LRTAP
Long-range Transboundary Air Pollution

Land Use and Landscape Management

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Background document for the Joint DG ENV & TFRN workshop: Towards joined-up nitrogen guidance for air, water and climate co-benefits.

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European
Commission

Contents

1. Introduction

The present document aims to review how different types of land use and landscape management practices can contribute to a more sustainable use of nitrogen (N) for production while mitigating the negative effects of reactive nitrogen (Nr) in the environment, and thereby summarize which elements to include in future joined-up nitrogen guidance for air, water and climate co-benefits.

The work is related to the UN Task Force on Reactive Nitrogen (UNECE-TFRN, http://www.clrtap-tfrn.org/). In line with previous guidance documents on Options for Ammonia Mitigation (Bittman et al. 2014), it synthesizes knowledge from national and international studies within the area, based on expert knowledge. In addition to the present theme 4 document, three other theme background documents are prepared on 1) Principles of overall nitrogen management (Oenema 2016), 2) Housed Livestock, manure storage and manure processing (Amon 2016), and 3) Field application of organic and inorganic fertilizers (Misselbrook et al. 2016). Thanks to support from the EU Commission, each of these subjects will be further interrogated during the workshop: Towards joined-up nitrogen guidance for air, water and climate co-benefits, in Brussels, October 11th and 12th, 2016, and the feed-back will be synthesized for the further guidance development.

1.1. Why consider landscape level management?

There are at least, two important reasons to consider land use changes and landscape level management practices for a better use of nitrogen, and the mitigation of unwanted air, water or climate related Nr effects:

1. The problems with Nr can be addressed exactly where they appear; both in space and time. For example hot spots of ammonia emissions from livestock houses and slurry tanks can be mitigated by planting trees around the source area, specifically in the major wind directions; or vegetation can be established specifically around protected nature areas, or in buffer zones around protected streams, to effectively catch Nr right before it reaches the vulnerable environment. Another example could be the strategic establishment of smaller or larger wetlands to clean/treat polluted water from field drains or dikes via denitrification and sedimentation before it reaches vulnerable surface waters, or spatio-temporal timing of grassland management and manure distribution for minimization of N-losses in vulnerable areas or times of the year (For example in dedicated groundwater protection areas).
2. The measures can be cheaper compared to the other types of measures[1], because they can be placed outside valuable production areas, without limiting the production, and thereby potentially at lower costs. In this way additional nature and recreational values from the new landscape elements in the form of hedgerows, forests, extensive buffer-zones around streams, and wetlands could be created.

Thereby, it can be stated that strategic land use changes and landscape level management practices have benefits via a combination of environmental (point 1) and economic (point 2) effects, corresponding to the biophysical and socioeconomic factors mentioned in section 1.3 below.

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[1] Described in the theme reports of Amon (2016) and Misselbrook et al. (2016)

As a recent example, both the environmental and the economic factors have been put forward as an argument for the paradigm shift towards a more landscape level measures in the Danish nitrogen regulation, with more geographically differentiated and targeted measures to be implemented over the coming years (Dalgaard et al. 2013, 2016). The environmental argument is that the requirements of the EU Water Framework- and The National Emissions Ceiling Directives can only be met by new geographically targeted, landscape scale measures on top of the exiting general measures, and therefore they are urgently needed. The economic argument is that a shift towards more landscape scale measures will be a cheaper solution, because of the arguments under point 2 above, and because the implementation extent of the general measures have been so large that they go considerably over both the farm- and the welfare economic optimum (for instance the N fertilisation of crops have until now been restricted to 15-18% below the production economic optimum).

One of the major challenges for the shift towards more geographically targeted, landscape level N measures is the knowledge about- and documentation of their effects. This was also the conclusion from the landscape component of the Nitro-Europe project (http://www.nitroeurope.eu/), where pilot research studies were carried out in 6 European case landscapes (se for example Dalgaard et al. 2012), and the corresponding chapter of the European Nitrogen Assessment (Cellier et al. 2011) experiences from key national research projects was included, covering studies from The Netherlands, Scotland, France, Denmark and others. Based on these studies, Cellier et al. (2011) synthesized that "At field or farmstead scales, processes of N transformation and transfer have been extensively studied, and have given a fair insight into the fate of N at small space and time scales. When going beyond the field or farmstead boundaries (i.e. the landscape, watershed, regional scales), N can be transferred in significant amounts from Nr sources (e.g. farmsteads, field after slurry/fertilizer application, etc.) to the recipient ecosystems by a variety of pathways. For example, atmospheric NH_3 emitted from animal housing or a field can be re-deposited to the foliage of nearby ecosystems in amounts that increase the closer the source is horizontally to the recipient ecosystem and vertically to the soil surface (Fowler et al. 1998; Loubet et al. 2006). Similarly, wetlands or crops/grasslands at the bottom of slopes can recapture NO_3^- in the groundwater that originates from N applied further up the slope. In both cases, this can lead to large inputs of N to the receptor ecosystem that may have potential impacts on the ecosystem (Pitcairn et al. 2003) and the biogeochemical cycles, possibly leading to enhanced N_2O and NO emission (Beaujouan et al. 2001; Skiba et al. 2006; Pilegard et al, 2006) and further feeding the N cascade (Galloway et al. 2003) (see below, Figure 1). These N_2O emissions resulting from N transfer in receptor ecosystem are usually called indirect emissions and may represent a significant fraction of total N_2O emissions, although how much remains uncertain (Mosier et al. 1998). The importance of uncultivated or marginal areas that are outside or peripheral to the agricultural systems for flows and budgets of energy and matter, including N, emphasizes the need to adopt a landscape perspective".

1.2. Nitrogen flows in the rural landscape

Figure 1 gives an overview of the reactive N flows in rural landscapes, and show the cascade of reactions from Nr input in the form of fertilisers and feed, through the cropping and livestock system, and to the natural ecosystems. I.e. it is especially the Nr flows to and from the natural/semi-natural ecosystems that are targeted by the landscape level measures exemplified above. These flows can be divided in those relating to air pollution, including the related greenhouse gas (GHG) emissions (section 1.2.1), those related to surface- and groundwater pollution (section 1.2.2), and those related to sources and sinks of nitrogen (section 1.2.3):

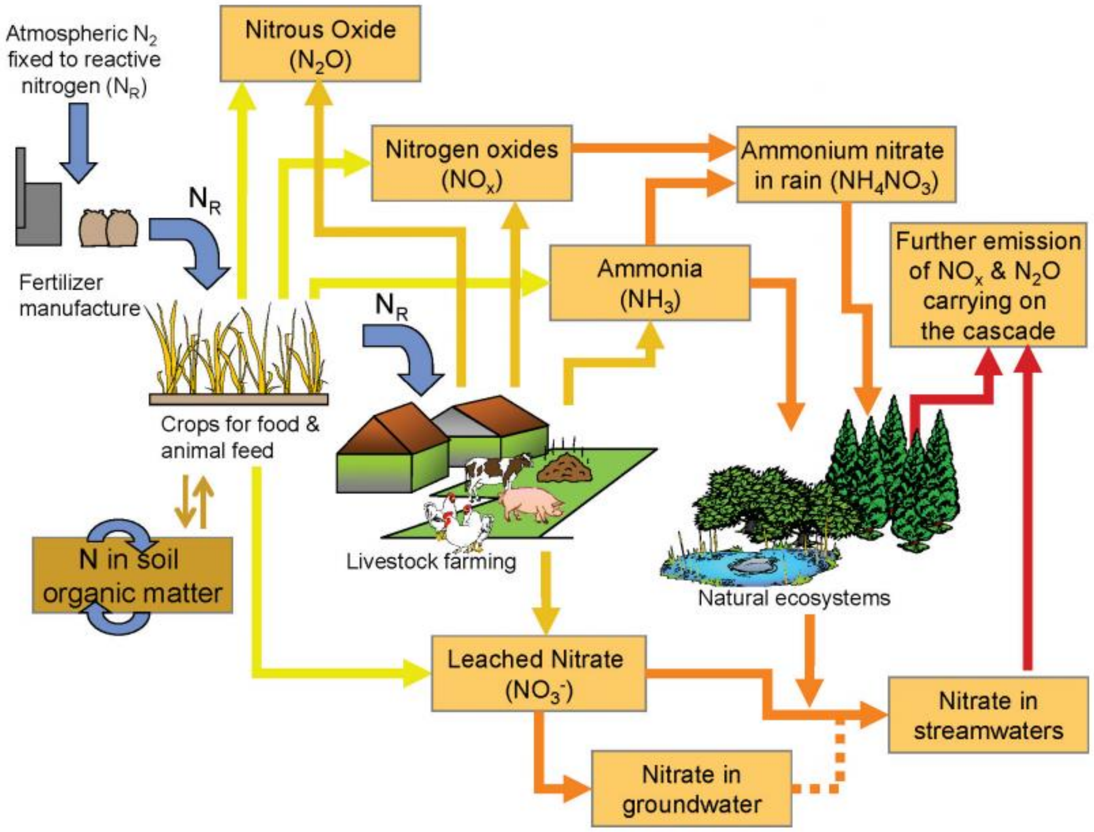

Figure 1: Nitrogen flows in the rural landscape (Adapted after Sutton et al. 2011; Galloway et al. 2003).

1.2.1. *Air pollution and related greenhouse gas emissions*

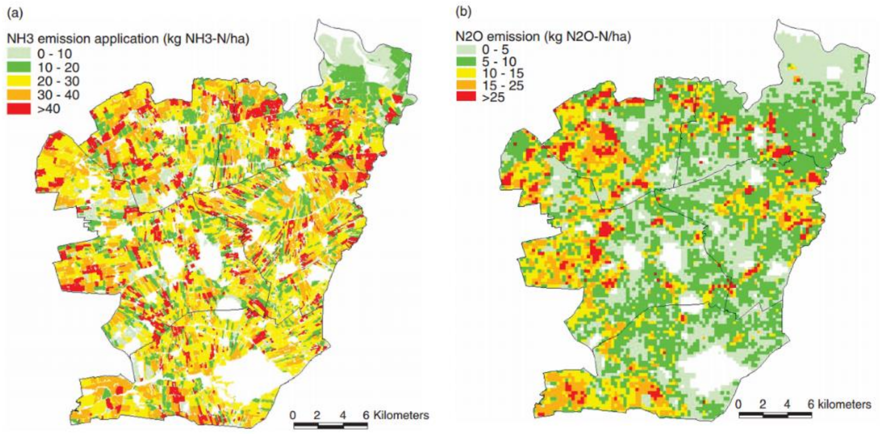

Figure 2: Nitrogen flows in the rural landscape (Adapted after Kros et al. 2007, cf. Cellier et al. 2011).

1.2.2. Surface- and groundwater pollution

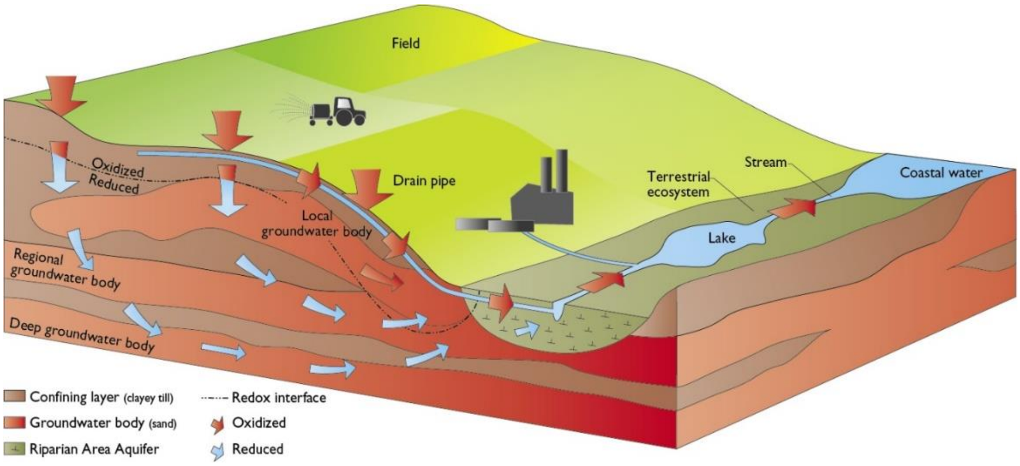

Figure 3. Hinsby et al. (2008)

1.2.3. Nitrogen sinks and sources

Point sources (also outside agriculture), agriculture, soil pools, ploughing

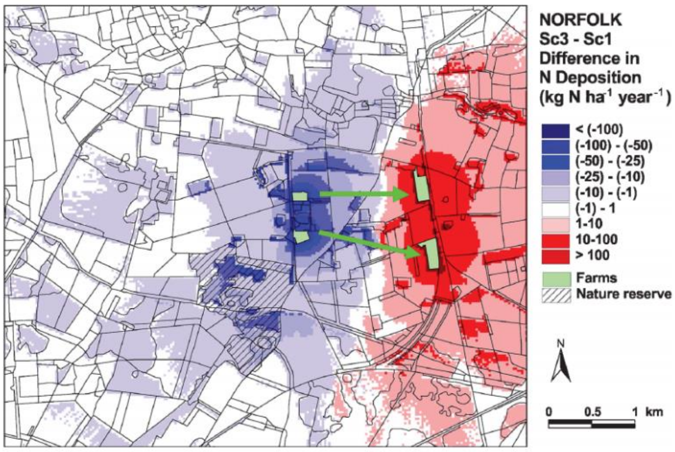

Figure 11.9 Difference in N deposition (NH_3 dry deposition) due to moving of poultry from two sets of buildings in the immediate vicinity of a nature reserve (hatched area) to a more distant location (approx. 1.5 km east/right) (from Dragosits *et al.*, 2005). With permission from Elsevier.

Figure 4. Dragosits et al. (2005)

1.3. Heterogeneity effects

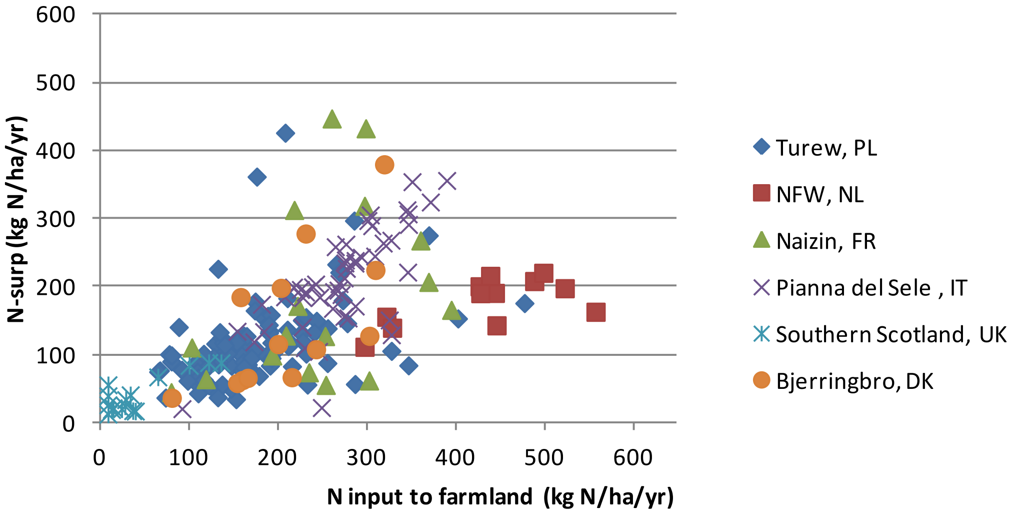

Figure 5. Dalgaard et al. (2012)

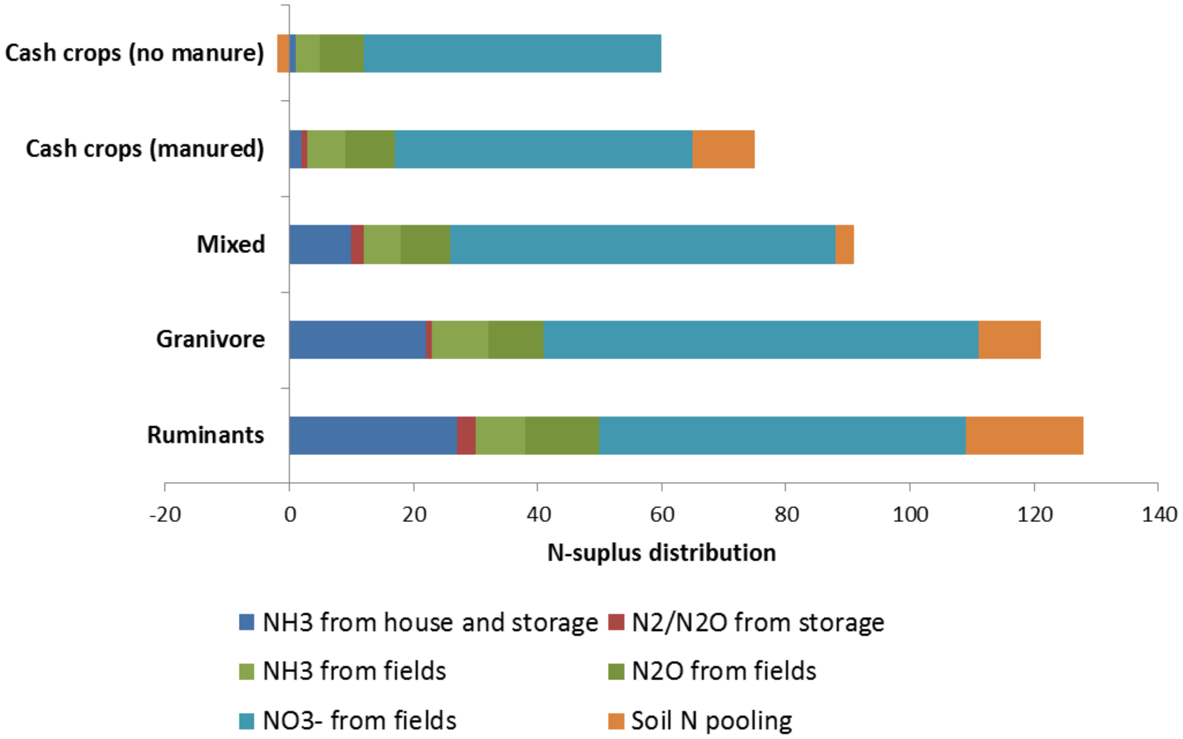

Figure 6. Example. summarized from Dalgaard et al. (2011).

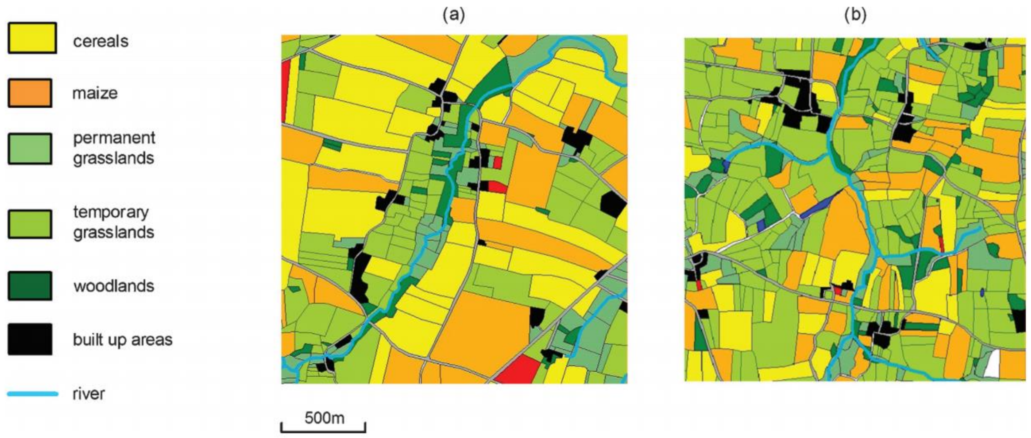

Figure 11.1 Two landscapes composed of dairy farms in the "Zone-atelier Pleine-Fougéres" in Brittany (western France). In landscape (a), farm areas are large, field patterns are clustered around the farmstead (shown in red) and enable an intensive use of space (large field) with specialized patches of cash crop, forage and pastures. In landscape (b), farms are smaller than in (a); field patterns are fragmented, scattered and dispersed; crops, forage and pastures are very mixed in the landscape giving a heterogeneous crop mosaic.

Cellier et al. (2011)

-→ illustrated by landscapes Figure 11.1

1.3.1. Biophysical factors

1.3.2. Socioeconomic factors

1.4. Scale issues

Nitrogen flow and transformations are determined by the fine scale topography and spatial variability of the biogeochemical and physical characteristics of the soil. These together with climate and agricultural N management determine In particular the nitrification and denitrification processes, which determine the fluxes of NO, N2O, N2 to the atmosphere and the leaching of dissolved organic N and NO3 to the rivers and other aqueous bodies.

In order to model N flow through the landscape it is important to have field scale/farm scale 'activity' data, such as agronomic management, N application rates, soil types and topography etc. New technologies, e.g. drones, satellites, aircrafts, are valuable tools to provide these data (e.g. soil moisture, topography, vegetation types). An example is the use of satellite vegetation maps to estimate landscape scale CH4 fluxes (Dinsmore et al, 2016).

Challenges....

Dalgaard et al. (2009)

2. Measures for optimized land use and landscape management

2.1. Land use change

2.1.1. Set aside

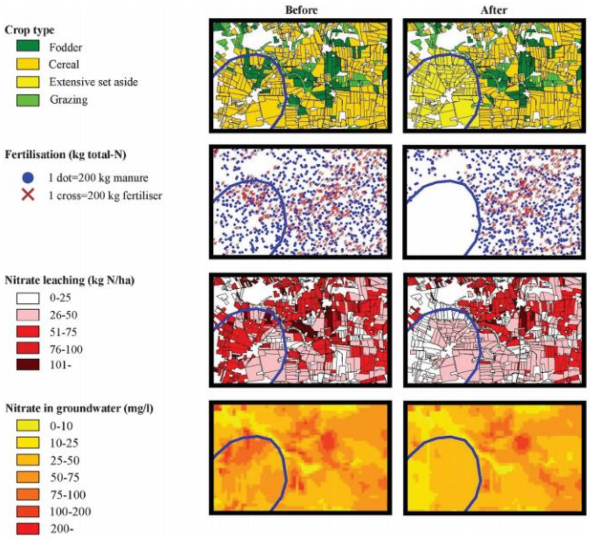

Figure 7. (Hutchings et al. 2004)

Odgaard et al. (2013)

2.1.2. Buffer zones

Christen and Dalgaard (2013)

Are they sources of N2O? How wide do they have to be to reduce N leaching to the waters?

2.1.3. Hedgerows and afforestation

2.1.4. Crop rotation and perennial crops

2.1.5. Comparing willow/miscanthus with perennial crops

Drewer et al.

2.1.6. Agroforestry

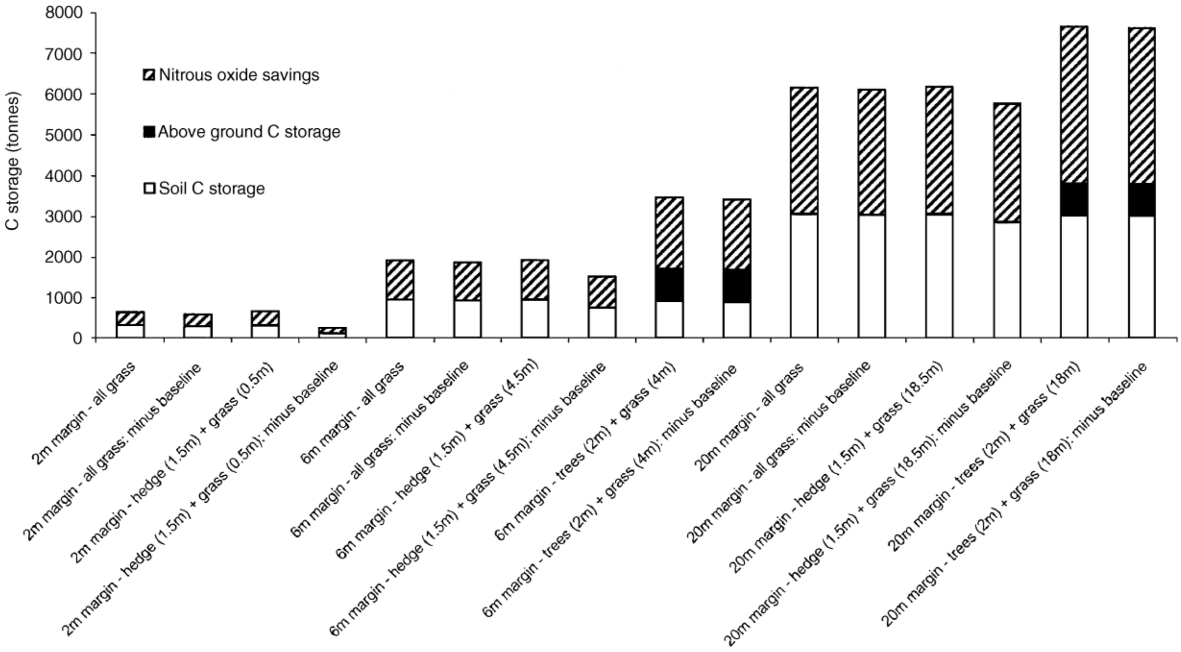

Figure. Carbon mitigation potential of field margin management options for an example 260 ha arable farm in the UK, over a 50-year period. (Falloon et al, Soil Use and Management (2004) DOI: 10.1079/SUM2004236)

2.1.7. Organic soil protection

2.1.8. Wetland restoration

Odgaard et al. (2016)

2.1.9. Constructed mini-wetlands

2.2. Landscape management and optimized regionalization

2.2.1. Soil tillage and conservation

2.2.2. Drainage and controlled drainage

2.2.3. Grassland management

Results from the UK inventory project: uncertainty of estimates and upscaling methods, none published yet, will supply graphs later

See also Smith (2014)

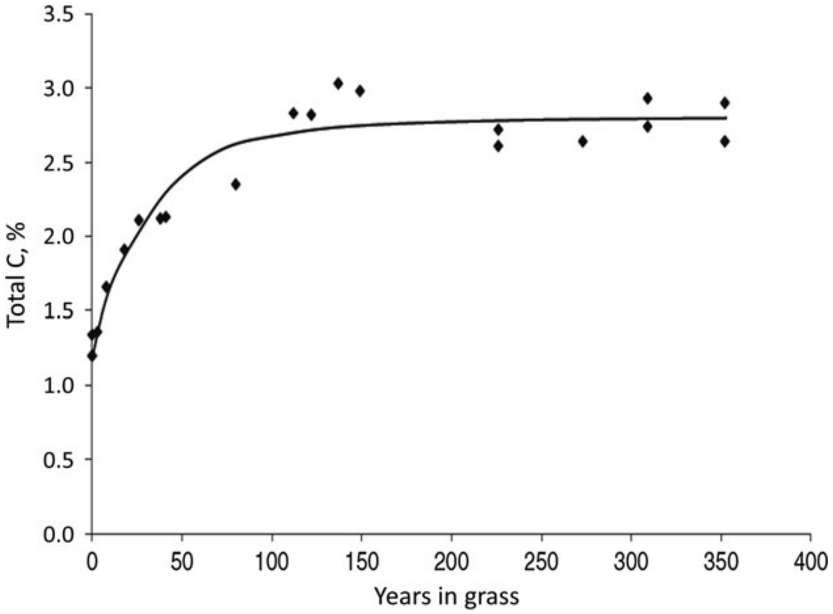

Figure. Increase in organic carbon (%C to 23 cm depth), calculated from total N values presented in Johnson et al. (2009), assuming a C : N ratio of 10 : 1. Total N values were from a number of silty clay loam soils sown to grass from cropland at various times and for various periods at Rothamsted, UK. Pete Smith (2014) Global Change Biology (2014) 20, 2708–2711, doi: 10.1111/gcb.12561

RE: Ploughing, stocking density, species mixes

Cowan et al. (2016), Drewer et al (2016) ploughing

Jones et al. (2016) C/N/GHG budget for a grasslands

2.2.4. Placement of livestock production

2.2.5. Manure (re)distribution

2.2.6. Biogas plants and bio-refineries for biomass redistribution

3. Summary and conclusions

Table 1. Landscape management impact on Nitrogen losses (first draft synthesis for discussion)

Practice	**Leaching/runoff**	**Ammonia volatilization**	**Nitrous oxide emissions**	**Notes**
Riparian buffer strips	↓	↓	↓ ↑	N2O mitigation rate depends on the soil matter content and soil wetness
Agroforestry	↓	↓	↓	Chickens or pigs in woodlands
Planting trees on steep slopes	↓	↓	↓	Taking these areas out of agriculture will reduce N translocation and accumulation in the valleys, and reduce erosion, dust
Shelterbelts around large NH_3 point sources	↓	↓ ↑	↑	Concentrates N deposition to the shelterbelts, so less NH_3 deposition onto other, perhaps fragile land, but increased NO, N_2O emissions and NO_3 leaching from these shelterbelts
Biodiversity buffer strips around fields	?	~↓	~↓	Can improve crop yield, thereby NUE and less N losses

				Reduction of Pathogen transfer
Hedgerows	~↓	~↓	~↓	May intercept some of the NH_3 from the field, when on slopes can reduce NO, N_2O & NO_3 Increased biomass = C sequestration,
Mixed farm model and crop rotation	~↓	~↓	~↓	Include outdoor pigs/chickens in crop rotation, and reduce fertiliser N input rates at landscape scale

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In the European Nitrogen Assessment, Cellier *et al.* (2011) summarized the following key points in relation to nitrogen flows and fate in rural landscapes: ”

Nature of the problem:

- The transfer of nitrogen by either farm management activities or natural processes (through the atmosphere and the hydrological network) can feed into the N cascade and lead to indirect and unexpected reactive nitrogen emissions.
- This transfer can lead to large N deposition rates and impacts to sensitive ecosystems. It can also promote further N2O emission in areas where conditions are more favourable for denitrification.
- In rural landscapes, the relevant scale is the scale where N is managed by farm activities and where environmental measures are applied.

Approaches:

- Mitigating nitrogen at landscape scale requires consideration of the interactions between natural and anthropogenic (i.e. farm management) processes.
- Owing to the complex nature and spatial extent of rural landscapes, experimental assessment of reactive N flows at this scale are difficult and often incomplete. It should include measurement of N flows in the different compartments of the environment and a comprehensive datasets on the environment (soils, hydrology, land use, etc.) and on farm management.
- Modelling is the preferred tool to investigate the complex relationships between anthropogenic and natural processes at landscape scale although verification by measurements is required. Up to now, no model includes all the components of landscape scale N flows: farm functioning, short range atmospheric transfer, hydrology and ecosystem modelling.

Key findings/state of knowledge:

- The way N is managed as well as the location of farming activities can have a strong influence on N flows at landscape scale. Consequently, environmental measures can be more or less effective according to the landscape and farming system, and the interactions between them.
- The magnitude of nitrate transfers and subsequent impacts is linked to the hydrology of the area (e.g. subsurface versus deep hydrological flows)
- The magnitude of N losses to the atmosphere depends on the agronomic management, soil properties and climate. There is a need to design mitigation options for local conditions.
- Source-sink relationships for atmospheric transfer are linked to land use (e.g. patchiness, hedgerows) and distance between sources and sensitive areas
- A verified integrated landscape model would be useful for investigating the N flows in rural landscapes, as well as evaluating different N management strategies and environmental measures at the landscape scale.

Major uncertainties/challenges:

- The multiple pathways of N transfer, the interactions between natural and anthropogenic processes and the risk of pollution swapping requires complex high resolution modelling. Linkage of the different model components and the verification and uncertainty assessment of the integrated model are big challenges.
- A network of European landscapes, including different climatic conditions, hydrology and farming systems, should be established as case studies to assess the influence of landscape processes on N budgets.
- Relevant data to verify the models

Recommendations:

- When designing and implementing new environmental measures, the landscape scale should be considered in order to take into account processes (such as N deposition to sensitive areas or indirect N2O emissions) that may mitigate the efficiency of the measures
- The implementation of environmental measures should consider the variety of landscape types and allow adaptation to local conditions since their effectiveness might vary according to landscape features and farming systems.
- Environmental measures applied to different landscapes and farming systems should be established and evaluated by modelling and verified, if possible, by monitoring once the measures are in place.”

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