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Nitrogen balances in Agriculture

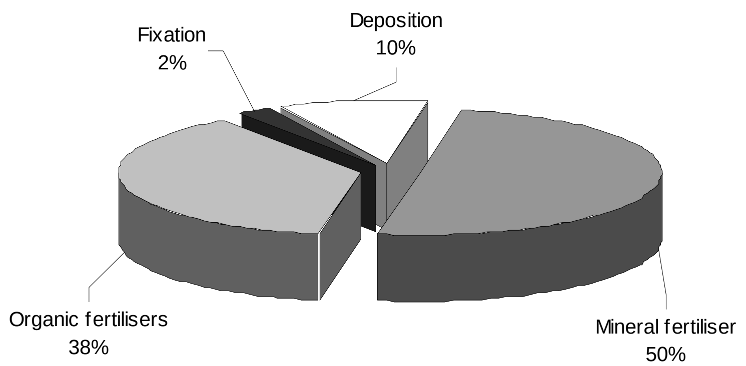
In 1997, 50% of the total supply of nitrogen was attributed to mineral fertilisers

Jakob Hansen

1. Introduction

The risk to the environment, and particularly to groundwater, due to leaching of minerals from soil is of major public concern. Agricultural activities are one of the major, but not the only, source of nitrogen pollution, and the quality of water is one of the most important environmental issues in areas with a high density of livestock per hectare. This can be due to either the high surplus of minerals from agriculture or to vulnerability of the soil to leaching, or a combination of these two phenomena. The relative distribution of the main nitrogen sources is shown below.

Figure 1: Supply of nitrogen EU-15, 1997



Harmonised statistical information, based on common standards and methods, on nitrogen surpluses in agriculture is nevertheless scarce. International organisations, such as OECD, have proposed the use of nitrogen balances as an indicator of the risk posed to the environment from excessive nitrogen.

However nitrogen balances on a national level do not provide useful information on the state of nitrogen surpluses, except perhaps in small homogenous countries. Regional balances provide a better picture for policy makers, enabling them to identify areas of high surplus and thus where surface and ground water may be at risk. Also, tracking the change in these surpluses over a number of years can be used to assess the effectiveness of policy measures. The use of the balance as an indicator of loss to water nevertheless requires careful interpretation. The balance between inputs and outputs for a system contains all potential losses, plus any change in the store of nitrogen, principally within the soil. The potential loss pathways for nitrogen are to air as ammonia by direct volatilisation; to air as nitrous oxide and nitrogen gas by denitrification; and to water by the leaching of nitrate.

Moreover, the relationship between nitrogen balance and loss to water differs between agricultural systems, and it is affected by intensity of land use, farm management, soil type, and climate conditions.

This publication presents a first attempt to construct nitrogen balances at national level and to extend the balances to the regional level.

2. Methodology and Data Sources

There are various methods to calculate nitrogen balances. The nitrogen balance presented here is calculated on an annual basis, using the *soil surface* approach and is deliberately simplified. The approach based on the soil surface nitrogen balance seems best suited to the objective of identifying structural excesses. Furthermore it is at this level that the statistical data is most readily useable and complete, especially for the calculation of regional nitrogen balances, even if certain assumptions have been necessary to compensate for missing data.

The soil surface balance looks at the nitrogen inputs to and exports from the soil surface. Thus grass growth, which is recycled internally within a farm, must be explicitly accounted for as nitrogen removal by cutting or grazing of grass.

Input of nitrogen

The nitrogen fluxes into the soil which are considered are those coming from :

- Mineral fertilisers applied to agricultural land
- Organic manure applied to agricultural land
- Fixation by leguminous crops and clover
- Wet and dry deposition from the atmosphere.

Regional data on *wet and dry deposition of nitrogen* are received from the RIMV (Rijksinstituut voor Volksgezondheid en Milieu - NL).

Fixation by leguminous crops and clover is calculated using expert estimates of the rate of fixation per hectare and statistics on areas concerned from the Farm Structure Survey (FSS).

Data on consumption of mineral fertilisers at national level[1] is converted to regional data, based on the application rates for different crops[2], and regional data on area cultivated for these crops, taken from the FSS.

Nitrogen input due to *livestock manure* is calculated as a function of the number of animals present in the different regions at the time of the FSS, and expert estimates of the quantities of nitrogen which they eject, taking into account that around 15% of ammonia is volatilised during storage before spreading.

In practice most countries provide a set of coefficients for different livestock types based on measurements of nitrogen content. This set of coefficients is used for all regions of the country. Some countries were unable to supply coefficients, and in this case coefficients from France were applied (Greece, Italy, Portugal).

Outtake (removals) of nitrogen

Outtake is taken to mean the nitrogen content of those crop parts removed from the field, whether at harvest or by grazing. Removals subsequently used as straw for livestock, and removals in grass by grazing livestock or by cutting have been quantified, but crop residues, which are left in the field or immediately returned to the field, have been ignored.

The nitrogen fluxes out of the soil are defined as nitrogen in:

- Harvested arable crops
- Crop used for fodder.

Outtake of nitrogen from harvested crops is calculated as a function of national crop production, coefficients for the N-content of the harvested crops and regional data on areas cultivated. Experts in Member States have supplied the N-outtake coefficients.

A particular problem arises for areas under grass, as it is difficult to know the amount of grass harvested and/or grazed. Statistics on harvested grass are only available for a few countries, and it is not always clear if existing data refer to harvested production or to potential production of grass. To overcome this some further estimation is needed, based on calculations of the animals' theoretical fodder needs. The grass removed corresponds to the total amount of grass eaten by the animal, whether harvested or grazed. From the quantity of dry matter in the form of fodder needed for different categories of animals, the difference between these needs and the quantity supplied by fodder other than grass is calculated. To overcome a tendency to overestimate the removal via grass, feedstuffs bought from outside agriculture have been taken into account.

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(1) as reported to FAO from Member States.

(2) supplied by the European Fertiliser Manufacturers Association (EFMA).

As no information on nitrogen content of bought feedstuffs is available, the calculations have been made in dry-matter equivalent, and the end product has been transformed into nitrogen, using standard coefficients.

Data quality and interpretation

A certain number of variables in the balance (on both the input and the outtake side) which can contribute to the change in stock have not been taken into account, either for lack of data or because they are considered negligible. The most important omitted variables are:

- *Volatilisation* of ammonia, following spreading of manure on the soil.
- S*ewage sludge* (no data are available at European level).
- *Denitrification* (which can be an important factor in wet-zones).
- *Nitrogen mineralised* (as a result of ploughing up of permanent grasslands).
- *Nitrogen contained in irrigation water*

Fixation by leguminous crops and clover is to an certain extent underestimated, as only fixation by dried pulses have been taken into account[3]. No estimates of N fixed by grasslands and other forage crops were possible, for lack of reliable information on the amounts and composition of these crops in most countries. It should also be noted that the figures presented here are partly based on experts' estimates of different biological relations, for the country as a whole.

However in reality, there may be large regional variations for some of these, and therefore the regional figures should be interpreted with care. Before comparing Member States, it should also be borne in mind that the calculations are based on a harmonised methodology, which may not in all cases reflect country-specific particularities. Moreover, the N-coefficients supplied by the Member States also differ remarkably between countries, to an extent, which is sometimes difficult to explain. (See for instance Table 1.)

As a general rule, the data on inputs are estimated to be more accurate and reliable than the data on outputs. Not only are the calculations on outputs mainly based on statistics at national level extrapolated to regional level, but also the lack of (reliable) data on harvested fodder and grass, mentioned above, also adds an element of uncertainty to the figures. As this uncertainty is carried through to the total N-balance, the same precautions should also be taken before drawing conclusions from the results of the total balance.

Although nitrogen surpluses can show areas where ground and surface waters may be at risk, they should not be interpreted as real losses to the environment. In order to assess the environmental impact of excess nitrogen, more information is needed on, among others, farm nitrogen management, soil type, and climate conditions, all of which play a role in the fate of nitrogen in the environment.

Table 1: Nitrogen - manure coefficient, 1997 *(kg N/animal*year)*

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Equidea	65.0	44.0	42.5	120.0	25.6	120.0	40.0	120.0	87.2	-	34.0	120.0	-	42.5	40.0
Bovines <1 year	28.0	38.8	26.4	21.9	21.9	21.9	24.0	21.9	33.5	27.6	23.1	21.9	25.0	23.0	17.3
Bovines <1 year,male	23.0	46.9	28.1	-	-	21.9	24.0	-	-	16.5	-	-	25.0	27.2	17.2
Bovines<1year,females	33.0	31.7	25.5	-	-	21.9	24.0	-	-	41.5	-	-	25.0	18.7	17.4
Bovines,>=1<2years,m.	61.0	57.7	38.3	43.8	43.8	43.8	57.0	43.8	55.8	59.2	40.5	43.8	40.0	49.3	40.2
Bovines,>=1<2 years,f.	56.0	41.5	42.5	43.8	43.8	43.8	57.0	43.8	55.8	88.7	40.5	43.8	37.0	40.0	43.4
Bovines, >=2 year,m.	77.0	52.9	42.5	51.1	51.1	51.1	68.0	51.1	79.7	72.3	57.8	51.1	40.0	49.3	62.0
Heifers,>= 2 years	77.0	51.4	42.5	58.4	58.4	58.4	63.0	58.4	79.7	88.6	57.8	58.4	40.0	40.0	54.5
Dairy cows >=2 years	97.0	121.6	80.3	73.0	60.2	73.0	85.0	73.0	87.2	123.7	80.8	73.0	100.0	99.5	103.5
Other cows >=2 years	10.5	18.2	11.1	10.0	10.2	10.0	15.0	10.0	10.5	23.5	18.7	10.0	17.0	10.2	8.8
Sheep,breeding female	4.4	8.3	-	4.5	2.9	4.5	4.0	4.5	4.4	-	-	4.5	-	-	4.5
Goats,breeding female	10.5	-	-	10.0	8.8	10.0	15.0	10.0	0.0	-	-	10.0	17.0	-	-
Piglets	2.5	0.4	-	4.6	1.2	2.9	10.0	4.6	3.2	-	-	4.6	3.2	2.0	4.4
Breeding sows	24.0	54.4	28.1	26.3	14.8	26.3	25.0	26.3	20.0	21.0	28.1	26.3	26.0	16.2	19.5
Other pigs	13.0	13.2	10.9	12.6	8.5	8.8	9.0	12.6	9.9	10.4	12.8	12.6	11.0	7.7	10.5

(3) *More detailed data from Denmark suggests an underestimation of 10 kg N/ha.*

3. Comments on main results

Mineral fertilisers are the major source of nitrogen in the EU

Within the EU, mineral (commercial) fertilisers are the largest source of nitrogen applied to agricultural soils, mainly as straight nitrogen fertilisers in the form of calcium ammonium nitrate and ammonium nitrate (table 2).

Nitrogen in commercial fertiliser is particularly soluble to facilitate uptake by crops, but this also makes it vulnerable to run-off after heavy rainfall, and to leaching to groundwater.

Table 2: Supply and use of nitrogen, 1997 *(kg N/ ha)*

	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK	EU-15
TOTAL INPUT	**370**	**246**	**201**	**146**	**73**	**157**	**225**	**120**	**284**	**486**	**104**	**75**	**127**	**114**	**163**	**149**
mineral fertiliser	**114**	**106**	**104**	**88**	**41**	**89**	**91**	**62**	**142**	**184**	**33**	**31**	**81**	**66**	**77**	**75**
Organic fertilisers	**220**	**114**	**65**	**49**	**23**	**46**	**123**	**45**	**114**	**265**	**48**	**39**	**39**	**39**	**67**	**56**
bovine	140	52	45	7	10	34	97	24	106	171	33	17	29	30	38	**34**
pigs	59	58	14	3	4	5	4	7	5	57	12	8	7	5	5	**9**
sheep and goats	1	1	1	33	8	3	19	7	0	9	0	8	1	1	17	**7**
poultry	18	3	3	3	1	3	2	5	0	28	2	3	2	2	7	**4**
Fixation	3	8	3	2	3	5	1	2	1	1	3	2	3	4	3	**3**
Deposition	33	18	29	7	6	16	10	12	27	36	20	3	5	5	15	**15**
TOTAL OUTTAKE	**225**	**135**	**109**	**98**	**38**	**116**	**162**	**80**	**186**	**230**	**68**	**51**	**72**	**79**	**125**	**96**
harvested	49	73	56	29	20	51	15	48	26	38	30	11	36	39	31	**39**
fodder[4]	177	62	54	69	18	65	147	32	160	192	38	40	36	40	94	**57**
Surplus 1997	**145**	**111**	**92**	**48**	**35**	**41**	**63**	**40**	**99**	**256**	**36**	**24**	**56**	**35**	**37**	**52**
Agricultural area 1997[1.000 ha][5]	1 383	2 689	17 169	3 486	25 625	28 303	4 342	14 773	127	2 011	3 407	3 796	2 172	3 109	16 169	**128 559**
total input 1995	370	248	199	146	68	152	219	121	284	517	103	77	128	110	165	**147**
total input 1993	372	263	192	155	68	147	217	122	282	517	:	78	:	:	163	**148**
total output 1995	235	130	104	97	31	112	152	78	185	243	72	51	67	73	123	**93**
total output 1993	232	128	100	96	34	110	152	72	181	245	:	49	:	:	121	**93**
surplus 1995	136	119	94	49	37	40	68	43	100	274	32	26	61	36	42	**55**
surplus 1993	140	135	92	59	34	38	64	50	100	271	:	29	:	:	41	**55**
Agricultural area 1995 [1.000 ha]	1 354	2 727	17 170	3 565	25 225	28 235	4 325	14 625	127	1 999	3 417	3 897	2 192	3 060	16 447	**128 362**
Agricultural area 1993 [1.000 ha]	1 344	2 739	17 029	3 525	24 707	28 070	4 278	14 670	127	2 015	:	3 919	:	:	16 383	**118 806**

Table 3: Total mineral fertilizer consumption distributed on crops, 1997 *(%)*

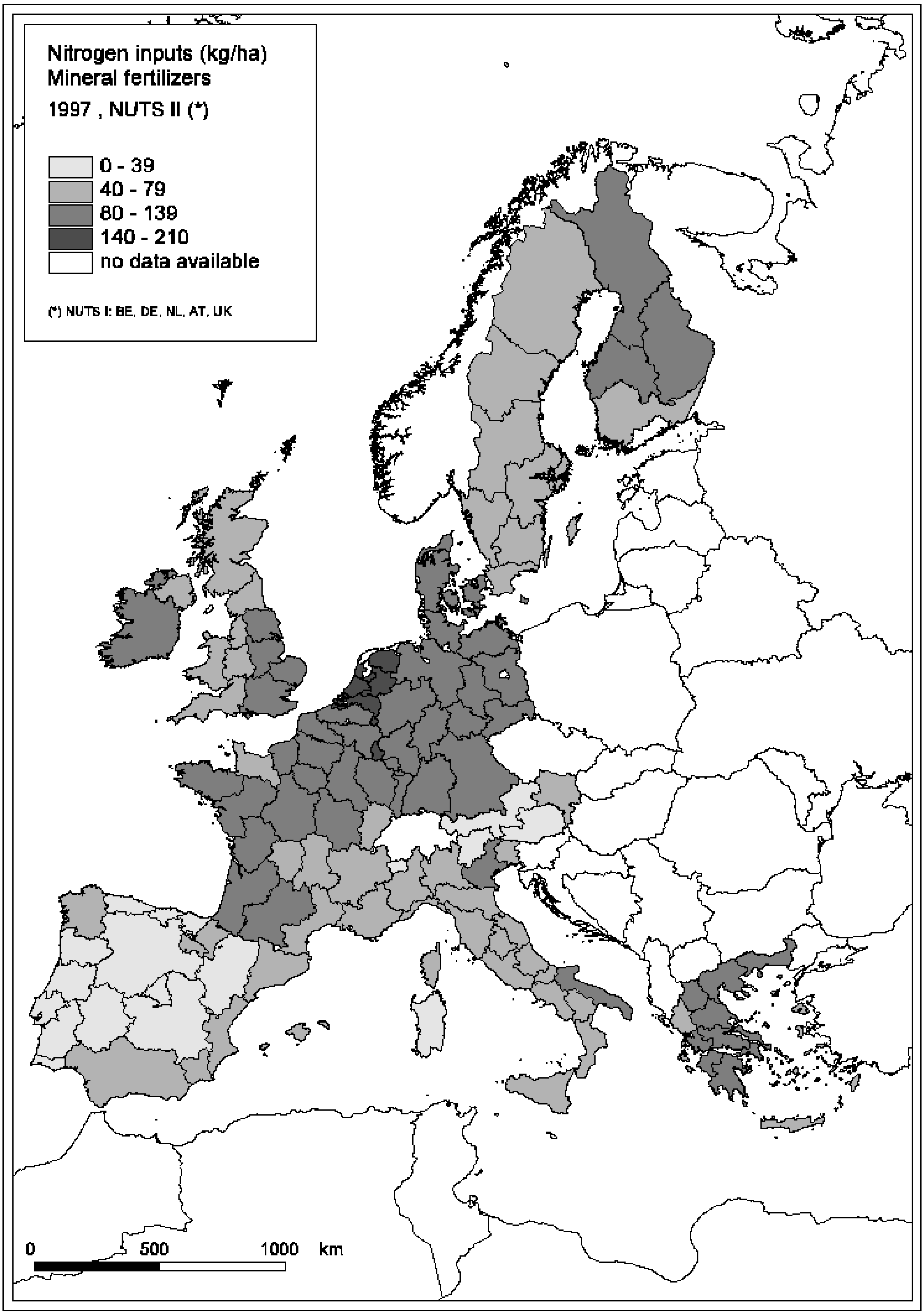
	B	DK	D	EL	E	F	IRL	I	L	NL	A	P	FIN	S	UK
Cereals	22	55	48	41	35	41	6	33	20	10	40	16	40	45	29
other arable	16	9	16	22	16	24	2	28	3	15	24	20	6	8	8
Fodder (including maize)	15	17	9	2	2	20	15	2	14	3	10	16	53	36	6
Fertilised grass land	46	19	27	0	22	13	77	6	62	72	25	21	1	11	57
Permanent crops (fruit, vineyard)	1	0	0	35	25	2	0	31	0	1	2	27	0	0	0
TOTAL N [1000 ton]	158	285	1 788	307	1 042	2 518	395	915	18	370	112	116	175	206	1 251

(4) Includes: fodder beets, other forage crops and pasture (grass)

(5) Includes: arable land, permanent crops and permanent meadows and pastures.

The regions with higher nitrogen fertiliser application rates are located in the Netherlands, Belgium, Germany and France (see map 1). In general, in Central and Western Europe, (with regional differences) an important share of the total input is due to fertilised grassland. For example, as shown in table 3, fertilised grassland accounts for more than 50% of total input in Irl, NL, L and UK.

Map 1: Nitrogen Inputs (kg/ha) / Mineral fertiliser, 1997



Livestock manure: the second major source of nitrogen

As shown in table (2), in 1997 the Netherlands and Belgium both of which have a high livestock density had the largest input of nitrogen per ha of agricultural area from livestock manure followed by Ireland, Luxembourg and Denmark.

Within the larger countries there are also some regional "hot spots", areas of high nitrogen loading from manure, again because of high livestock densities. In particular North-west in England, Wales, Britanny and Lombardy. (See map 2).

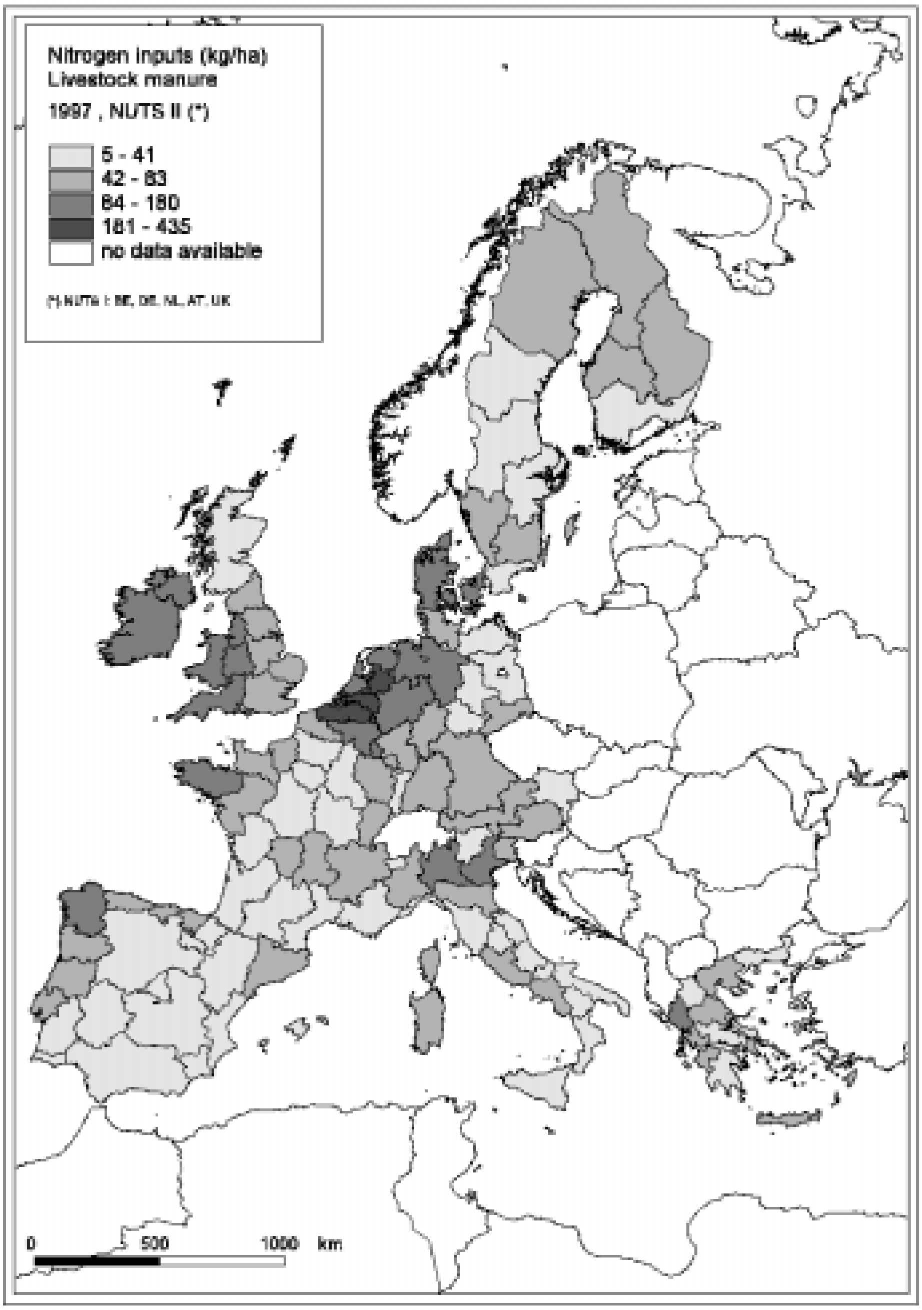
Removals of nitrogen from agricultural soils

As shown in table 2, fodder crops is the main crop responsible for removing nitrogen from soil in all EU countries. It accounts for more than 50% of the nitrogen removals in 12 of the 15 countries.

The Netherlands (190 kg N/ha) and Belgium (180 kg N/ha) had the largest outtake of nitrogen per ha of agricultural area by fodder crops, followed by Luxembourg and Ireland.

Within other arable crops, cereals dominate, with wheat the second most important crop in terms of nitrogen removals for most countries.

Map 2: Nitrogen Inputs / Livestock manure, 1997

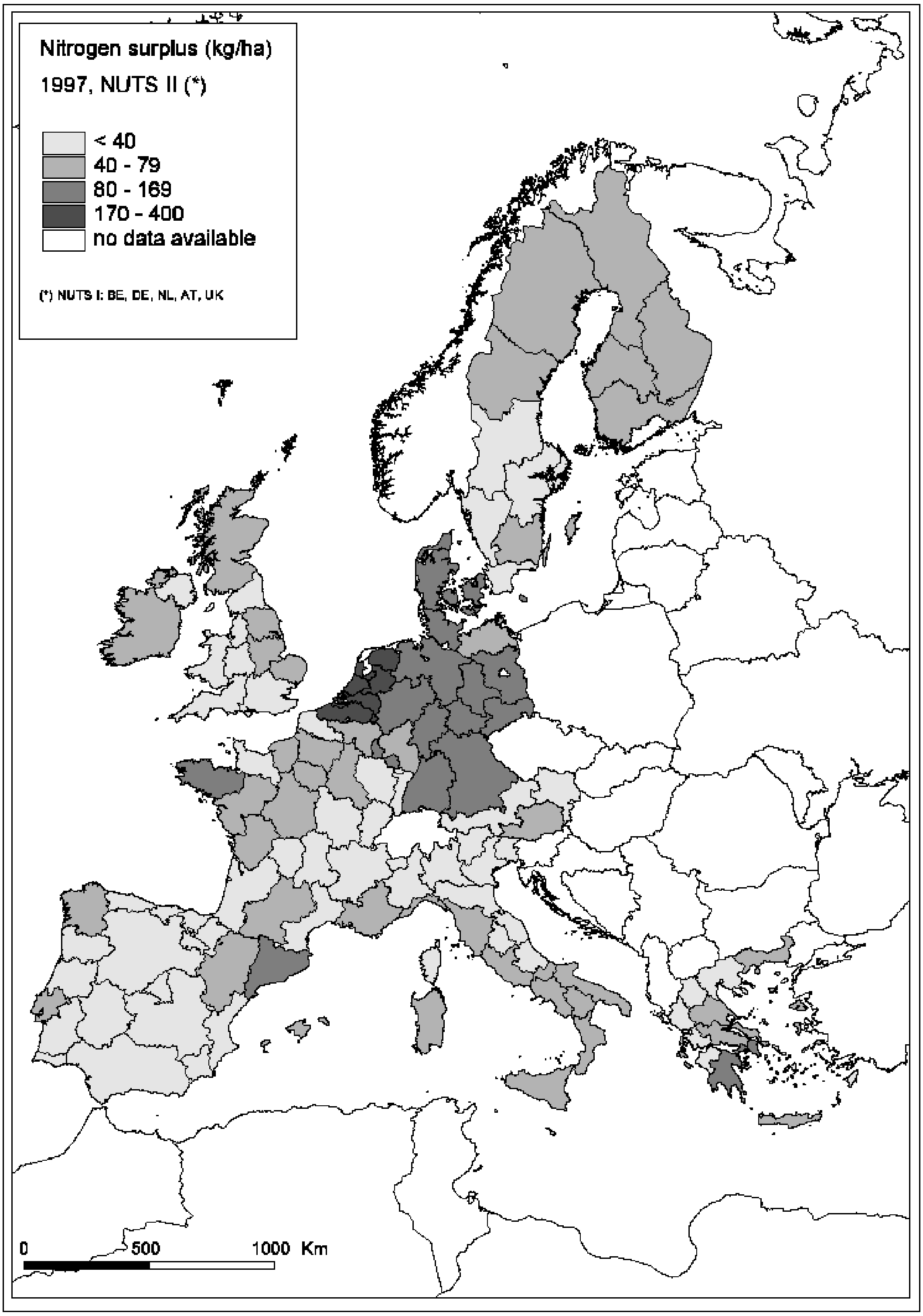


Surplus of nitrogen

Not surprisingly the Member States with high livestock densities are also the ones with high N-surpluses. In the Netherlands the average indicative surplus is 256 kg N/ha, followed by Belgium and Denmark with respectively 145 kg N/ha and 111 kg N/ha.

Within the larger countries, regions with relatively high indicative surpluses are Nordrhein-Westfalen, Niedersachsen, Britanny and Catalonia (See map 3).

Map 3: Nitrogen surplus (kg/ha), 1997



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Payment on receipt of invoice, preferably by:

❒ Bank transfer
❒ Visa ❒ Eurocard

Card No: _______________________ Expires on: _____/_____

Please confirm your intra-Community VAT number:
If no number is entered, VAT will be automatically applied. Subsequent reimbursement will not be possible.

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