to the mineralisation of the nitrogen during the anaerobic digestion. Moreover, slightly lower N leaching can be expected in the long term when fertilising crops with digested manure instead of untreated manure, although ammonia emissions can be higher during storage and land application if suitable techniques are not used (storage covers and injectors). The reuse of manure for energy generation is also a way to reduce fossil fuel use and save greenhouse gas emissions. However, digesters may require a large amount of biomass, which may lead to energy crops being substituted (e.g., for permanent crops) or food crops being diverted for use in energy production. This can cause competition with other land uses and may result in negative environmental effects, such as soil erosion, lower water quality, loss of soil organic matter, and habitat loss from potential arable expansion and/or intensification.

Using adequate tillage techniques to limit nutrient leaching

Conservation tillage decreases the decomposition of residues, constituting a “sink” of nutrients bound to soil elements that can be slowly released to the plants, thereby decreasing the risk of leaching and nitrous oxide emissions. It can also increase the aeration of compacted soils, thereby increasing water and nutrient infiltration into the soil. Extending the use of conservation tillage or even no tillage in the region could be a highly efficient and effective technique to reduce nutrient leaching on the regional scale. Implementing conservation tillage may require an important reorganisation of fieldwork since manure is usually spread before tillage and then incorporated into the soil through ploughing.
Further relevant links

Further information (links) on the issue of reducing nutrient losses in agriculture which are relevant for the Lombardy region can be found below. This information entails links to legal documents, institutions, networks and studies.

**EU level**

DG Environment - Nitrates Directive:

The study ‘Resource Efficiency in Practice - Closing Mineral Cycles’ is available at the following link:

DG Environment - Sustainable use of phosphorus:
http://ec.europa.eu/environment/nutres/phosphorus.htm

Contacts:
ENV-NITRATES@ec.europa.eu;
ENV-USE-OF-PHOSPHERUS@ec.europa.eu

**National and regional level**

Ministry of Agriculture, Food and Forestry:
http://www.politicheagricole.it

Ministry of the Environment and Marine:
www.minambiente.it

National Rural Network:
http://www.reterurale.it

Regional government of Lombardy - Directorate General for Agriculture:
www.agricoltura.regione.lombardia.it

Regional Agency for Services to Agriculture and Forestry:
http://ersaf.lombardia.it/servizi/notizie/notizie_homepage.aspx

Regional Agency for Environmental Protection:
www.arpalombardia.it

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(1) Programma d’Azione vigente per le Zone Vulnerabili ai Nitrati (Regional action programme for Nitrate Vulnerable Zone), D.g.r. IX/2208 of 14 September 2011 - BURL Serie Ordinaria n. 38 of 22 September 2011.


(3) Nitrates Directive 91/676/EEC.

