Integrated measures in agriculture to reduce ammonia emissions; final summary report

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Service contract "Integrated measures in agriculture to reduce ammonia emissions"
Contract number 070501/2005/422822/MAR/C1

Final summary report

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Administrative summary

Service contract:
Integrated measures in agriculture to reduce ammonia emissions”,
Contract number 070501/2005/422822/MAR/C1

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Alterra, Wageningen University and Research Centre

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Preface

The results presented in this report are a summary and synthesis of four underlying reports drafted by a team with a blend of multidisciplinary expertise within a 15 months period.
The team acknowledges the strong support and many suggestions provided by the representatives of the European Commission, notably Michel Sponar, Alexander Paquot, Caroline Raes, Liliana Cortellini, Jeroen Casaer, Ger Klaassen, Eduard Dame and Adrian Leip, as well as the fruitful cooperation with Zbigniew Klimont and Willem Asman from IIASA.
The team also acknowledges the support provided by members of various working groups acting within the field of Environmental policies as well as representatives of Member States for providing data, information and suggestions.

A draft version of this Final Report has been reviewed. The suggestions and comments of the reviewers have been addressed in this final version.

Wageningen, 31 May, 2007

Oene Oenema

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EXECUTIVE SUMMARY

Introduction

This Final Summary Report summarizes the main findings of the service contract “Integrated Measures in Agriculture to reduce Ammonia Emissions”, issued by the European Commission, Directorate-General Environment (Contract 070501/2005/422822/MAR/C1). The general objective of the service contract is to have defined the most appropriate, integrated and consistent actions to reduce nitrogen (N) emissions from agriculture to atmosphere, groundwater and surface waters. Specifically, the objective is “*to have developed and applied a methodology allowing the assessment and quantification of the effects of various policies and measures aiming at reducing the impact of N losses from agriculture on water and air pollution and climate change*”. Both ancillary benefits and trade offs of measures have to be identified. The impacts and feasibility of the most promising measures have to be analysed in depth. The terms of reference of the contract is attached as Annex 5 to this report. This Summary Report is based on four reports, which are attached as Annexes 1[1], 2[2], 3[3] and 4[4].

The background of the service contract is the Thematic Strategy on Air Pollution (TSAP). In the TSAP, the European Commission outlined the strategic approach towards cleaner air in Europe, and concluded among other that the emissions of ammonia (NH_3) into the atmosphere have to decrease significantly. To decrease the emissions of NH_3 from agriculture, the following approaches were identified:

1) The National Emission Ceiling Directive (NEC) (2000/1258/EC) will be reviewed in 2007 and emission reduction targets will be fixed that are needed to meet the environmental and health objectives of the Thematic Strategy on Air Pollution. In the framework of the revision of the emission ceilings under the NEC, integration of new objectives for eutrophication, acidification and for particulate matter are required.
2) A possible extension of the Integrated Prevention and Pollution Control Directive (IPPC) to include installations for intensive cattle rearing and a possible revision of the current thresholds for installations for the intensive rearing of pigs and poultry. The review of the IPPC is done parallel to the Thematic Strategy on Air Pollution.
3) In the context of the Rural Development Regulation for the period 2007-2013, the Commission encourages Member States to make full use of the measures related to farm modernisation, meeting standards and agro-environment to tackle NH_3 emissions from agricultural sources.

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[1] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

[2] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen

[3] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. Alterra Report. Wageningen

[4] Annex 4. Monteny, G.J., H.P Witzke and D.A. Oudendag 2007. Impact assessment of a possible modification of the IPPC Directive. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Alterra Report. Wageningen.

During the preparation of the Thematic Strategy on Air Pollution, the desired integrated approach was only partly taken into account, because no tools were available to assess for example the effect of measures taken to decrease NH_3 emission on nitrate (NO_3) losses to the aquatic environment. Also, no assessments were available about the impact of measures taken in the framework of the Nitrates Directive to decrease nitrate emissions to water, on the emissions of NH_3, nitrous oxide (N_2O) and methane (CH_4) to the atmosphere. Further, the impact of the reform of the Common Agricultural Policy (CAP) on N use in agriculture and N emissions from agriculture were not addressed in the preparation of the Thematic Strategy on Air Pollution. Hence, further studies were needed to be able to implement the integrated approach set out by the Thematic Strategy on Air Pollution. The study reported here is a first step towards implementing the suggested integrated approach.

Nitrogen and agriculture in the European Union

Agriculture contributes on average about 80-90% to the total emissions of NH_3 into the atmosphere in the 27 Member States of the European Union (EU-27). Most of the NH_3 originates from animal manure in animal houses, manure storage systems and following the application of animal manure to agricultural land. Mineral N fertilizers also contribute to NH_3 emissions. For accurate assessment of total NH_3 emissions and NH_3 emissions abatement potentials, detailed information is needed about the effects of agricultural practices and management on N inputs and outputs and N transformation processes in agriculture.

Major sources of N in agriculture of the EU-27 are shown in Table A. These sources include mineral N fertilizers (about 10 Tg per year), animal manure (excreted about 10 Tg per year, of which 5 Tg is applied to agricultural land and 3.5 Tg is dropped to to land by grazing animals), biological N_2 fixation (about 1 Tg per year) and atmospheric N deposition (about 2 Tg). The N from animal manure is derived from animal feed and can be considered as recycled N. Part of the excreted N is derived from imported animal feed (about 7 Tg per year). The N from atmospheric N deposition can be considered also as recycled N; about half is derived from NH_3 emitted from agriculture and the other half is largely derived from nitrogen oxides (NO_X) derived from combustion sources.

Table A. Major sources of N in agriculture in the 27 Member States of the European Union (EU-27) in 2000, in kton N (1 kton = 1 million kg 1 = Gg = 10^9 g). Source: MITERRA-EUROPE.

N source	Sub-total kton N	Total kton N
Applied N fertilizer		10748
Total amount of N excreted by domestic animals		10372
Animal manure N applied to agricultural land	4778	
N excreted by animals during grazing	3560	
Atmospheric N deposition		1977
Biological N fixation		823

Livestock in EU-27 is dominated by cattle (both dairy and beef), pigs and poultry. The number of dairy cattle increased until the implementation of the milk quota system in the EU-15 in 1984, and decreased thereafter by about 1% per year. Between 1961 and 2005, the numbers of pigs and poultry have increased by 60 and 70%, respectively. Political changes in central European countries in the early 1990s, the regional incidences of animal diseases, and the implementation of governmental policies and measures (Reform of the Common Agricultural Policy, and environmental directives and regulations) have shaped these trends. The total amount of N excreted by livestock in EU-27 was about 7-8 Tg in the early 1960s and increased to 11 Tg in the late 1980s. Thereafter, it tended to decrease again. Fertilizer N use was 4 Tg in 1960, peaked at 12 Tg in the late 1980s and was 10.7 Tg in 2000.

Only a fraction (on average 40-50%) of the N input via fertilizers and animal manure to agricultural land is utilized for crop production. The remainder is lost to the environment. Emissions of N to the wider environment occur via various N species and can lead to serious problems, including human health problems and ecosystem degradation. The volatilization of NH_3, leaching of NO_3, and the emissions of di-nitrogen (N_2), N_2O and nitrogen oxide (NO) following nitrification-denitrification reactions are the main N loss pathways from agriculture. About 80-90% of the NH_3 emissions, 50-60% of the N_2O emissions and 40-60% of the N loading of surface waters in the EU-27 originate from agriculture. Figure A presents a notion of the complexity of the N cycling and N transformation processes in agriculture. It shows how N is cascading through agriculture and the environment, from the site of its 'fixation' (fertilizer industry, biological N_2 fixation) via agriculture (where it contributes to increased crop production) to the environment (atmosphere, groundwater and surface waters, and terrestrial natural ecosystems), where it contributes to a range of ecological effects.

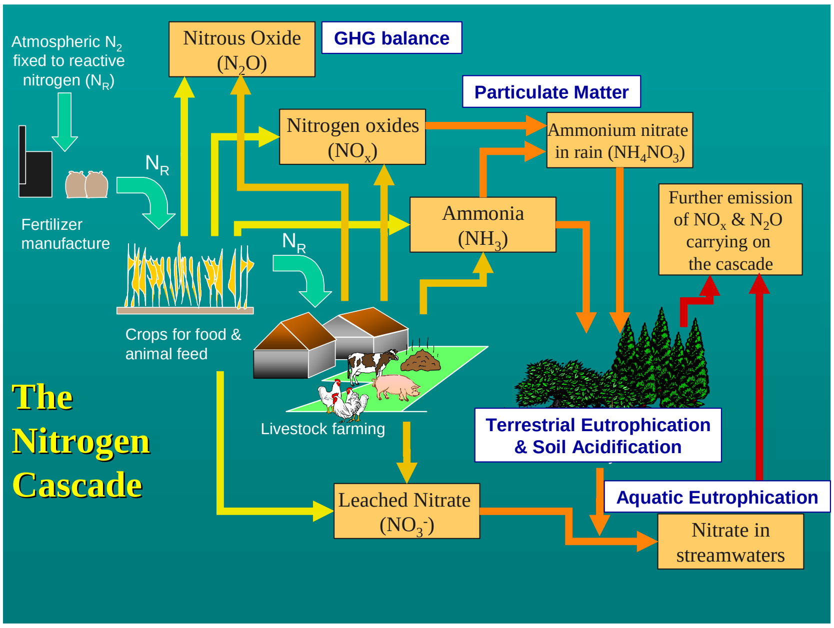

Figure A. The flow of nitrogen in agriculture according to the 'Nitrogen Cascade'.

Developing a simple integrated approach: MITERRA-Europe

The first task of the service contract dealt with "*to have developed and applied a methodology allowing the assessment and quantification of the effects of various policies and measures aiming at reducing the impact of N losses from agriculture on water and air pollution and climate change*". The methodology referred to is the integrated assessment tool MITERRA-EUROPE, which has been developed on the basis of the existing instruments RAINS/GAINS and CAPRI.

The RAINS/GAINS model instrument (IIASA; www.iiasa.ac.at/rains/) is commonly employed by European Commission to assess gaseous emissions into the atmosphere in the EU, and has been used also during the preparation of the Thematic Strategy on Air Pollution. Therefore, an intensive link and cooperation was developed during the execution of the service contract between the consortium of the service contract and the IIASA team working on RAINS/GAINS so as to achieve consistency in the use of scenarios, emission factors and activity data. The RAINS/GAINS model has been a cornerstone for MITERRA-EUROPE, and vice versa, MITERRA-EUROPE will be the basis for the extension of RAINS/GAINS (so as to allow RAINS/GAINS making integrated assessments for agriculture in the near future). The model CAPRI (Common Agricultural Policy Regionalised Impact; http://www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm) has been another cornerstone for MITERRA-EUROPE. CAPRI is a regional economic optimization model, commonly employed by European Commission to assess the effects of for example changes in the CAP and WTO on agricultural production and economics.

MITERRA-EUROPE is a modelling tool for the assessment of possible synergistic and antagonistic effects of European and International policies and measures, including the IPPC, NEC and Gothenborg Protocol (UNECE Ammonia Abatement Technologies), the Nitrates Directive and Water Framework Directive, and the possible measures of the UNFCCC to decrease greenhouse gases from agriculture, at the scales of the EU-27, Member States and regional levels (NUTS-2 and Nitrate Vulnerable Zones). Hence, MITERRA-EUROPE can be used to fine-tune policy instruments and measures aimed at decreasing the emissions of N species from agriculture. The results presented below are based on model calculations by MITERRA-EUROPE and in part also by RAINS and CAPRI. Results generated by MITERRA-EUROPE are made available through the website www.scammonia.wur.nl.

Assessment of synergies and antagonisms of emissions abatement measures

The implementation of single abatement technologies for NH_3 emissions can lead to slight increases in the leaching of N and the emissions of N_2O, when no supplemental measures are taken to correct for the increased N contents of the animal manure (Figure B; upper panel). However, when the last mentioned measure of the guidelines of the UNECE Working Group on Ammonia Abatement Technologies is taken into account, the increased N leaching and N_2O emissions will be prevented. This measure deals with 'Nitrogen management; balancing manure nutrients with other fertilizers to crop requirements' and will lead to a correction in the total N application rate.

The effects of the implementation of N leaching abatement measures on N leaching and on NH_3 and N_2O emissions are shown in the lower panel of Figure B. Essentially all measures taken to decrease N leaching have synergistic effects, i.e. the measures also decrease the emissions of NH_3 and N_2O. Effects on CH_4 emissions are absent, and therefore not shown. Balanced fertilization has the largest effects on N leaching losses and also the largest synergistic effects.

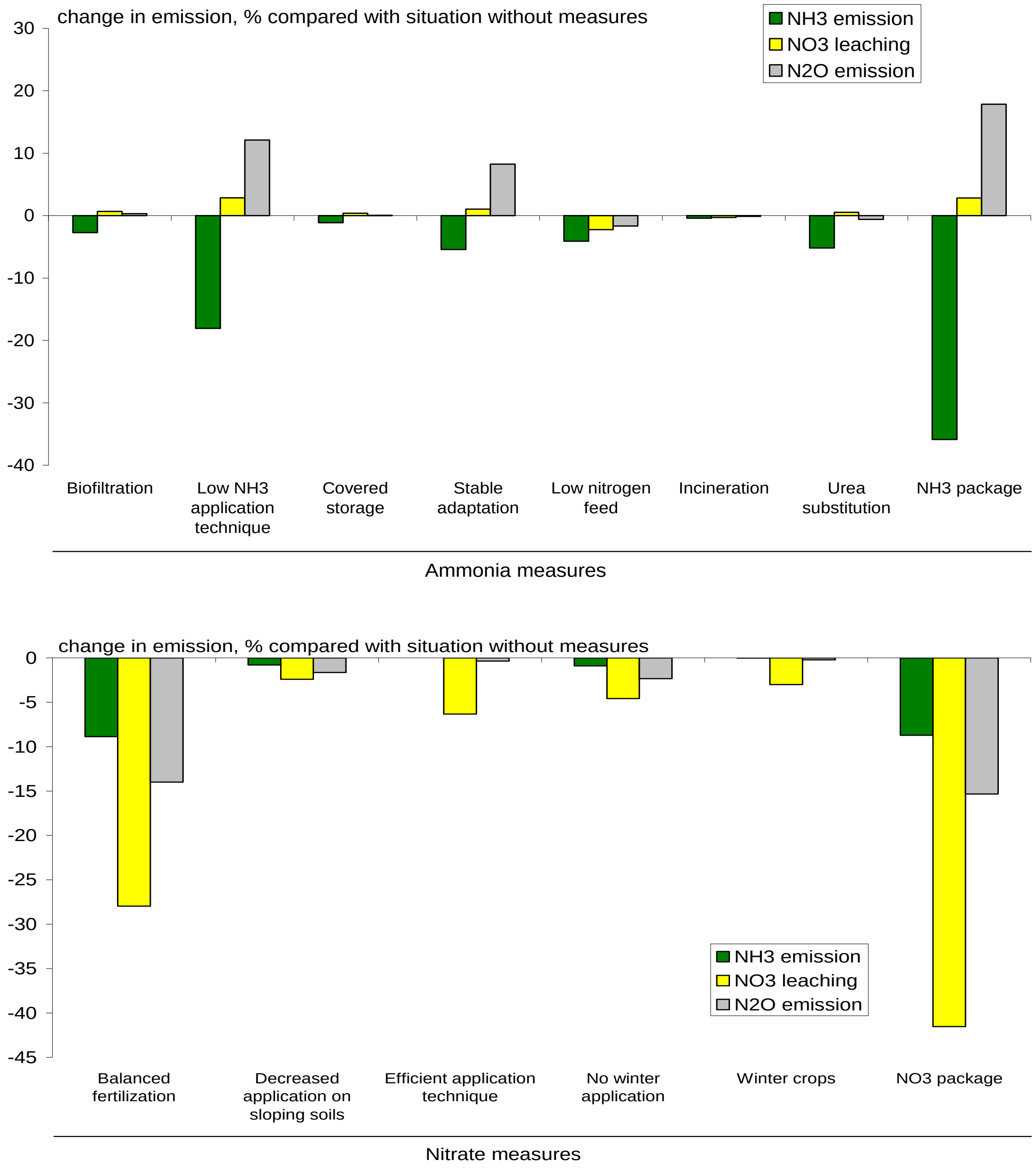

Figure B. Potential effect of NH_3 emissions abatement measures on changes in the emissions of NH_3 and N_2O to the atmosphere and N leaching to groundwater and surface waters (upper panel), and potential effect of N leaching abatement measures on changes in the emissions of NH_3 and N_2O to the atmosphere and the N leaching to groundwater and surface waters (lower panel), in EU-27 for the year 2000. Results of calculations with MITERRA-EUROPE

Assessment of NEC and Nitrates Directive scenarios

Various scenarios have been examined in terms of emissions of NH_3, N_2O, NO and N_2 to the atmosphere, and leaching of N (mainly nitrate (NO_3)) to groundwater and surface waters. Also emissions of methane (CH_4) and balances of phosphorus (P) have been assessed. The scenarios have been defined by the European Commission, in consultation with the IIASA team and the consortium. The scenarios related to the National Emission Ceiling (NEC) Directive and the Nitrates Directive analyzed in task 1 of the service contract are listed in Table B. Reference year is 2000, the target year is 2020. It should be noted that scenarios are not predictions, but ‘narratives of alternative future environments’. They are like hypotheses of different futures, designed to highlight the risks and opportunities involved in specific developments.

Table B. Overview of the scenarios analyzed in Task 1.

Scenarios	**Description**
1. RAINS A 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000 (Amann M. et al., 2006)
2. RAINS A 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010 (Amann M. et al., 2006)
3. RAINS A 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020 (Amann M. et al., 2006)
4. RAINS optimized 2020	National Projections baseline scenario for the revision of the NEC Directive, optimized to achieve the targets of the Thematic Strategy in 2020 (Amann M. et al., 2006)
5. ND partial 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000, including partial implementation of the measures of the Nitrates Directive (ND) in Nitrate Vulnerable Zones (Annex 1)
6. ND partial 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010, including partial implementation of the measures of the Nitrates Directive (ND) in Nitrate Vulnerable Zones (Annex 1)
7. ND full 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures of the Nitrates Directive (ND) in Nitrate Vulnerable Zones (Annex 1).
8. WFD 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures of the Nitrates Directive in Nitrate Vulnerable Zones plus (strict) equilibrium P fertilization on all agricultural land, following the Water Framework Directive (WFD) (Annex 1).

Results of the scenarios are summarized in Tables C and D, and Figure C. The results of the NEC Directive, Nitrates Directive and Water Framework Directive scenario analyses lead to the following conclusions:

- The NEC National Projection scenario (RAINS A 2020) scenario leads to a ~10 % decrease in NH_3 emission in EU-27 in 2020 relative to the reference year 2000, mainly due to a lower N fertilizer use and a less N excretion (due to less domestic animals). The leaching of N to groundwater and surface waters decreases by ~9 %. Differences between countries are large.
- The ‘optimized 2020 scenario’ defined to achieve the targets of the TSAP, lead to a ~21 % decrease in NH_3 emission in EU-27 in 2020 relative to the reference year 2000, mainly due to the implementation of ‘cost-effective’ NH_3 emission abatement measures. The leaching of N to groundwater and surface waters decreases by 9%.

- The Nitrates Directive (ND) scenarios, especially full implementation of the Nitrates Directive (ND full 2020 scenario) and the Water Framework (WFD 2020 scenario), have a strong effect on the N input via N fertilizer and animal manure, and hence on total N losses. The ND full 2020 and the WFD 2020 scenarios lead to a ~26 and 29 % decrease in N leaching in EU-27 in 2020 relative to the reference year 2000, respectively. The NH_3 emission decrease by 14 and 16% in the ND full 2020 and the WFD 2020 scenarios, respectively.
- Though effective in decreasing N leaching and gaseous N (NH_3, N_2O and NO_X) emissions, the ND full 2020 and the WFD 2020 scenarios have significant effects for agriculture. Strict implementation of the code of Good Agricultural Practice and balanced N fertilization according to the Nitrates Directive, and ‘equilibrium P fertilization’ (in the WFD scenario) will decrease ‘the room for N and P fertilizer use and application of animal manure N and P’ in various regions in EU-27. Achieving a strong decrease in the application of animal manure N and P will require a combination of low-protein and low-P animal feeding, as well as manure treatment and disposal of the N and P outside agriculture.
- The ND full 2020 and the WFD 2020 scenarios, as defined here, greatly contribute to achieving the targets of the Thematic Strategy on Air Pollution. As yet, the RAINS optimized 2020 scenario developed to achieve the TSAP targets, did not include the effects of the ND full 2020 and WFD 2020 scenarios. This suggests that new optimizations runs may be needed, taking into account the measures of the Nitrates Directive and the Water Framework Directive, to be able to calculate the most cost-effective combination of measures.
- Denitrification, with emissions of N_2, N_2O and NO as end-products, is the largest N loss pathway in European agriculture, followed by NH_3 volatilization, and N leaching. Emissions of N_2O and NO_X contribute little to the total N loss (but have a significant environmental effect).
- The NH_3 emission abatement measures of the UNECE Working Group on Ammonia Abatement Technologies are effective in decreasing NH_3 emission but some of these measures increase the emissions of N_2O and the leaching of N. The measures ‘low-protein animal feeding’ and ‘N management’ have the potential of inducing synergistic effects, i.e., decreasing all N losses simultaneously. When the NH_3 emission abatement measures are implemented as integrated package and emphasis is given to ‘overall N management’, the possible antagonistic effects may disappear.
- The nitrate leaching abatement measures of the Nitrates Directive are effective in decreasing N leaching, but some have the potential to increase the emissions of NH_3. Assessments made by MITERRA-EUROPE indicate that the measures of the Nitrates Directive are effective in decreasing N leaching and that the antagonistic effects are relatively small. Overall, the nitrate leaching abatement measures of the Nitrates Directive (especially balanced fertilization) have the potential of creating synergistic effects.

Table C. Summary of the calculated NH_3 emission in the scenarios explained in Table B, in kton NH_3 per year. Results are presented for agriculture and for the total EU-25 and/or EU-27, using different modeling tools.

Model (literature source)	RAINS(1)	RAINS (1)	RAINS (2)	MITERRA (3)	CAPRI (3)
Area	EU 25	EU 27	EU 25	EU 27	EU 27
Sector	Total	Total	Agriculture	Agriculture	Agriculture
Water Directives scenarios					
Reference RAINS A 2000	***3774***	***3976***	***3455***	***3488***	
ND partial 2000				3455	
ND partial 2010				3086	
ND partial 2020					3044
ND full 2020				2989	2983
Water framework D				2894	
NEC national 2020 (RAINS A 2020)	3359	3600	3072	3132	

(1) Klimont et al, 2007
(2) Amann et al, 2006
(3) this study

Table D. Summary of the calculated N leaching, emissions of N_2O and CH_4, and the phosphorus surplus in agriculture of the EU-27 in the scenarios explained in Table B, in kton per year. Results of MITERRA-EUROPE.

Scenario	N leaching, kton N	N_2O, kton N	CH_4, kton	P-surplus, kton P_2O_5
RAINS A 2000	2782	377	9848	3357
ND partial 2000	2575	368	9848	3336
RAINS A 2010	2595	382	9036	3115
ND partial 2010	2299	369	9036	3077
RAINS A 2020	2507	382	8840	2911
ND full 2020	1908	354	8840	2688
WFD 2020	1830	346	8840	290

Assessment of most promising measures)

Task 3 of the service contract dealt with the identification and assessment of three 'most promising measures' to decrease N emissions from agriculture. In order to be considered as promising, the measures should correspond to the following criteria:

(i) Co-beneficial effects for water, air, climate change and soil protection;
(ii) Feasible in practice, notably from administrative and enforceability points of view;
(iii) Potentially acceptable by the farmers, notably for what concerns costs and additional efforts at farm level;
(iv) Compatible with the need for improved animal welfare'.

Three (packages of) 'most promising' measures for decreasing N emissions have been identified and examined, namely (1) low-protein animal feeding (LNF), (2) balanced N fertilization (Balfert), and (3) a combination of balanced N fertilization and NH_3 emission abatement techniques (Optimal combination). All three packages of measures combine a decrease of N input into agriculture with increasing the N use efficiency. All three packages of measures were 'translated' into scenarios, as indicated in Table E. For the package of low-protein animal feeding, four sub-variants have been defined.

Table E. Overview of the scenarios analyzed in Task 3.

Scenarios	Description
1. ND full 2020 (Reference scenario)	National Projections baseline scenario for the revision of the NEC Directive, 2020, plus full (strict) implementation of Nitrates Directive in extended areas of Nitrate Vulnerable Zones (Annex 1).
2. LNF 10%, 'all' farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to 'all' (50-100%) farms.
3. LNF 10%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to IPPC farms only
4. LNF 20%, 'all farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to 'all' (50-100%) farms
5. LNF 20%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to IPPC farms only
6. Balfert 2020	ND full 2020 (see above) plus strict implementation of balanced N fertilization on all farms, irrespective of NVZs
7. Optimal Combination, 2020	Rains optimized 2020 (see Table 2.6) plus Balfert 2020

Justification for lowering the protein level of animal feed was based on literature and modelling studies. There is scope for decreasing the protein content of the animal feed by on average 10 to 20% in practice, within a 10 to 20 years period, but the rate of implementation of such was varied between Member States (range 50-100%). The scenarios assessed in task 3 of the service contract are shown in Table E. Justification for implementation of balance fertilization outside Nitrate Vulnerable Zones was also based on literature and modelling studies. Justification for the optimal combination scenario was based on a previous IIASA study. The reference scenario for the most promising measures is the ND full 2020 scenario, indicated in Table B. The target year for all scenarios is 2020. Results of the scenarios are summarized in Tables F, G and H, and Figure B.

Implementation of low-protein animal feeding (LNF) has multiple beneficial environmental effects. The analyses indicate that a decrease of 10% of the protein content of the animal feed on 'all' farms will lower the NH_3 emissions by 6% and the N leaching and emissions of N_2O by 4% relative to the ND full 2020 scenario. Decreasing the protein content of the animal feed by 20% would further decrease the NH_3 emissions by 10% and the N leaching and emissions of N_2O by 7%.

Table F. Summary of the calculated NH_3 emission in the scenarios explained in Table D, in kton NH_3 per year. Results are presented for agriculture of the EU-27 only, using the modeling tools MITERRA-EUROPE and CAPRI.

Model	MITERRA	CAPRI
Area	EU 27	EU 27
Sector	Agriculture	Agriculture
Most promising measures		
ND full 2020 Reference	2989	2983
ND full 2020 + LNF 10%	2833	2810
ND full 2020 + LNF 10% IPPC	2959	2952
ND full 2020 + LNF 20%	2657	2575
ND full 2020 + LNF 20% IPPC	2925	
ND full 2020 + Balfert	2873	2838
ND full 2020 + Optimal combination	2416	2363

Table G. Summary of the calculated N leaching, emissions of N_2O and CH_4, and the phosphorus surplus in agriculture of the EU-27 in the scenarios explained in Table B, in kton per year. Results of MITERRA-EUROPE.

Scenario	N leaching, kton N	N_2O, kton N	CH_4, kton	P-surplus, kton P_2O_5
ND full 2020	1907	354	8840	2688
ND full 2020 + LNF 10% all	1838	341	8840	2708
ND full 2020 + LNF 10% IPPC	1893	350	8840	2660
ND full 2020 + LNF 20% all	1769	328	8840	2731
ND full 2020 + LNF 20% IPPC	1878	347	8840	2669
ND full 2020 + Balfert 2020	1700	338	8840	2346
ND full 2020 + Optimal combination	1634	344	8844	2380

Table H. Summary of the changes in agricultural income, and consumer and total welfare in the EU-27, relative to the changes in emissions of NH_3, N_2O and CH_4 and in N leaching, for a selection of most promising scenarios. Results of CAPRI.

	agric income [m €]	consumer welfare [m €]	total econ welfare [m €]	total NH3 loss [kton]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
BALFERT	-3058	-26	-3056	-53	-1	-19	-157
LNF10 all	-6425	-2841	-11505	-203	53	-35	-120
LNF10 IPPC	-397	-1450	-2437	-35	16	-6	-15
LNF20 all	-8962	-16966	-31372	-436	-368	-80	-250
Opt combination	-10831	-3954	-16959	-558	17	40	-266

	abatement relative to welfare cost estimate			
	NH3 [g / €]	CH4 [g / €]	N2O [g / €]	leaching [g / €]
BALFERT	17	0	6	51
LNF10 all	18	-5	3	10
LNF10 IPPC	14	-7	2	6
LNF20 all	14	12	3	8
Opt combination	33	-1	-2	16

Full implementation of balanced fertilization (Balfert 2020) in this study (removing ‘over-fertilization’) was equivalent to decreasing the N input via N fertilizer by on average 9% and that via animal manure by up to 6%, relative to the reference scenario (ND full 2020). Balanced fertilization outside Nitrate Vulnerable Zones (Balfert 2020) decreases the NH_3 emissions by 4%, N leaching by 11% and the emissions of N_2O by 4% relative to the ND full 2020 reference scenario. However, balanced fertilization as applied in this study is not without cost for the farmer (Table H). Agricultural income decreases by ~3 billion euro per year, because of the assumed cost to implement this measure (demonstration, extension services, soil and crop analyses, etc.). It may also increase the risk of a decrease in crop yield. Further, areas with high livestock density will be forced to lower the N content of the animal manure through further implementation of low-protein animal feeding or farmers in these areas may have to treat the manure, to be able to implement balanced fertilization and to utilize the nutrients in the animal manure efficiently. The balanced N fertilization measure has considerable perspectives for decreasing the N loading of the environment, but when applied too strict it can have considerable agronomic and economic effects. Further sensitivity analyses are needed here.

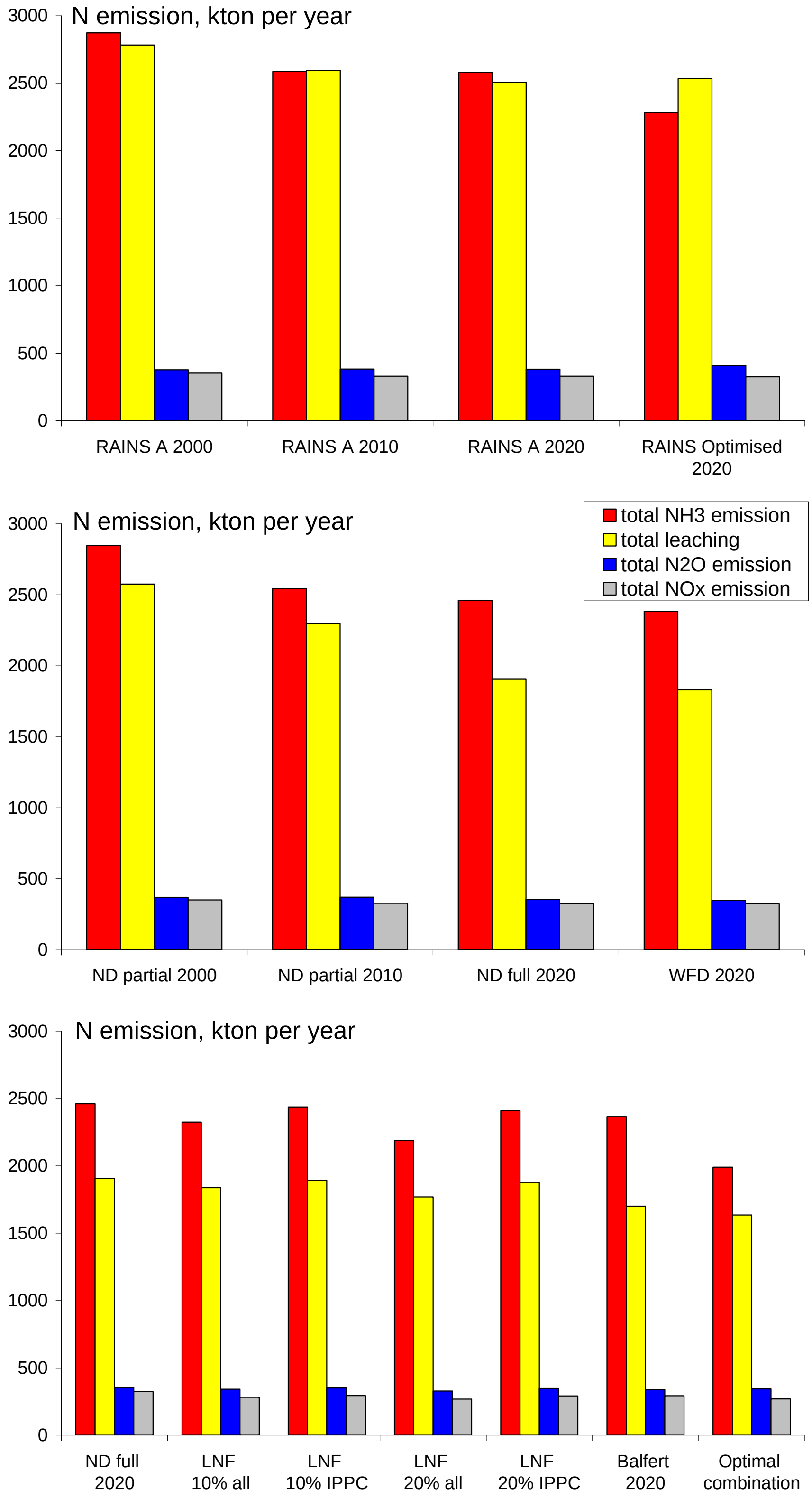

Figure B. Summary of the gaseous N losses and N leaching losses from agriculture in the scenarios of task1 and 2, as described in Tables B and E.

Combined implementation of an optimal set of NH_3 emission abatement measures and balanced fertilization (‘Optimal Combination 2020’) has the most ‘far-reaching’ effects. It decreases the NH_3 emission by another 19% relative to the ND full 2020 reference scenario to reach a level of ~2416 kton NH_3 from agriculture in EU-27 (Table F). This level is below the target levels (~2450 kton for EU-25 and ~2650 kton for EU-27) needed to achieve the objectives of the Thematic Strategy on Air Pollution in 2020. In addition, the Optimal Combination 2020 scenario decreases mean N leaching by 14% and mean N_2O emissions by 3% relative to the ND full 2020 reference scenario (Table G). However, the Optimal Combination 2020 scenario is not without cost for the farmer (Table H). The annual cost of the NH_3 emission abatement measures have been estimated by IIASA at € 1.6 billion for the EU-25, in addition to the cost already associated with current legislation. Combination of these measures with Balfert 2020 decreases agricultural income to 10.8 billion euro per year (Table H). Relatively large amounts of manure N have to be ‘neutralized’ through a combination of low-protein animal feeding and manure treatment and manure disposal in some regions, at considerable additional costs.

For making more accurate assessments of the prospects for lowering N excretion through lowering of the protein content in the animal feed, it is recommended that a thorough survey is being made of the animal feeding practices and animal performances in the EU-27. A uniform methodology must be applied for estimating the regional variation in N excretion by animals. Lowering N excretion through further lowering of the protein content in the animal feed and through improving the genetic potential of the herd are key for areas with relatively high livestock density.

There are also possible developments that may hinder a decrease in the protein content of the animal feed. For example, the increasing demand for biofuels will compete with the demand for high-quality animal feed, because there is hardly land unused in the world. Increasing the acreage of biofuels will increase the cost of animal feed (because of competition) and will contribute an increasing supply of low-quality by-products from the production of biodiesel and ethanol on the market. These by-products (DDGS) of the biofuel industry are poor in energy and rich in protein and fiber (but have low-quality protein). As a consequence, the protein content of the animal feed and N excretion may have the tendency to increase again in the near future (and the emissions of NH_3 likely too).

Increases in the interest in biofuel will also increase the area of biofuel crops, such as rapeseed, as is currently the case in a number of Member States (e.g. Germany, Poland). Increased areas of biofuel will likely also contribute to increases in total fertilizer N use. This trend is opposite to the trend of decreasing fertilizer use in the ND full 2020 and Balfert 2020 scenarios. In short, there is considerable uncertainty about the future developments in fertilizer use and the protein content of the animal feed.

Assessment of IPPC scenarios

In task 4, an extensive inventory has been made of the number of farms and number of animals falling under the regime of the IPPC Directive. Next, an assessment has been made of the effects of changes in the thresholds values for the number of animals for IPPC farms, using four scenarios including the reference scenario (Current threshold and full implementation of the Nitrates Directive). The threshold values are shown in Table I; the calculated changes in NH_3 emissions are shown in Table J.

The contribution of IPPC pig and poultry farms tot the total NH_3 emissions is relatively large, because of the large percentage of animals (20 to 80%) that fall under the IPPC, depending also on threshold. The results of the IPPC scenarios indicate that lowering the thresholds for poultry and pig farms and including cattle rearing under the IPPC has the potential to decrease the NH_3 ammonia emission by 26 to 113 kton per year. The results also indicate that "low-NH_3-emission-manure-application" has to be included as a Best Available Technique (BAT) in IPPC permits to increase the 'NH_3 trapping efficiency'. The 'NH_3 trapping efficiency' of permits decreases when the IPPC thresholds are lowered. When "low- NH_3-emission-manure-application" is not include as BAT in the permit, the 'NH_3 trapping efficiency' is in the range of 1800 to 2700 kg NH_3 per permit, depending on the choice of the thresholds. When "low-NH_3-emission-manure-application" is included as BAT in the permit, the 'NH_3 trapping efficiency' is in the range of 4000 to 8000 kg NH_3 per permit, depending on the choice of the thresholds.

Table I. Thresholds values for the number of animals for IPPC farms in the four scenarios; current IPPC and SCE1, SCE2 and SCE3.

Animal species	Scenarios 2020			
	Current IPPC	SCE1	SCE2	SCE3
Fattening pigs	> 2000	> 2000	> 1750	> 1500
Sows	> 750	> 750	> 675	> 600
Hens	> 40000	> 27500	> 25000	> 20000
Broilers	> 40000	> 37000	> 32000	> 27000
Dairy cows	-	> 450	> 400	> 350
Other cattle	-	> 1000	> 850	> 700

Table J. Summary of the changes in agricultural income, and in consumer and total welfare in the EU-27, relative to the changes in emissions of NH_3, N_2O and CH_4 and in N leaching for a selection of IPPC scenarios. Results of CAPRI.

	agric income [m €]	consumer welfare [m €]	total econ welfare [m €]	total NH3 loss [kton]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
IPPC1	-240	-236	-532	-47	5	7	-1036
IPPC2	-392	-471	-980	-63	5	8	-5
IPPC2 + more LNA	-482	-640	-1239	-107	5	12	-3
IPPC3	-558	-686	-1425	-85	4	9	-7
IPPC3 + more LNA	-655	-877	-1712	-138	4	304	-5

	abatement relative to welfare cost estimate			
	NH3 [g / €]	CH4 [g / €]	N2O [g / €]	leaching [g / €]
IPPC1	88	-10	-13	1947
IPPC2	65	-6	-8	5
IPPC2 + more LNA	86	-4	-10	3
IPPC3	60	-3	-6	5
IPPC3 + more LNA	81	-2	-177	3

The effect of including the BAT for manure spreading (Low Nitrogen Application, LNA) under the IPPC ranges from 44 - 61 kton, depending on the scenario. The lowest value of this range (44 kton) is related to implementing LNA on installations already falling under the current scope of the IPPC Directive. The largest value (61 kton) is observed for the IPPC3 scenario. The estimated reduction of 44 – 61 kton is in good agreement with the reduction estimated with RAINS by IIASA (around 50 kton for Scenario IPPC1).

A uniform base for poultry farms falling under the IPPC can be derived from total N excretion. Such base would give the following thresholds for poultry farms: broilers: 40,000 (no change); laying hens: 30,000; ducks: 24,000; and turkeys: 11,429. Using these thresholds, around 900 extra poultry farms would fall under the IPPC, bringing the total to 17,000 IPPC farms for all animal species. The additional emission reduction is around 10 kton when LNA is included.

Recommendations to policy

- The measures dealing with N input control in the Nitrates Directive (Balanced N fertilization) and the UNECE – CLRTAP and the IPPC and NEC Directives (protein content of the animal, integrated N management) should be the guiding and overall arching principles of measures aimed at to decrease emissions of NH_3 and N_2O and the leaching of N.
- The implementation and enforcement of the measures of the Nitrates Directive must be jointly with those of Ammonia Abatement Technologies of the UNECE – CLRTAP and the IPPC and NEC Directives, so as to circumvent pollution swapping.
- In addition to NH_3 emission ceilings and limits, input limits for N from animal manure and NO_3 concentration in groundwater and surface waters, there is scope for formulating targets for N use efficiency for specified farming systems. Such targets for N use efficiency have the advantage of providing a measure for an integrated N input control and for N losses to the environment.
- Providing incentives via Rural Development measures to the N use efficiency for specified farming systems provides opportunities for rewarding those farmers that go beyond certain standard criteria and thereby decreasing N losses in an integrated way.
- Animal welfare regulations for animal housing should be combined with NH_3 and N_2O abatement measures and NO_3 leaching abatement measures
- In addition to spatial *zoning* of areas with high nature values and/or vulnerable to NO_3 leaching (within the context of the Nitrates Directive and the Birds and Habitats Directives), there is scope for spatial *planning* of N polluting agricultural activities in areas that are less vulnerable. This can be relevant also given the trends towards conglomerating large, specialized and intensive farms in areas with cost-specific advantages.
- The role of the agro-complex (suppliers, farmers, processing industry and retailers) has so far received little or no attention in decreasing N losses from agriculture. This is surprising, as the agro-complex and especially suppliers, processing industry and retailers play a dominant role in (the development of) agriculture. It is suggested to

explore the potentials of the agro-complex in improving N use efficiency and decreasing N losses from agriculture.

1. Introduction

Nitrogen (N) is a key input in agriculture. The availability of relatively cheap N fertilizers from the 20th century onwards has contributed greatly to increased food and feed production, though not equally on all continents (Smil, 2000; 2001). This increased food and feed production allowed the human population to double and the number of domestic animals to triple between 1960 and 2000. Forecasts suggest further increases in human population and animal numbers in the range of 30 to 50%, respectively, suggesting the need for increasing amounts of available N (Bruinsma, 2003; Mosier et al., 2004). Current global N fertilizer use is about 80 billion kg (80 Tg), but not more than 50% of this N is utilized by the crop while the remainder is dissipated into the wider environment (Mosier et al., 2004). On average not more than 30% of the amount of N excreted by livestock (globally 100 - 130 Tg per year) is utilized by the crop, while the remainder is dissipated into the wider environment (Smil, 1999; Oenema and Tamminga, 2005).

The 27 Member States of the European Union (EU-27) used about 4 Tg fertilizer N in 1960 and about 12 Tg in the late 1980s when fertilizer use peaked. In 2002, fertilizer use in EU-27 was about 10.5 Tg (FAOstat, 2006). The total amount of N excreted by livestock in EU-27 was about 7-8 Tg in the early 1960s and increased to 11 Tg in the late 1980s. Thereafter, it tended to decrease again to about 10.3 Tg in 2000. With a human population (490 million in 2005) of less than 10% of the global human population, EU-27 has a relatively large share in the use of N fertilizer (13%) and in the N excreted by animals (~10%). In addition, there are inputs in EU-27 via biological N_2 fixation ~2.2 Tg), atmospheric deposition (~7.3 Tg), and imported products (7.6 Tg) (Van Egmond et al., 2002). Only a small part of the total N inputs is effectively utilized and/or exported; the greater part is lost to the wider environment.

Emissions of N to the wider environment occur via various N species and can lead to serious problems related to human health and ecosystem degradation. The volatilization of ammonia (NH_3), leaching of nitrate (NO_3), and the emissions of di-nitrogen (N_2), nitrous oxide (N_2O) and nitrogen oxide (NO) following nitrification-denitrification reactions are the main N loss pathways from agriculture. Apart from N_2, the N species mentioned are often termed “reactive N”, as they are biologically, photo chemically and/or radiatively active N compounds. Galloway (2003) and Galloway et al. (2002) made an integral analysis of the cause - effect relationship between the creation of reactive N and a sequence of environmental effects, the so-called nitrogen cascade. Observed environmental and human health effects include (e.g., Galloway et al., 2002; AEA Technology Environment, 2005):

- Decrease of human health, due to NH_3 and NO_x induced formation of particle matter ($PM_{2.5}$) and smog,
- Plant damage through NH_3 and through NO_x induced ozone formation;
- Decrease of species diversity of natural areas due to N enrichment through atmospheric deposition of NH_3 and NO_x;
- Acidification of soils because of deposition of NH_3 and NO_x
- Pollution of ground water and drinking water due to nitrate leaching;

- Eutrophication of surface waters due to N enrichment, leading to excess and possibly toxic algal blooms and a decrease in faunal and floristic species diversity;
- Global warming because of emission of N_2O; and
- Stratospheric ozone destruction due to N_2O.

About 90% of the NH_3 emissions, 60% of the N_2O emissions and 40 to 60% of the N loading of surface waters in the EU-15 originate from agriculture (EEA, 2002; EEA, 2005). Emissions of N from agriculture to the wider environment are decreasing in many Member States from about the 1990s onwards, but emissions from other sources (industry, households, and waste water treatments) have seen a stronger decrease than those from agriculture during the last decades (EEA, 2005).

Figure 1 presents a notion of the N cycling and N transformation processes in agriculture, according to the so-called ‘Nitrogen Cascade’. It emphasizes the net ‘linear’ flow of N from its site of fixation (fertilizer industry, biological N_2 fixation) via agriculture (where it contributes to increased crop production) to the environment (atmosphere, groundwater and surface waters, and terrestrial natural ecosystems), where it contributes to a range of ecological effects. It shows the many different and also adverse effects of N lost from agriculture into the environment.

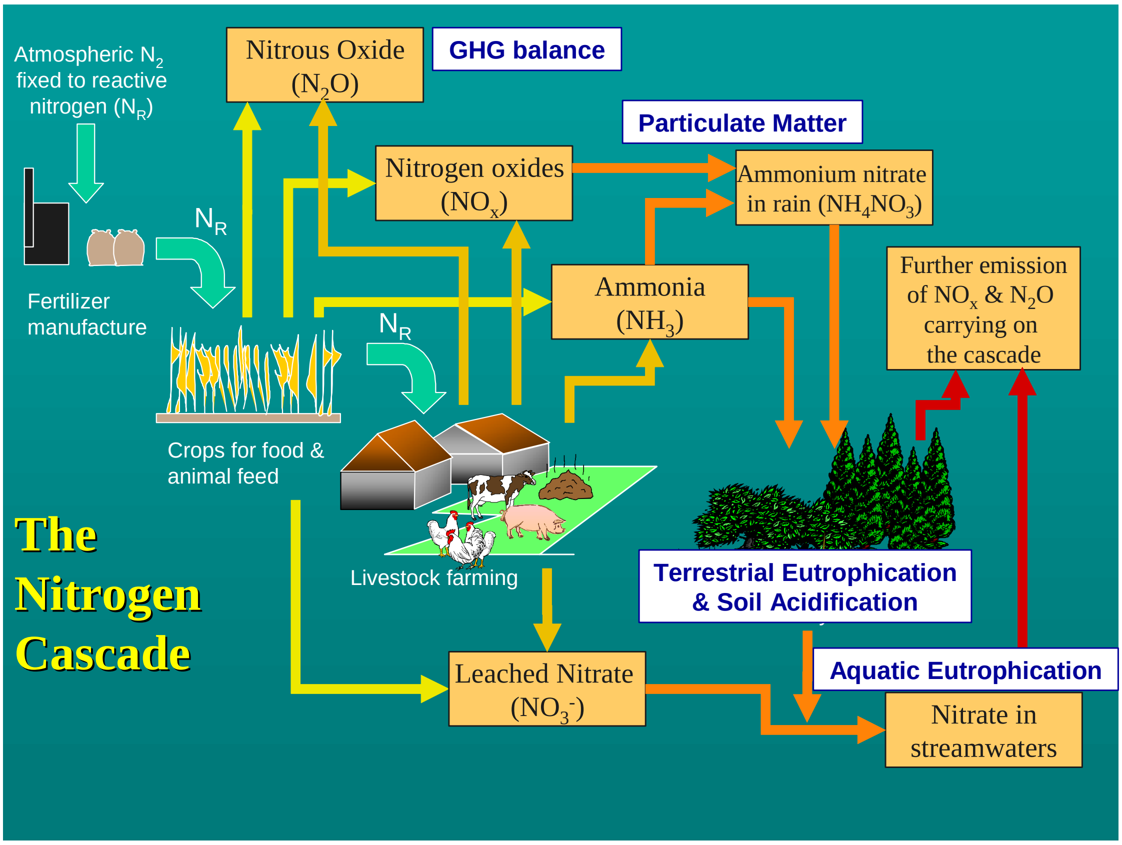

Figure 1. The flow of nitrogen in agriculture according to the ‘Nitrogen Cascade’ (after Galloway et al., 2002).

In response to the environmental side effects of the increasing N losses from agriculture, especially during the period 1960-1990, series of environmental policies and measures has been implemented in the European Union (EU) from the early 1990s onwards (e.g., Romstad et al., 1997; De Clercq et al., 2001). These policies and measures specifically aim at decreasing the emissions of NH_3 to the atmosphere, the leaching of NO_3^- to groundwater and surface waters, and the emissions of greenhouse gases, notably N_2O, CH_4 and CO_2 to the atmosphere.

Currently, the use of N from animal manure and fertilizers in agriculture and the emissions of N from agriculture to the environment are regulated directly or indirectly by four categories of EU policies and measures:

i. Air quality related Directives and climate change policy (Thematic Strategy on Air Pollution, NEC Directive, IPPC Directive, Air Quality Directive, Kyoto Protocol);
ii. Water Framework Directive, including the Nitrates Directive and Groundwater Directive;
iii. Common Agricultural Policy (CAP), and especially the reform of CAP, including Cross Compliance, Agri-Environmental and Rural Development Regulations; and
iv. Nature conservation legislation, the Birds and Habitats Directives

Further, the Expert Group on Ammonia Abatement of the United Nations Economic Committee for Europe (UNECE) promotes the use of the “Advisory Code of Good Agricultural Practice for Reducing Ammonia Emissions”. This UNECE Group works in close collaboration with members participating in EMEP, which is the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe. The expert group aims at improving the quality of ammonia emission inventories, comparing national inventories, projections and abatement strategies, and has developed the Guidance Document on Control Techniques for Preventing and Abating Emissions of Ammonia (http://www.unece.org/env/aa/welcome.htm).

There is increasing awareness that the large number of policies and measures might not be the most efficient way of decreasing N emissions. Moreover, there is increasing awareness that measures aiming at decreasing the emissions of one N species or one N loss pathway may increase the emission of another N species and/or another N loss pathway, when the policies and measures are not sufficiently integrated. The importance and relevance to consider the N cycle as a whole and in an integrated way for policy development was recently highlighted notably through the Nanjing declaration (http://www.initrogen.org/nanjing_declaration.0.html) on N management. Such an integrated approach has to address also phosphorus (P) and methane (CH_4) and carbon dioxide (CO_2) emissions, because the cycling and transformations of carbon (C) and phosphorus (P) are intimately linked to nitrogen.

In its Thematic Strategy on Air Pollution, the European Commission outlined the strategic approach towards cleaner air in Europe (CEC, 2005). To decrease the emissions of NH_3 into the air, the following approaches were identified:

1) The National Emission Ceiling Directive (NEC) (2000/1258/EC) will be reviewed in 2007 and emission reduction targets will be fixed that are needed to meet the environmental and health objectives of the Thematic Strategy on Air Pollution. In the framework of the revision of the emission ceilings under the NEC, integration of new objectives for eutrophication, acidification and for particulate matter are required. In response, new scenarios for NH_3 emission ceilings have been developed by the end of 2006 (Amann et al., 2006a, 2006b) as well as new guidelines for the national programs required under the Directive.
2) In the context of the general review of the Integrated Prevention and Pollution Control Directive (IPPC), a possible extension of the directive to include installations for intensive cattle rearing and a possible revision of the current thresholds for installations for the intensive rearing of pigs and poultry. The review of the IPPC is done parallel to the Thematic Strategy on Air Pollution. Evidently, this review will have consequences for the Thematic Strategy.
3) In the context of the Rural Development Regulation for the period 2007-2013, the Commission encourages Member States to make full use of the measures related to farm modernisation, meeting standards and agro-environment to tackle NH_3 emissions from agricultural sources.

During the preparation of the Thematic Strategy on Air Pollution, the desired integrated approach was only partly taken into account, because no tools were available to assess for example the effect of measures taken to decrease NH_3 emission on nitrate losses to the aquatic environment. Also, no assessments were available about the impact of measures taken in the framework of the Nitrates Directive to decrease nitrate emissions to water, on NH_3, N_2O and CH_4 emissions. It was felt that an integrated approach to the N-cycle should also consider the obligations set out by the Water Framework Directive (2000/60/EEC) to achieve a good status for all water by 2015. These obligations may have as implication the need to decrease N and P inputs into agriculture via fertilisers and animal manure beyond the levels currently required, to be able to tackle water pollution and euthrophication satisfactorily and to achieve good status of all water by 2015. Further, the impact of the reform of the Common Agricultural Policy (CAP) on N use in agriculture and N emissions from agriculture were not addressed in the preparation of the Thematic Strategy on Air Pollution. Hence, further studies were needed to be able to implement the integrated approach set out by the Thematic Strategy on Air Pollution.

This Report summarizes the results of the Ammonia Service Contract "Integrated measures in agriculture to reduce ammonia emissions", issued by the European Commission, DG-Environment (Contract 070501/2005/422822/MAR/C1). This Final Summary Report is based on four underlying reports (Annexes 1, 2, 3 and 4). The general objective of the Ammonia Service Contract is "*to have defined the most appropriate integrated and consistent actions to reduce various environmental impacts (notably water, air, climate change) from agriculture*" (see call for tender in Annex 5). Specifically, the objective is "*to have developed and applied a methodology allowing the assessment and quantification of the costs and the effects of various policies and measures aiming at reducing the impact of N losses from agriculture on water air pollution and climate change*". The Ammonia Service Contract was signed on 21

December 2005 (official starting date). The Interim Report was submitted by 21 September 2006, and the draft Final Report by 21 January 2007. The draft final report was discussed in Brussels on 14-15 February 2007, and thereafter revised. The Final Report was submitted by 21 March 2007, the revised Final Report by 31 May 2007.

This Final Summary Report is structured according to the five tasks of the Ammonia Service Contract. Chapter 2 describes the development and application of an integrated approach for the assessment of policies and measures in EU-25+. It starts with a summary of the modelling tool MITERRA-EUROPE that was developed for the purpose of this study and presents the results of integrated assessments of four scenarios (Task 1). Chapter 3 summarizes the main findings of the qualitative assessment of the main International and European policy instruments that have an influence on the use and emissions of N from agriculture. Emphasis in this assessment has been on synergistic and antagonistic effects, i.e., their potential to influence the emissions of other pollutants than the target pollutant of the policy instrument (Task 2). Chapter 4 describes the results of an in-depth assessment of most promising measures to decrease the emissions of N from agriculture in an integrated approach. In this assessment, use has been made of MITERRA-EUROPE, and the modelling tool CAPRI, which is commonly used for assessing the effects of changes in the Common Agricultural Policy on agriculture in the EU-25+ by the University of Bonn (Task 3). Chapter 5 summarizes the results of an Impact assessment of possible modifications of threshold values for the number of pigs and poultry per farm in the Integrated Prevention and Pollution Control Directive (IPCC Directive). It also discusses the effects of the possible inclusion of cattle rearing under the IPPC, in terms of number of farms and animals and in terms of decreases in the emissions of NH_3, N_2O and CH_4 (Task 4), using MITERRA-EUROPE and CAPRI. Chapter 6 briefly summarizes the interactions with the stakeholders during the execution of the Ammonia Service Contract (Stakeholder consultation, presentations and workshops; Task 5). Finally, chapter 7 discusses the overall conclusions of the Ammonia Service Contract.

The RAINS/GAINS model instruments, developed by the International Institute for Applied Systems Analysis (IIASA; www.iiasa.ac.at/rains/) are commonly employed by European Commission (DG ENV) to assess gaseous emissions into the atmosphere in the EU, and the effects of various (policy) scenarios on these emissions. As a result, an intensive link and cooperation has been set-up between the consortium of the Ammonia Service Contract and the IIASA team working on RAINS/GAINS so as to achieve consistency in the use of scenarios, emission factors and activity data between RAINS/GAINS, MITERRA-EUROPE and CAPRI. Basically, the gaseous N emission module of MITERRA-EUROPE is based on RAINS/GAINS, while the integrated approach implemented in MITERRA-EUROPE will be the basis for the extension of RAINS/GAINS to allow integrated assessments by RAINS/GAINS. However, the actual extension and implementation of new algorithms in RAINS/GAINS fall outside the scope of the Ammonia Service Contract. A special service contract between European Commission and IIASA covers the implementation of the results of the Ammonia Service Contract into RAINS/GAINS.

2. Development and application of an integrated approach

2.1. Introduction

This chapter summarizes the results of task 1 ‘Development and application of an integrated approach’ of the Ammonia Service Contract. The aims of this task have been described in the call for tender of the Ammonia Service Contract (see Annex 5), and can be summarized as follows:

To develop a simple, integrated model (including parameters and data), which allows to make bridges between on one hand the grid/country approach as developed in RAINS/GAINS and on the other hand the different zones as defined in the nitrate directive, and which has to be used subsequently for the assessment of

- *(i) the impact of measures/technologies aiming at reducing ammonia emissions as integrated in the RAINS/GAINS model on nitrate emissions and,*
- *(ii) the effects of the EU Nitrate Directive at 3 levels of implementation on* NH_3, N_2O *and* CH_4 *emissions.*

The simple, integrated model (including parameters and data), has to be made available to the European Commission.

In the call for tender of the Ammonia Service Contract, the European Commission emphasized that the approaches and results of the RAINS/GAINS model from IIASA must be taken as the starting point for the development and application of the simple, integrated model. This is so because the Commission has used the RAINS/GAINS model as a basis for the Thematic Strategy on Air Pollution, and the Commission will use RAINS/GAINS again for the review of the NEC ceilings. Therefore, it was considered important to ensure a good understanding and compatibility with the RAINS/GAINS model and to use and build bridges between the information, results and approaches of the RAINS/GAINS model and the simple integrated model that needs to be developed. This holds especially for the grid/country approach in RAINS/GAINS and the linked models (such as the atmospheric pollutant dispersion model EMEP) and on the other hand the different zones as defined in the Nitrates Directive. In addition, all the calculations have to be made at the EU-25+ level and have to be made for the same years (2000, 2010 and 2020) as those used in the RAINS/GAINS model.

The first paragraph of this chapter describes the development of the ‘simple integrated model MITERRA-EUROPE, and compares the results of MITERRA-EUROPE with those of RAINS/GAINS. Draft versions of MITERRA-EUROPE have been reviewed and discussed intensively with the partners and subcontractors of the consortium, and have led to the inclusions of various improvements and feedbacks in the model, relative to the versions presented in the Interim and Draft Final Reports. These changes have made the model more robust, but also less simple. The second paragraph describes the scenarios and the background of the scenarios, as defined in joint meetings in Brussels with representatives of the European Commission and the IIASA-team. The third paragraph presents results of the scenarios. Detail (background) information for this chapter can be found in Annex 1[5] of this Summary Report. MITERRA-EUROPE and its databases and scenarios have been made available through the website www.scammonia.wur.nl.

2.2 Development and application of MITERRA-EUROPE

The model MITERRA-EUROPE is derived from the existing models RAINS/GAINS (see Amann 2006a; 2006b; www.iiasa.ac.at/rains) and CAPRI (www.agp.uni-bonn.de/agpo/rsrch/capri/capri_e.htm), supplemented with additional modules and databases. MITERRA-EUROPE has four modules, namely:

- an input module with activity data and emission factors,
- a module with (packages of) measures to mitigate NH_3 emission and NO_3 leaching,
- a calculation module, and
- an output module.

The data-base is on regional level (NUTS-2 (Nomenclature of Territorial Units for Statistics, http://ec.europa.eu/eurostat/ramon/nuts/introduction_regions_en.html) and HMSUs (Homogenous Spatial Mapping Units)) and includes data about land use, crop types, crop yields for 2000, soil type, topography, livestock numbers, fertilizer N and P use, etc. The emission factors for NH_3, N_2O, NO_X and CH_4 are derived from the RAINS/GAINS model (Klimont and Brink, 2004), so as to maintain consistency in the assessments of gaseous emissions. The N_2O and CH_4 emission factors are based on IPCC (Mosier et al., 1998). Leaching fractions are based on an extensively literature review and calculated by MITERRA-EUROPE as function of topography, soil type, land use and climate, as reported in Annex 1.

The following N leaching pathways in soils are considered:

- Leaching from stored manure
- Runoff from agricultural soils
- Leaching below rooting depth in agricultural soils, dived into
    - Leaching to larger surface water via subsurface flow
    - Leaching to deep groundwater + small surface waters

For the leaching from stored manure, a distinction is made between solid manure (dung, with or without litter) and liquid manures (slurries), and between sealed and unsealed floors and between covered and uncovered storages. This results in a total of 8 leaching factors, ranging from 0-10% of the amount of N in the manure. Surface runoff is calculated from the applied amounts of fertilizer and manure, a maximal surface runoff, and a set of leaching factors.

$$LF_{\text{surface runoff}} = LF_{\text{surface runoff, max}} * f_{lu} * \text{MIN}\ (f_p, f_{rc}, f_s)$$

In which

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[5] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

- $LF_{surface\ runoff}$ = leaching fraction for runoff in % of the N applied via fertilizer and manure (including grazing);
- $LF_{surface\ runoff,\ max}$ the maximum leaching fraction for different slope classes;
- f_{lu} = reduction factor for land use or crop;
- f_p = reduction factor for precipitation;
- $f_{s\ =}$ reduction factor for soil type;
- $f_{rc\ =}$ reduction factor for depth to rock;

Leaching below rooting depth in agricultural soils is calculated from the N surplus and various correction factors. The leaching faction (LF, in % of the corrected N surplus) is calculated as:

$LF = LF_{soil\ type,\ max}$ * flu * MIN (fp, fr, ft, fc).

The corrected N surplus is defined as
Total N input - total N output – NH_3 $emission_{soil}$ – N_2O $emission_{soil}$ - surface runoff

where

- total N input = N input via fertilizer, manure, grazing, atmospheric deposition, and biological N fixation
- total N output = N removed via harvested crop
- NH_3 $emission_{soil}$ = NH_3 emission from soil applied fertilizer, manure, and grazing
- N_2O $emission_{soil}$ = N_2O emission from soil applied fertilizer, manure, grazing, atmospheric deposition and biological N fixation
- surface runoff = surface runoff of fertilizer and manure

Figure 2.1 provides an overview of the calculation procedure in MITERRA-EUROPE. The following calculations are carried out:

- The total N excretion is calculated for each NUTS-2 area, using the number of animals per animal category and the N excretion per animal category, and summed for all animals and animal categories;
- Part of the N is excreted during grazing and part of the N is excreted in housing systems and subsequently stored in manure storage systems;
- Gaseous N losses (NH_3, N_2, N_2O, NO_X) from housing and storage systems are calculated using housing system' and manure storage system' specific emission factors;
- Leaching from manure storage is calculated using manure storage system' specific leaching fractions;
- Corrections are made for manure that is treated or exported (and not used in agriculture);
- Gaseous N losses (NH_3, N_2, N_2O, NO_X) from soils are calculated, using source-specific emission factors (manure, grazing, fertilizer, atmospheric deposition, biological N fixation, mineralization);
- Surface runoff from the different N sources in soils is calculated with soil, hydrology and topography specific surface runoff fractions;

- The net N mineralization of drained peat soils is calculated, i.e. mineralization minus accumulation of N;
- The N uptake by the crop is calculated, as function of N input via N fertilizer, animal manure, crop residues, biological N fixation, atmospheric deposition, etc. and climatic conditions;
- The N removal via harvested crop and the amount of N in crop residues are calculated;
- The N surplus of the soil is calculated from the total N input, the N removal via crops, and gaseous N losses and surface runoff from the different N sources of soils (manure, grazing, fertilizer, atmospheric deposition, biological N fixation);
- The N surplus is divided in leaching below the rooting zone and denitrification, using leaching fractions as function of soil type and climate (leaching fraction = 1 – denitrification fraction).

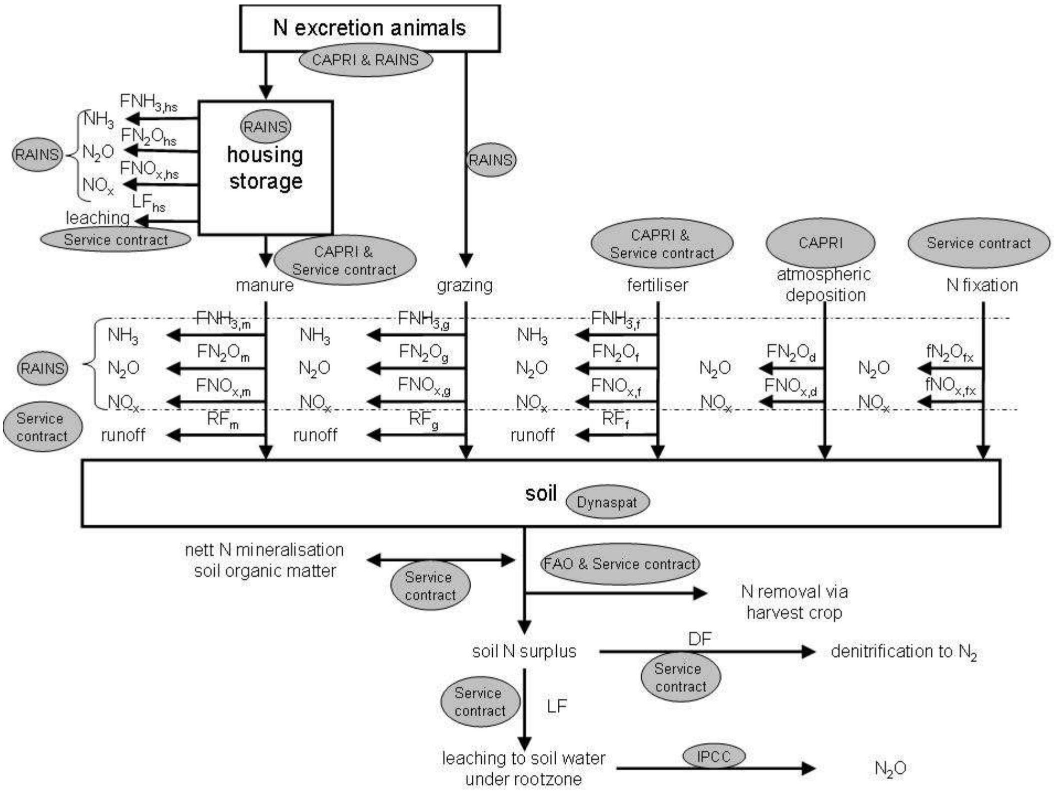

Figure 2.1. Calculation procedure of MITERRA-EUROPE. Arrows indicate N flows and the partitioning of the N flows over various N species emissions. The letter 'F' indicates the emission factors for gaseous emission, the letter 'L' indicates the leaching fractions, D the denitrification fraction, and R the runoff fraction. Grey circles indicate the origin (source) of information. The sources are RAINS, CAPRI, and CAPRI Dynaspat. Service contract means that the data/calculation is derived in the current project (see Annex 1).

The reference year is 2000. Measures that are implemented will start from the situation in 2000. MITERRA-EUROPE calculates emissions on NUTS-2 level, the level of Nitrate Vulnerable Zones (NVZ), country level and EU-25+ level. In total 27 countries are included. Croatia and Turkey are not included, because the required activity data and emission factors are only partly available. However, good progress has been made with collecting regional activity data in Turkey (Zwart et al., 2007).

The calculated NH_3 emissions with MITERRA-EUROPE are similar to those calculated with RAINS. This holds for emissions from animal manure and fertilizers (Figures 2.2 and 2.3). However, the estimates of MITERRA-EUROPE are slightly lower (on average 5%), because of a slight difference in the calculation procedure. In MITERRA-EUROPE, corrections are made for N losses via leaching (organic N, NH_4 and NO_3) and denitrification (NO_X, N_2O, and N_2) from animal manure storage systems. As a consequence, less manure N is applied to the soil and hence less NH_3 is emitted to the atmosphere (when using equal emission factors). There is ample evidence in literature for N losses via leaching and denitrification from animal manure storage systems, suggesting that RAINS/GAINS should also make such corrections. For mineral N fertilizer, the slight differences in NH_3 emission are due slight differences in the amount of applied N fertilizer, because of different data sources (see Annex 1[6]).

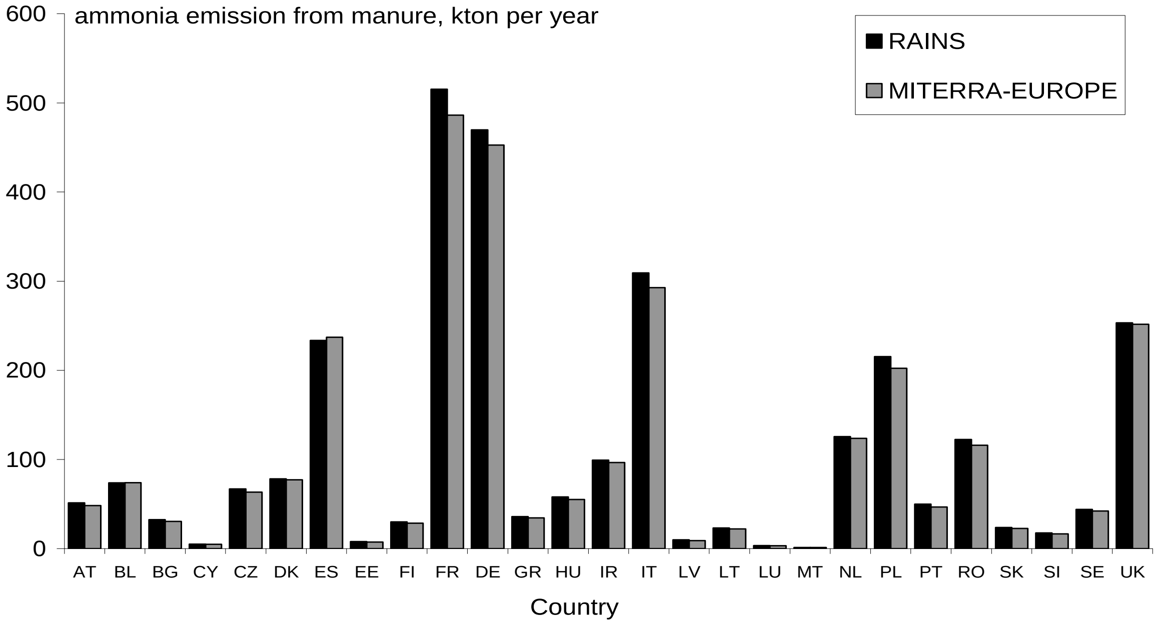

Figure 2.2. Ammonia emission from manure (housing, storage, and soil) in 2000 calculated with MITERRA-EUROPE and RAINS.

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[6] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

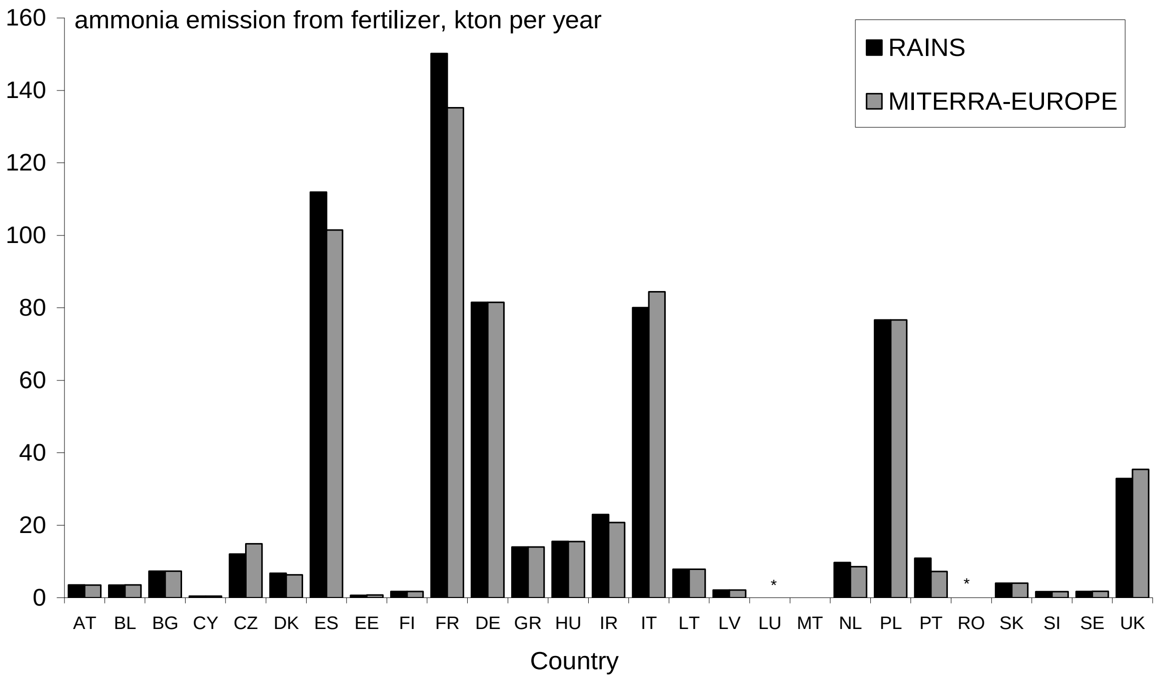

Figure 2.3. Ammonia emission from mineral N fertilizer in 2000 calculated with MITERRA-EUROPE and RAINS.

The calculated nitrate concentrations in the soil solution below the rooting zone have been compared with maps showing nitrate concentrations in groundwater and surface waters at monitoring stations in the EU-15 (Zwart et al., 2006). Such comparison is hampered by the fact that MITERRA-EUROPE does not account (yet) for N removal below the rooting zone in the soil, for N removal in surface waters, and for lateral transport of groundwater and surface waters. However, the comparisons indicate that the *patterns* of the nitrate concentrations according to MITERRA-EUROPE are rather similar to those of the groundwater monitoring stations in the EU-15.

Regional patterns and total amounts of the emissions of N_2O and CH_4 also compare reasonable well with literature data (e.g., Smith et al., 2004; Freibauer et al., 2003), but further checks are needed. MITERRA-EUROPE can also assess various scenarios and the affects of various emission abatement measures, and the results of these assessments compare well with the NH_3 emissions results generated by RAINS/GAINS.

Summarizing, the integrated approach of MITERRA-EUROPE allows reproducing the NH_3 emissions results generated by RAINS. It is also able to calculate the effects of measures and technologies that aim at reducing NH_3 emissions on N leaching, as well as the effects of measures that aim at reducing N leaching on NH_3, N_2O and CH_4 emissions. The measures can be implemented at EU-25+ level, at country level and at regional levels (NUTS-2 and/or Nitrate Vulnerable Zones, NVZs), and the results can be generated also at these different scales. Its functionality is high and it is programmed transparently and systematically according to ISO standards, but it is not as ‘simple’ as initially suggested. It has become available via www.scammonia.wur.nl.

2.3. Tracing uncertainties

MITERRA-EUROPE is derived from existing models (RAINS and CAPRI) and data bases (Eurostat and FAO), supplemented with a new method to calculate N transformations and loss pathways (mineralization, denitrification, N uptake by the crop, N leaching to groundwater, surface water, runoff) and effects of measures on these loss pathways. Moreover, a new method for the distribution of N fertilizer and manure over crops has been developed. A large number of data sources have been used and combined, and various assumptions had to be made.

Crop yield, area and number of animals are derived from data bases as Eurostat and FAO. The major uncertainties here are the areas and the yields of grassland. Different types of grassland use can be considered (intensively managed, extensively managed, rough grazing, natural). These types of grassland strongly differ in N input (fertilizer and manure) and yield. The treatise of these grasslands in the databases affects the mean estimated emissions per surface area (emissions per ha or per km^2). For example, considering rough grazing (very extensively managed grassland) as agricultural land, will ‘dilute’ the N emission expressed per ha agricultural land. This is especially the case for countries with a large area of rough grazing. A considerable amount of time was invested to arrive at reasonable estimates of the areas of grassland as discussed in Annex 1[7].

Crop yield and N content of the crop determine the N offtake via harvested products and thereby also the N surplus. It is well-known that the N content is dependent on the input of N, but this is mostly not included in models that calculate N balances at country level. In MITERRA-EUROPE a new approach has been included to account for the effect of N input on the N content, but there is clear scope for improvement of this approach. These data also affect the ‘balanced N fertilization’ concept. The ‘balanced N and P fertilization’ concepts in MITERRA-EUROPE are based on a straightforward interpretation of the definition of ‘balanced fertilization, i.e.,

Σ (input of available N from all sources) = Σ (N output via harvested crop + crop residues).

This concept was applied to all Member States equally. The amount of ‘available N’ was derived from the total N inputs of all sources and their availability fractions, while corrections were made for ‘unavoidable N losses’. The uptake efficiency for all crops was set at 25%, i.e. we assumed that the roots of the crops were not able to take up 25% of the calculated amount of available N. Sensitivity analyses were made, also to differentiate among various crops, and it turned out that this uptake efficiency factor is a sensitive factor. However, in this report only results are shown for an uptake efficiency of 25%.

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[7] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

The calculation of emissions of NH_3, N_2O, NO_X, and CH_4 and the effects of NH_3 emission abatement measures on these emissions are derived from the RAINS/GAINS model. Data about number of animals and N excretion are also derived from RAINS/GAINS. These data are mainly derived from consultation of experts from member states. This approach has the risk of introducing ‘personal bias’ and also inconsistency in approaches and data between Member States. Another point for discussion is the calculation of NH_3 emissions as function of total N excretion, while there is increasing empirical evidence that the NH_3 emission is related to the ammonium content (“TAN”) and the pH of in the manure. Further, low protein animal feeding and changing the ratio of easy-degradable carbohydrates to the crude protein content of the animal feed affects the total N excretion but also the TAN content and the pH of the animal manure. As a consequence, we believe that the effects of low protein animal feeding on NH_3 emissions may be underestimated by MITERRA-EUROPE.

The leaching module of MITERRA-EUROPE is developed on the basis of desk studies, data bases and expert knowledge. Data about soil properties, climate and crop were derived from the CAPRI Dynaspat project. All main mechanisms that affect leaching (N surplus, crop types, rainfall, soil types, slope) are included in the model. Leaching fractions have been derived at HSMU level, but are up-scaled and presented at NUTS II level only, because the N input via fertilizer and manure is derived at NUTS-2 level. The model considers only the processes on the soil surface and in the top soil. As a consequence, the calculated leaching losses may not represent the N concentrations in surface waters and groundwater.

The implementation of the nitrate leaching abatement measures was derived from information of Action Programmes of EU-15 Member States as summarized by Zwart et al. (2006). The measures and implementation of measures in countries had to be ‘translated’ to input for MITERRA-EUROPE, by which simplification had to be made. However, it is uncertain how measures are really implemented in practice. This suggests that consultation with experts from the various Member States is needed to verify the assumptions made in MITERRA-EUROPE.

Various preliminary assessments were made of sensitivities and uncertainties in MITERRA-EUROPE that relate to assumptions and data sources. The main factors have been identified. However, further sensitivity and uncertainty analyses are needed, using e.g., Monte Carlo simulations. This would allow identifying the most sensitive factors more precise and thereby would allow focusing further improvements of the model on these factors and assumptions. Monte Carlo methods suppose that the uncertainty of the model inputs, variables and parameters can be characterized by their distribution functions and their correlations. If so, simulations can be carried out with randomly selected set of values from the distributions functions to assess the variance of emission estimates (see Janssen et al., 1992; De Vries et al., 2003).

Summarizing, the uncertainty in the emission estimates is relatively large. The uncertainty in the animal numbers per Member State has been estimated at 5 to 10%, while the uncertainty in the N excretion per animal category per Member State is in the range of 10-20%. The uncertainties in the emission factors for NH_3, and especially NO, N_2O and N_2 and in the leaching factors for N and P are even larger than the uncertainty in the activity data (range 0-100%). The latter uncertainties mainly relate to the poor information about the actual manure management in practice (e.g., Menzi, 2002) and farm management in practice, the complex biogeochemical processes involved and the many emission controlling factors. The uncertainties in the final emission estimates increase in the order: EU-27 < Member States < NUTS-2 < Nitrate Vulnerable Zones (NVZ). Hence, estimates are most accurate at the EU-27 level and least accurate at level of NVZ. The uncertainty at the NVZ level mainly originates from the lack of suitable activity data (number of animals, fertilizer use, crops, etc.). The uncertainty range in the overall emission estimates can be assessed using Monte Carlo simulations, but these assessments have not been made yet, because of the time-consuming calculations with current model.

2.4. Description of the scenarios

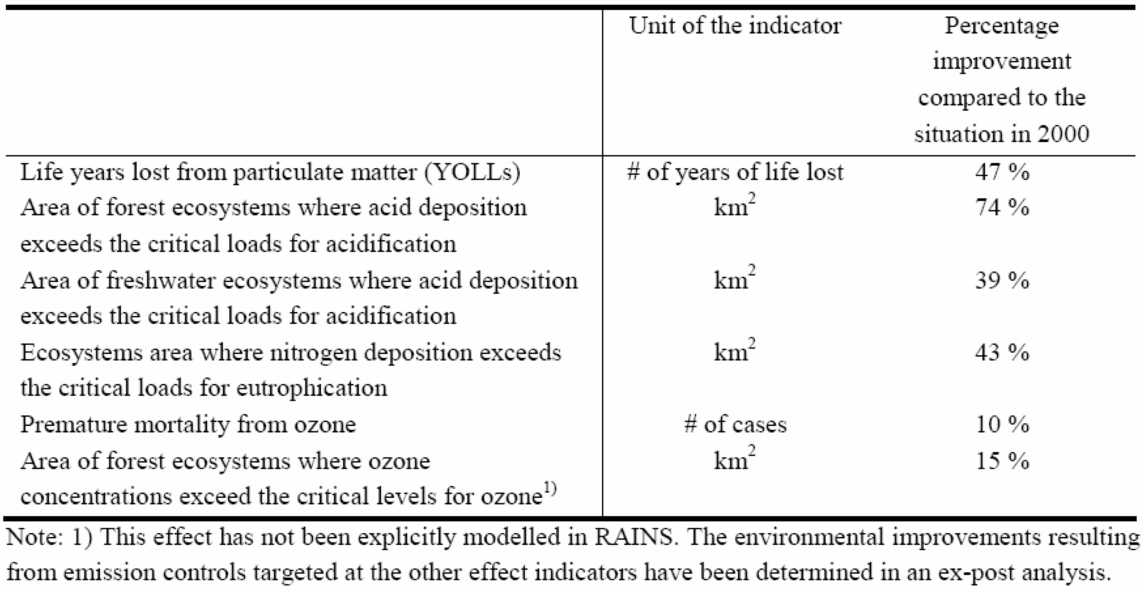
Scenarios are narratives of alternative future environments and/or development paths. Scenarios are like hypotheses of different futures, specifically designed to highlight the risks and opportunities involved in specific developments. Scenarios are not predictions; instead, scenarios are an approach to help manage the inherent uncertainties by examining several alternatives of how the future might unfold, and compare the potential consequences of different future contexts (Shearer, 2005).

Within the Ammonia Service Contract, various scenarios have been examined in terms of emissions of N (and CH_4 and P) from agriculture in EU-27 to the environment. Basically, one main scenario ("National Projections" baseline scenario for the revision of the NEC Directive, Amann, et al., 2006b), and various sub-scenarios or variants derived from the main scenario have been examined. However, for reasons of clarity and ease of writing, both the main scenario and the sub-scenarios are termed 'scenarios' in this report.

The 'National Projections baseline scenario' is described in detail by Amann et al., 2006b). It is based on bilateral consultations with Member States in 2006, agricultural developments derived from CAPRI, fertilizer projection by European Fertilizer Manufacturing Association (EFMA), and projections developed by the Food and Agricultural Organization (FAO). For the EU-25 as a whole, these national projections anticipate between 2000 and 2020 for cattle a 13 percent decline in livestock numbers (dairy cattle drops by about 18 percent and beef cattle by about 10 percent), for sheep a reduction by 10 percent and a four to five percent increase in the number of pigs and poultry. While these national projections reflect the latest governmental views of the individual Member States on the future agricultural development, there is no guarantee for Europe-wide consistency in terms of assumptions on economic development trends, and national as well EU-wide agricultural policies (Amann, et al., 2006b). This 'National Projections baseline scenario' for 2000-2020 is abbreviated in this Report to 'RAINS A 2000', 'RAINS A 2010' and 'RAINS A 2020'.

In its Thematic Strategy on Air Pollution (CEC, 2005), the European Commission has established environmental interim targets for the year 2020 to guide the ambition level of further measures to reduce the impacts of air pollution in Europe. The choice of the policy targets relied on the analyses conducted under the Clean Air For Europe (CAFE) program. The targets have been expressed in terms of relative improvements compared to the situation as it has been assessed for the year 2000 (Table 2.1). These targets have been used subsequently to identify cost-effective sets of emission abatement measures that would meet these objectives in 2020, using RAINS/GAINS and the National Projections baseline scenario. The National Projections baseline scenario (RAINS A 2020) with the cost-effective sets of emission abatement measures to meet the objectives of the Thematic Strategy on Air Pollution in 2020 is abbreviated in this Report as 'RAINS optimized 2020'. Underpinning for this scenario is described in Amann, et al. (2006b).

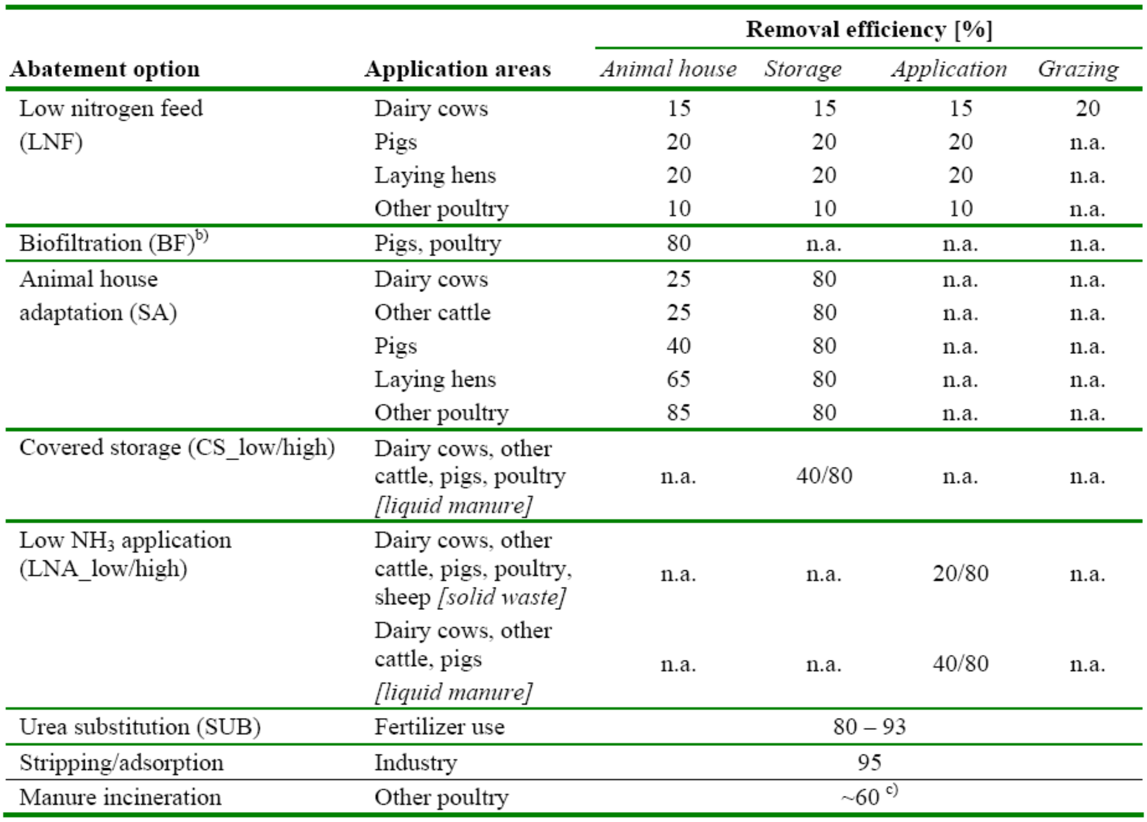
Table 2.1. Environmental targets of the Thematic Strategy on Air Pollution for the year 2020, expressed as percentage improvements relative to the situation in the year 2000 (after Amann et al., 2006b, p. 85).



	Unit of the indicator	Percentage improvement compared to the situation in 2000
Life years lost from particulate matter (YOLLs)	# of years of life lost	47 %
Area of forest ecosystems where acid deposition exceeds the critical loads for acidification	km^2	74 %
Area of freshwater ecosystems where acid deposition exceeds the critical loads for acidification	km^2	39 %
Ecosystems area where nitrogen deposition exceeds the critical loads for eutrophication	km^2	43 %
Premature mortality from ozone	# of cases	10 %
Area of forest ecosystems where ozone concentrations exceed the critical levels for ozone1)	km^2	15 %

Note: 1) This effect has not been explicitly modelled in RAINS. The environmental improvements resulting from emission controls targeted at the other effect indicators have been determined in an ex-post analysis.

Table 2.2. The removal efficiencies for ammonia for each of the NH_3 emission abatement option in RAINS (table 5.1 in Klimont & Brink, 2004).



		Removal efficiency [%]			
Abatement option	**Application areas**	*Animal house*	*Storage*	*Application*	*Grazing*
Low nitrogen feed (LNF)	Dairy cows	15	15	15	20
	Pigs	20	20	20	n.a.
	Laying hens	20	20	20	n.a.
	Other poultry	10	10	10	n.a.
Biofiltration (BF)b)	Pigs, poultry	80	n.a.	n.a.	n.a.
Animal house adaptation (SA)	Dairy cows	25	80	n.a.	n.a.
	Other cattle	25	80	n.a.	n.a.
	Pigs	40	80	n.a.	n.a.
	Laying hens	65	80	n.a.	n.a.
	Other poultry	85	80	n.a.	n.a.
Covered storage (CS_low/high)	Dairy cows, other cattle, pigs, poultry *[liquid manure]*	n.a.	40/80	n.a.	n.a.
Low NH_3 application (LNA_low/high)	Dairy cows, other cattle, pigs, poultry, sheep *[solid waste]*	n.a.	n.a.	20/80	n.a.
	Dairy cows, other cattle, pigs *[liquid manure]*	n.a.	n.a.	40/80	n.a.
Urea substitution (SUB)	Fertilizer use	80 – 93			
Stripping/adsorption	Industry	95			
Manure incineration	Other poultry	~60 c)			

The NH_3 emission abatement options in RAINS are shown in Table 2.2 (after Klimont and Brink, 2004). There are 8 options and the efficiency of the options in decreasing the NH_3 emission ranges from 10 to 80%. For some countries changes to these efficiencies are made as RAINS allows for country-specific reduction efficiencies. These efficiencies are then based on consultations with national experts during the work on the scenarios for Gothenburg Protocol (UNECE working group on Ammonia Abatement Technologies).

Table 2.3. Total ammonia (NH3) emissions in kton (1 kton = 1 Gg = 10^6 kg = 10^9 g) from all sources per country in the reference year 2000 (RAINS A 2000), and in the year 2020 following the National Projections baseline scenario (RAINS A 2020), the optimized scenario to meet the targets of the Thematic Strategy on Air Pollution for the year 2020 (RAINS opt.2000), and the 'maximum reduction scenario' (RAINS MRR 2020) (after Amann et al., 2006b).

Country	RAINS A 2000	RAINS A 2020	RAINS opt. 2020	RAINS MRR 2020
Austria	60	59	44	37
Belgium	85	81	76	73
Cyprus	7	7	6	5
Czech Rep.	84	74	64	62
Denmark	90	74	52	43
Estonia	9	10	9	7
Finland	35	26	24	21
France	702	636	474	399
Germany	601	449	391	374
Greece	54	46	36	34
Hungary	77	83	62	54
Ireland	125	91	79	77
Italy	425	384	327	272
Latvia	13	14	9	9
Lithuania	37	39	28	25
Luxembourg	6	6	5	5
Malta	2	3	3	2
Netherlands	149	138	123	117
Poland	317	316	245	208
Portugal	76	68	52	43
Slovakia	31	30	27	18
Slovenia	20	20	14	14
Spain	390	364	270	219
Sweden	55	50	50	37
UK	328	265	225	210
Bulgaria	70	65	65	nd
Romania	151	145	145	nd
EU-25	3777	3332	2694	2364
EU-27	3999	3543	2905	2365
Agriculture EU-25	3455	3072	2452	2123

Table 2.3 presents the NH_3 emissions per country in the EU-27 as well as the sum of EU-25, from all sources in the reference year 2000 and in 2020 following the National Projections baseline scenario, the optimized scenario to meet the targets of the Thematic Strategy on Air Pollution for the year 2020 and the 'maximum reduction scenario' according to the calculations of RANS/GAINS (Amann et al., 2006b). The 'maximum

reduction scenario' assumes the implementation of all NH_3 emissions abatement measures according to RAINS. For the EU-25, NH_3 emissions in 2020 have decreased by 445 kton (1 kton = 1 Gg = 10^6 kg = 10^9 g) relative to 2000 according to RAINS A 2020 and by 638 kton according to RAINS opt. 2020. The RAINS MRR 2020 gives a maximum decrease of 938 kton relative to the reference year 2000. Total NH_3 emissions in EU-25 in the year 2020 have to be in the range of 2700 kton to achieve the objectives of the Thematic Strategy on Air Pollution. For the EU-27, this will be about 2900 kton. The contribution of agriculture in the EU-25 ranges from 90 to 92% of the total emissions in the scenarios (Amann et al., 2006b).

It has been considered that the effects of the (full) implementation of the Nitrates Directive and the Water Framework Directive have not been taken into account (sufficiently) in the National Projections baseline scenario (RAINS A 2000-2020). Therefore, another set of scenarios was developed which consider the implementation of the Nitrates Directive (ND) and the Water Framework Directive (WFD). The measures of the Nitrate Directive were considered applicable only to the areas where action programs of the Nitrate Directive apply. These are also called Nitrate Vulnerable Zones (NVZs). The possible nitrate leaching abatement measures are derived from the Nitrates Directive (Code of Good Agricultural Practices) and are as follows:

- Balanced N fertilizer application based on soil analysis, expected N mineralisation, weather conditions, and crop demand;
- Maximum manure N application standard of 170 kg N per ha (except where a derogation applies);
- No fertilizer and manure application in winter and wet periods;
- Limitation to fertilizer application on steeply sloping grounds;
- Manure storage with minimum risk on runoff and seepage;
- Appropriate fertilizer and manure application techniques, including split application of nitrogen fertilizer;
- Prevention of leaching to water courses and riparian zones buffer zones;
- growing winter crops;

For implementation of the Water Framework Directive (WFD) it is assumed that the following measures apply:

- Full implementation of measures of the Nitrate Directive in Nitrate Vulnerable Zone;
- Equilibrium phosphorus (P) fertilization, to decrease the risk on P leaching to surface water. Equilibrium P fertilization means that P input via animal manure and fertilizer = P output via harvested crops. This measure is applied to all agricultural land in all Member States equally.

The decrease in N leaching following the implementation of the nitrate leaching abatement measures of the Nitrates Directive are calculated by MITERRA-EUROPE, on the basis of soil, crop, climate and management conditions. Hence, the decrease in N leaching is soil-, crop-, climate- and management-specific. The procedure for calculating the decrease in N leaching is described in detail in Annex 1[8].

The measures of the Nitrates Directive are applied only to all designated areas, where Action Programs apply, because the measures of the Nitrate Directive are only mandatory here. Some Member States have designated part or whole of the territory as Nitrate Vulnerable Zone (NVZ) and apply Action Programs to these NVZs, while other Member States have designated the whole territory, but not as NVZs, and consider the Action Program simply applicable to this territory. In this study, we simply assume that all designated areas have Action Programs and that the measures of the Nitrates Directive are applicable to these areas. For reasons of simplicity and to facilitate reading, we simply abbreviate these areas as NVZs. Within the EU-15, there are 34 different Action Programs for NVZs and these Action Programs are revised each four years, depending on the NO_3 concentrations in groundwater and surface waters and the eutrophication status of surface waters.

Table 2.4. Surface areas of NVZ in Member States of the EU-15 in 1999 and 2003, in 1000 km^2. Source: JRC, copied from Zwart et al. (2006)

Member State	**Total land area**	**NVZ area**		
		1999	**2003**	**% of total land area**
AT	83.9	83.9	83.9	100.0
BE	30.5	1.8	7.2	23.6
DE	357.0	357.0	357.0	100.0
DK	43.1	43.1	43.1	100.0
EL	132.0		14.0	10.6
ES	506.0	26.0	55.4	10.9
FI	338.1	338.1	338.1	100.0
FR	544.0	197.9	239.7	44.1
IE	69.8		69.8	100.0
IT	301.3	5.7	18.4	6.1
LU	2.6	2.6	2.6	100.0
NL	41.5	41.5	41.5	100.0
PT	91.9	0.2	0.3	0.3
SE	441.3	41.6	67.1	15.2
UK	244.0	5.8	79.9	32.7
EU	**3227.0**	**1145.2**	**1418.0**	**43.9**

An overview of the Action Programs for the reporting period 2000-2003 is presented by Zwart et al. (2006). These Action Programs have been studied to estimate the decrease in leaching in the reference year 2000, relative to the National Projections baseline

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[8] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

scenario (RAINS A 2000). This scenario is abbreviated as ND partial 2000. The surface areas of the NVZs in 2000 are presented in Table 2.4. For the year 2010, greater compliance to the Nitrates Directive was assumed and hence a greater decreases in N leaching losses (ND partial 2010), but the NVZ areas were considered to be similar to those in 2000 (Table 2.4). For the year 2020, we assumed full implementation of the Nitrates Directive (ND full 2020). Moreover, it was assumed that the area of NVZs had been extended, on the basis of information obtained from Joint Research Centre JRC (Table 2.5). In the ND full 2020 scenario a strict interpretation of balanced N fertilization was assumed, i.e., input of available N from all sources = N demand by the crop for optimal growth. If the input of available N exceeds the N demand by the crop, the N input via N fertilizers (according to the data statistics) was lowered till input of available N = N demand by the crop. In areas with high livestock density, also some manure N had to be removed to be able to satisfy the objective of balanced N fertilization. It was assumed that the excess manure was processed and that the N and P were removed to elsewhere, and/or that low-protein and low-phosphorus feeding of livestock decreased the amounts of excreted N and P to the level that all manure N and P can be applied to land within the limits of balanced fertilization.

Table 2.5. Expected surface areas of NVZ in countries of the EU-27 in 2020, in % of total Agricultural area. Source: JRC.

Country	Area NVZ, %	Country	Area NVZ, %
Austria	100	Italy	27
Belgium	61	Lithuania	100
Bulgaria	0	Luxembourg	100
Cyprus	?	Latvia	13
Czech	38	Malta	?
Germany	100	Netherlands	100
Denmark	100	Poland	2
Estonia	7	Portugal	10
Spain	21	Romania	0
Finland	100	Sweden	49
France	53	Slovenia	100
Greece	19	Slovakia	38
Hungary	45	United Kingdom	81
Ireland	99		

The Water Framework Directive (WFD) scenario (WFD 2020) assumed full implementation of the ND (in NVZs only) and equilibrium P fertilization on all agricultural land. To be able to achieve equilibrium P fertilization, the P input via P fertilizer was decreased till P input via fertilizer and animal manure = P demand by the crop. In areas with high livestock density, also some manure had to be removed to be able to satisfy the objective of equilibrium P fertilization. It was assumed that the excess manure was processed and that the N and P were removed to elsewhere. An overview of the scenarios analyzed in Task 1 of the Ammonia Service Contract in presented in Table 2.6.

Table 2.6 Overview of the scenarios analyzed in Task 1 of the Ammonia Service Contract

Scenarios	**Description**
1. RAINS A 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000 (Amann M. et al., 2006)
2. RAINS A 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010 (Amann M. et al., 2006)
3. RAINS A 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020 (Amann M. et al., 2006)
4. RAINS optimized 2020	National Projections baseline scenario for the revision of the NEC Directive, optimized to achieve the targets of the Thematic Strategy in 2020 (Amann M. et al., 2006)
5. ND partial 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000, including partial implementation of the measures in Nitrate Vulnerable Zones (Annex 1)
6. ND partial 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010, including partial implementation of the measures in Nitrate Vulnerable Zones (Annex 1)
7. ND full 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures in extended areas of Nitrate Vulnerable Zones (Annex 1).
8. WFD 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures in extended areas of Nitrate Vulnerable Zones plus (strict) equilibrium P fertilization on all agricultural land (Annex 1).

2.5. Effects of NH_3 emission abatement measures on nitrate leaching

In the call for tender of the Ammonia Service Contract, the Commission asked for an assessment of the effects of abatement technologies for ammonia emissions, as indicated in the UNECE Working Group guidelines and the RAINS/GAINS model, on nitrate leaching. Results of this assessment are shown in Figure 2.4, while further underpinning is provided in Chapter 3 and in Annex 2[9]. Clearly, the implementation of single abatement technologies for ammonia emissions can lead to slight increases in the leaching of nitrate and the emissions of N_2O, when no supplemental measures are taken to correct for the increased N contents of the animal manure. However, when the last (but not least) measure of the guidelines of the UNECE Working Group on Ammonia Abatement Technologies is taken into account, the increased leaching of nitrate and the emissions of N_2O will be prevented. This measure (number 8) deals with 'Nitrogen management; balancing manure nutrients with other fertilizers to crop requirements' and will lead to a correction in the application rates of animal manure and/or N fertilizer use (see also Annex 2). This measure is formulated rather general and not implemented in RAINS/GAINS, and hence not shown in Figure 2.4.

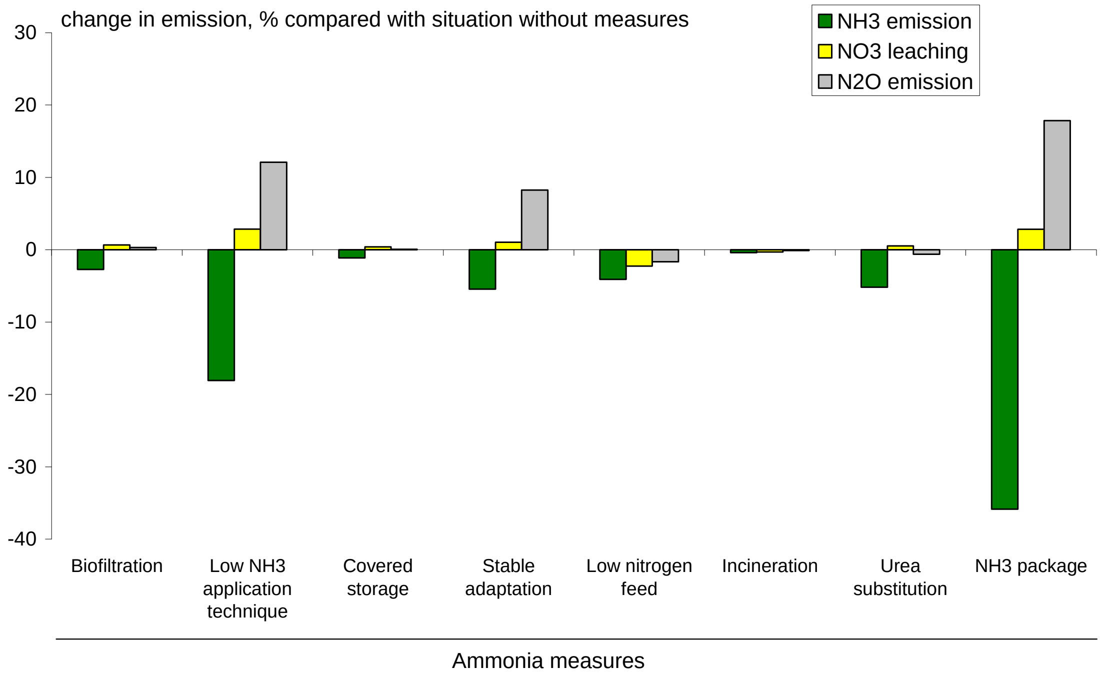

Figure 2.4. Potential effect of single measures and of a package of ammonia emission abatement measures on changes in the emissions of NH_3 and N_2O to the atmosphere and the leaching of nitrate to groundwater and surface waters in EU-27 for the year 2000. Results of calculations with MITERRA-EUROPE (see also text).

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[9] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen

As discussed further in Chapter 3, greater emphasis should be given to this measure/recommendation of the UNECE Working Group on Ammonia Abatement Technologies (‘Nitrogen management; balancing manure nutrients with other fertilizers to crop requirements’) so as to prevent the pollution swapping to the leaching of nitrate and the emissions of N_2O.

2.6. Effects of N leaching abatement measures on NH_3 emission

In the call for tender of the Ammonia Service Contract, the Commission also asked for an assessment of the effects of N leaching abatement measures on NH_3, N_2O and CH_4 emissions. Results of this assessment are shown in Figure 2.5. All measures taken to decrease N leaching have synergistic effects, i.e. the measures also decrease the emissions of NH_3 and/or N_2O. Effects on CH_4 emissions are absent, and therefore not shown in Figure 2.5. Balanced fertilization has the largest effects on N leaching losses and also the largest synergistic effects. The package of measures is also highly effective and has the potential of significant synergistic effects. However, the calculated synergistic effects of some N leaching abatement measures on emissions of NH_3 and/or N_2O may be somewhat too optimistic. This holds especially as regards the ban on manure spreading in autumn and winter.

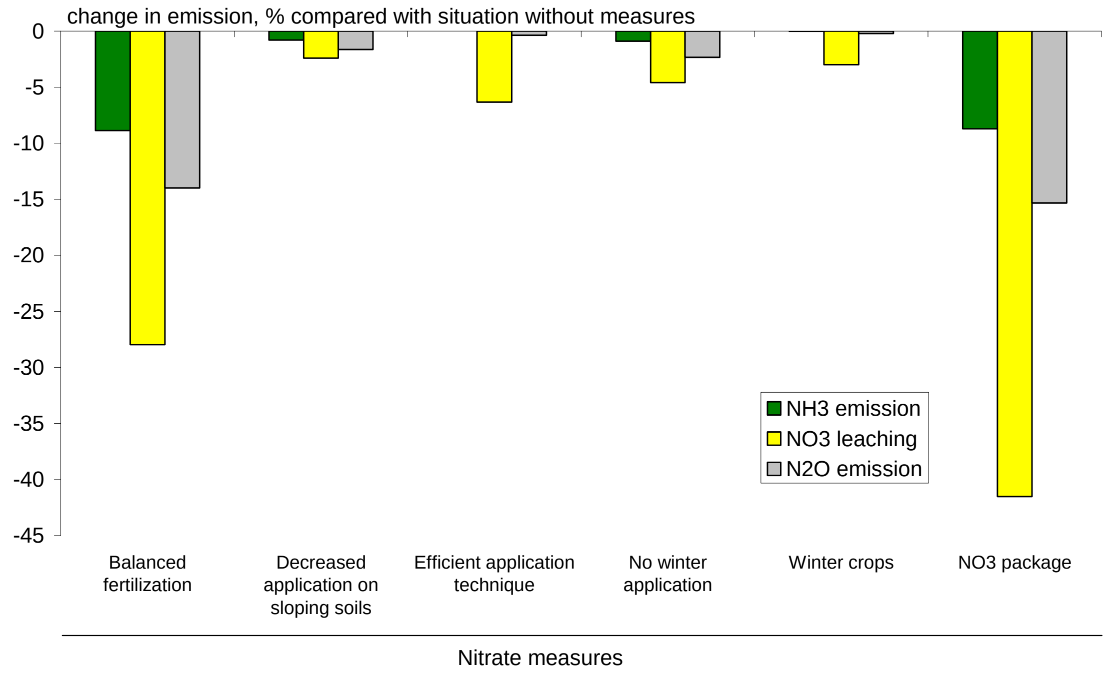

Figure 2.5. Potential effect of single measures and of a package of N leaching abatement measures on changes in the emissions of NH_3 and N_2O to the atmosphere and the leaching of nitrate to groundwater and surface waters in EU-27 for the year 2000. Results of calculations with MITERRA-EUROPE (see also text).

It has been observed in the UK (e.g. Williams et al., 2006) that a ban on manure spreading in autumn and winter, to decrease N leaching losses, may contribute to increased emissions of NH_3 because of the higher temperature and drier conditions in summer and spring compared to autumn and winter in most EU countries. In MITERRA-EUROPE, emissions of NH_3 are calculated following the procedure in RAINS, and are calculated independent of temperature and or rainfall. However, the overall effects do agree with the qualitative assessments made in Task 2 (Chapter 3).

2.7. Results of the 'RAINS' scenario analyses

The analysis presented in this paragraph explores the effects of the 'RAINS A' (National Projections baseline scenario for the revision of the NEC Directive; Amann, et al., 2006b) and the 'RAINS optimized 2020' (Optimized scenario to achieve in 2020 the environmental objectives of the Thematic Strategy on Air Pollution; Amann, et al., 2006b) on the emissions of NH_3, N_2O, NO_X and CH_4 and the leaching of N (see Table 2.6). Figure 2.5 provides an overview of the changes in the emissions of NH_3, N_2O and NO_X and the leaching of N in these scenarios. Decreases are larger in the emissions of NH_3 than the emissions of N_2O and NO_X and the leaching of N.

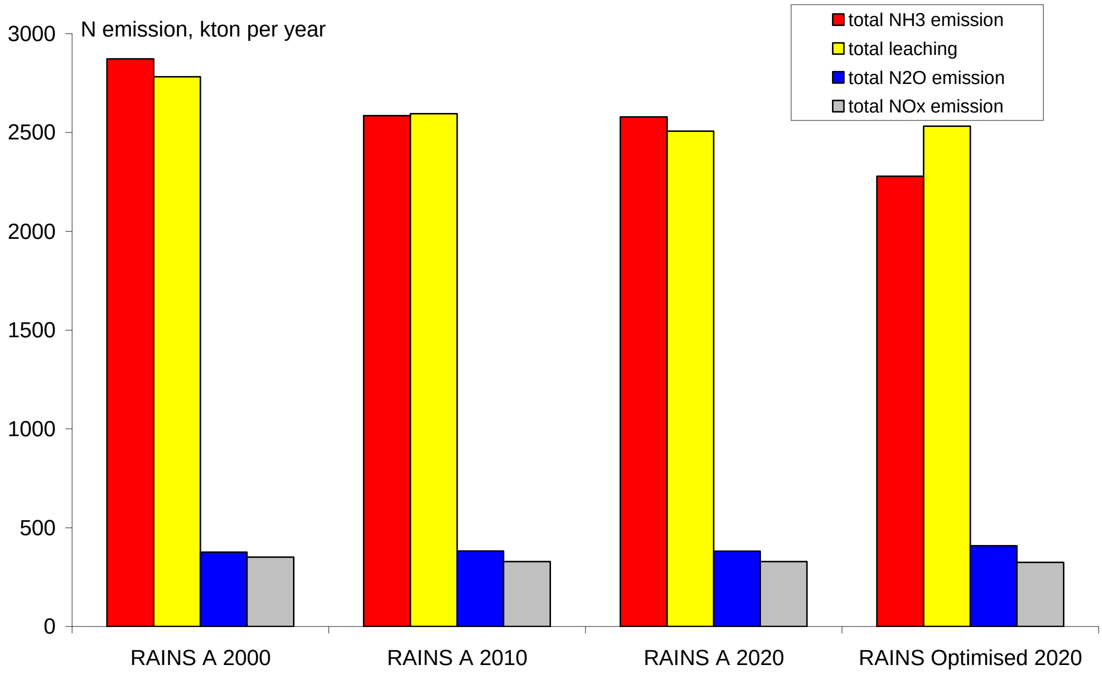

Figure 2.6. Gaseous N losses and N leaching losses from agriculture in the RAINS A 2000, 2010 and 2020 scenarios and in the RAINS optimized 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

Total NH_3 emissions in EU-27 are 10 and 21% lower in the year 2020 than in 2000, according to the RAINS A 2020 and RAINS optimized 2020 scenarios, respectively (Table 2.7). The NH_3 emissions levels for the RAINS A scenarios for 2000 and 2020, as calculated by MITERRA-EUROPE, compare well with the emission levels presented in Table 2.3 (after Amann et al., 2006b). However, the estimated decrease in NH_3 emissions in the RAINS optimized 2020 relative to the RAINS A 2000 scenario according to MITERRA-EUROPE is less (~21%) than the percentage decrease calculated by RAINS (~29%). The cause of this difference is related to the difference in basic scenario. Amann et al. (2006b) used the Current Legislation (CLE) scenario, while the NEC-NAT scenario (RAINS A) was used in this study. Further, the emission reduction percentage of Amann et al. (2006b) refers to all NH3 sources, while only agricultural sources are considered in our study. There are also differences between the two studies in the relative emission decreases per Member States, suggesting in part also different abatement strategies

Table 2.7. Ammonia emission in 2000 for EU-27 in kton NH_3 and the calculated changes relative to 2000 for the RAINS A 2010 and 2020 scenario and the RAINS optimized 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

Country	RAINS A 2000	RAINS A 2010	RAINS A 2020	RAINS optimised 2020
	kton NH3	% change compared to RAINS A 2000		
EU-27	3488	-10	-10	-21
Austria	52	-3	1	-22
Belgium	77	0	-3	-8
Bulgaria	38	-14	-11	-11
Cyprus	5	-12	-11	-28
Czech. Rep	78	-8	-10	-16
Denmark	83	-11	-15	-37
Estonia	8	7	11	1
Finland	30	-13	-24	-31
France	618	-8	-8	-26
Germany	534	-19	-22	-25
Greece	48	-14	-16	-31
Hungary	70	-4	7	-11
Ireland	117	-19	-27	-36
Italy	376	-5	-6	-14
Latvia	11	11	12	-14
Lithuania	30	-1	6	-12
Luxembourg	3	-6	-9	-29
Malta	1	63	75	75
Netherlands	132	-18	-6	-14
Poland	278	1	1	-8
Portugal	53	-9	-10	-27
Romania	135	-4	-4	-4
Slovakia	27	-3	1	-6
Slovenia	18	5	5	-29
Spain	336	-11	-9	-23
Sweden	44	-7	-6	-7
United Kingdom	285	-19	-18	-26

Differences between Member States in the relative changes are large. For some Member States (e.g. Malta), the results presented are at odd, likely because of inconsistency in statistical data. For the other Member States, decreases in NH_3 emissions in the RAINS optimized scenario range from ~0 (for Estonia) to 37% for Denmark. There is a high covariance in the relative changes in NH_3 emissions between the scenarios.

The RAINS A and RAINS Optimized 2020 scenarios also lead to a considerable decrease (~ 10%) in the leaching of N to groundwater and surface waters (Table 2.8) and in the emissions of CH_4 (Table 2.10), but to an increase in the emissions of N_2O (Table 2.9). The decreases in N leaching are mainly related to the decreases in N fertilizer use and N excretion by animals (because of fewer animals). Note that the mean decrease in N leaching for EU-27 is smaller in the RAINS Optimized 2020 scenario than in the RAINS 2020 scenario. The estimated mean increases in the emissions of N_2O in the RAINS optimized 2020 are related to the changes in the animal manure management (low-emission manure application techniques), and suggest ‘pollution swapping’ (see also Chapter 3).

Table 2.8. Total N leaching in 2000 for EU-27 in kton N and the calculated changes relative to 2000 for the RAINS A 2010 and 2020 scenario and the RAINS optimized 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

Country	RAINS A 2000	RAINS A 2010	RAINS A 2020	RAINS optimised 2020
	kton N	% change compared to RAINS A 2000		
EU-27	2782	-7	-10	-9
Austria	26	-14	-11	-10
Belgium	76	-1	-4	-4
Bulgaria	50	-13	-19	-19
Cyprus	4	6	5	6
Czech. Rep	87	10	-1	0
Denmark	85	-19	-26	-23
Estonia	6	18	-9	-7
Finland	14	-16	-27	-27
France	555	-7	-9	-7
Germany	438	-8	-14	-13
Greece	34	-21	-22	-21
Hungary	77	23	24	25
Ireland	86	-34	-47	-46
Italy	198	1	-2	0
Latvia	9	26	8	9
Lithuania	27	17	-3	0
Luxembourg	5	-9	-13	-12
Malta	1	79	88	88
Netherlands	137	-25	-6	-13
Poland	229	4	-2	-2
Portugal	25	2	2	6
Romania	78	6	-4	-4
Slovakia	13	35	13	14
Slovenia	8	3	-7	-2
Spain	205	-7	-8	-5
Sweden	14	-10	-10	-10
United Kingdom	298	-19	-20	-20

Again, differences between Member States in the relative changes are large. Changes in NO_3 leaching in the RAINS optimized 2020 scenario range from -46% (for Ireland) to +25% for Hungary (please note that Malta is excluded in this comparison). Clearly, there is a high covariance in the relative changes in leaching between the scenarios; relative decreases in NO_3 leaching in Ireland were also large in the RAINS A 2010 and RAINS A 2020 scenarios (Table 2.8), and relative increases in NO_3 leaching in Hungary were also large in the RAINS A 2010 and RAINS A 2020 scenarios.

Table 2.9. Nitrous oxide emission in 2000 for EU-27 in kton N_2O-N and the calculated changes relative to 2000 for the RAINS A 2010 and 2020 scenario and the RAINS optimized 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

Country	RAINS A 2000	RAINS A 2010	RAINS A 2020	RAINS optimised 2020
	kton N	% change compared to RAINS A 2000		
EU-27	377	2	1	8
Austria	5	-10	-11	5
Belgium	9	1	-1	3
Bulgaria	5	-6	0	0
Cyprus	0	29	32	44
Czech. Rep	8	18	22	27
Denmark	9	-2	-5	5
Estonia	1	15	14	20
Finland	5	-10	-21	-15
France	70	1	0	14
Germany	52	1	-3	-2
Greece	8	-10	-10	-3
Hungary	8	35	44	61
Ireland	16	-17	-24	-20
Italy	31	7	5	10
Latvia	1	18	18	39
Lithuania	3	12	18	31
Luxembourg	0	-6	-9	2
Malta	0	59	69	69
Netherlands	17	-11	1	-2
Poland	28	6	7	11
Portugal	5	16	16	39
Romania	12	14	20	20
Slovakia	2	29	32	37
Slovenia	1	1	0	20
Spain	33	5	5	19
Sweden	6	-2	-1	-1
United Kingdom	40	-6	-5	-1

Table 2.10. Methane emission in 2000 for EU-27 in kton CH_4, and the calculated changes relative to 2000 for the RAINS A 2010 and 2020 scenario and the RAINS optimized 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

Country	RAINS A 2000	RAINS A 2010	RAINS A 2020	RAINS optimised 2020
	kton CH4	% change compared to RAINS A 2000		
EU-27	9848	-8	-10	-10
Austria	181	-9	-10	-10
Belgium	249	-4	-9	-9
Bulgaria	89	-14	-14	-14
Cyprus	13	1	1	1
Czech. Rep	142	-7	-7	-7
Denmark	237	-3	-8	-8
Estonia	22	-1	-5	-5
Finland	90	-14	-36	-36
France	1558	-6	-6	-6
Germany	1372	-11	-17	-17
Greece	201	-2	-2	-1
Hungary	101	-5	8	8
Ireland	550	-17	-25	-26
Italy	986	-4	-7	-6
Latvia	30	0	-3	-3
Lithuania	81	-8	-10	-10
Luxembourg	13	-7	-15	-15
Malta	2	2	2	2
Netherlands	479	-12	-6	-6
Poland	517	-7	-10	-10
Portugal	176	9	3	3
Romania	339	-4	-4	-4
Slovakia	61	5	5	6
Slovenia	41	5	6	6
Spain	1028	-1	0	0
Sweden	142	-6	-6	-6
United Kingdom	1146	-23	-23	-23

2.8. Results of ‘Nitrates Directive’ scenarios

In the call for tender of the Ammonia Service Contract, the Commission asked for an assessment of three scenarios for the implementation of the Nitrates Directive, namely (i) partial, (ii) full compliance, and (iii) reinforced actions (to address phosphate pollution through balanced fertilization, with reference to the WFD by 2015 for each Member State). These scenarios have been described briefly in paragraph 2.4 and are summarized in Table 2.6. Full description of these scenarios and the underlying assumptions in the assessments can be found in Annex 1[10].

Table 2.11. Main N flows in agriculture in EU-27 in 2000, according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 scenario, the ND full 2020 scenario and the WFD 2020 scenario.

N source	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton N	% change compared to ND partial 2000		
Total N excretion	10372	-5	-5	-5
Applied N fertilizer	10748	-7	-14	-14
Applied manure N	4778	-3	-9	-19
N excreted during grazing	3560	-8	-8	-8
N deposition	1977	-4	-4	-4
Biological N fixation	823	0	0	0

Measures of the Nitrates Directive focus on decreasing N leaching, mainly through improved management of N fertilizer and animal manure. Various good agricultural practices have been defined. A prime measure is balanced fertilization, i.e., N application is adjusted to the N demand by the crop and the native N supply by soil and atmosphere. As a consequence, N input via N fertilizer and animal manure may have to be adjusted in some cases, depending on the degree of implementation. Indeed, Tables 2.11 and 2.12 show that the Nitrates Directive scenarios have a large effect on the N input via fertilizer and animal manure. It is assumed that this decrease in manure N is brought about by a combination of low-protein animal feeding and manure treatment (see below). The Water Framework Directive (WFD 2020) has in addition a large effect on the input of P fertilizer (Table 2.12).

Balanced N fertilization requires careful N management. The ‘balanced N fertilization’ concept in MITERRA-EUROPE is based on a straightforward interpretation of the definition of ‘balanced fertilization’, i.e., the total supply of plant-available N is equal to the total N demand of the crop at ‘optimum’ crop yield level. The N demand by the crop

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[10] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

is derived from the total N yield (total amount of N in harvested crop + crop residues) times an efficiency factor. In formula:

Σ *(input available N from all sources) =* Σ *{Upeff * (N output via harvested crop + crop residues)}.*

This concept was applied to all Member States equally. The amount of ‘available N’ was derived from the total N inputs of all sources, using N source specific correction factors for the fraction of total N that is available during the growing season. The uptake efficiency factor ‘Upeff’ was set at 1.25 for all crops in all Member States, i.e. we assumed that the roots of the crops were not able to take up 25% of the available N. The results of balanced fertilization assessments are very sensitive for Upeff. It may be argued that an Upeff of 1.25 is too high for some crops grown under optimal conditions, like grassland in western Europe. For crops with a shallow rooting system and short growing period (e.g. vegetables), an Upeff of 1.25 may be too low. We made various sensitivity analyses, but have chose quit arbitrarily for a uniform Upeff of 1.25. Clearly, further studies are needed to provide a possible differentiation and underpinning for the Upeff factor.

The N demand by the crop is derived from the calculated N output via harvested crop + crop residues, and these values are based on country specific yield data for the year 2000. The yield data for most crops have been derived from FAO data statistics. For grassland, yields have been derived from various assessments (see Annex 1[11]). We assumed that yields in EU-15 remained constant and that yields in the new Member States in 2020 have increased on average by 15% relative to the yield statistics of 2000. Hence, the concept of balanced fertilization has the target of ‘optimal’ crop yields (yields do not decrease). In practice though, balanced N fertilization may increase the risk of a crop yield decrease.

Implementation of Good Agricultural Practice, including balanced N fertilization according to the Nitrates Directive, in the ND full scenario suggests that the N fertilizer input will decrease by 14% and that the N input via applied animal manure will decrease by 9% relative to the reference year at EU-27 level. There are however large differences between Member States. Decreasing the N input via animal manure N was assumed to be realised through low-protein animal feeding (see Chapter 4) and/or manure treatment. Differences in the relative amounts of manure N that have to be removed differ greatly between Member States (Table 2.13). Please note that the results for Malta and Cyprus are at odd, due to inconsistency in the statistical data. Decreases are relatively large for The Netherlands and Belgium, which have a highly livestock density. However, relative decreases are also large for France, Portugal and Spain.

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[11] Annex 1: Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen

Table 2.12. Main P flows in agriculture in EU-27 in 2000 according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 scenario, the ND full 2020 scenario and the WFD 2020 scenario.

P source	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton P2O5	% change compared to ND partial 2000		
Total P excretion	4248	-6	-7	-7
Applied P fertilizer	3476	0	0	-64
Applied manure P	2769	-6	-14	-24
P excreted during grazing	1441	-9	-11	-11

Table 2.13. Relative surpluses of manure N, in per cent of the total N excretion per Member State, in the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario. These relative amounts of manure N have to be treated and/or removed via low-protein animal feeding (see text).

	Surplus amount of manure N, %		
Country	ND partial 2010	ND full 2020	WFD 2020
Austria	0	-2	-2
Belgium	0	-21	-24
Bulgaria	0	0	0
Cyprus	0	0	-43
Czech. Rep	0	0	0
Denmark	0	-6	-6
Estonia	0	0	0
Finland	-4	-10	-10
France	-3	-13	-17
Germany	-3	-7	-7
Greece	-1	-4	-4
Hungary	0	0	0
Ireland	0	0	0
Italy	0	-1	-11
Latvia	0	0	0
Lithuania	0	0	0
Luxembourg	0	0	0
Malta	0	0	-69
Netherlands	-8	-14	-24
Poland	0	0	-4
Portugal	0	0	-26
Romania	0	0	0
Slovakia	0	0	0
Slovenia	-1	-8	-9
Spain	0	0	-20
Sweden	0	0	0
United Kingdom	0	0	0

The WFD 2020 scenario project even further decreases in the amount of manure N and P to be applied to agricultural land (Tables 2.11, 2.12 and 2.13). This is because the WFD 2020 scenario includes ‘equilibrium P fertilization’, in addition to balanced N fertilization. The results indicate that applying this concept will decrease the fertilizer P input by 64%. The input via applied animal manure will decrease by ~24% (Table 2.12). Again, it is assumed that this decrease in animal manure P will be realized through a combination of low-P animal feeding and manure treatment.

The changes in N input and the application of Good agricultural practices and balanced fertilization have a large effect on the leaching of N from agriculture (Table 2.14). The mean decrease in N leaching in the ND full and WFD scenarios is ~31%.

Table 2.14. Total N leaching losses from agriculture to groundwater and surface waters in EU-27 according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 scenario, the ND full 2020 scenario and the WFD 2020 scenario.

Leaching pathway	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton N	% change compared to ND partial 2000		
Manure storage	231	-9	-31	-31
Surface runoff	733	-5	-10	-13
Small surface water and groundwater	1511	-13	-32	-36
Large surface water	103	-17	-36	-40
Total	2575	-11	-26	-29

The implementation of Good Agricultural Practices and balanced fertilization and the decreases in N input via animal manure and fertilizer in the ND full 2020 and WFD 2020 scenarios have also a strong effect on the emissions of NH_3, N_2O, NO_X and CH_4 to the atmosphere. Figure 2.7 provides an overview of the changes in the emissions of NH_3, N_2O and NO_X and the total leaching of N in these scenarios. Decreases are equally large for NH_3 and N_2O emissions and the leaching of N. Decreases in emissions and leaching are large between ND partial 2000 and ND full 2020, but changes ND full 2020 and WFD 2020 are small. The difference between the ND full 2020 and WFD 2020 scenarios is mainly a difference in fertilizer P input (and not in N input; see Table 2.12). Therefore, N emissions do not change (much).

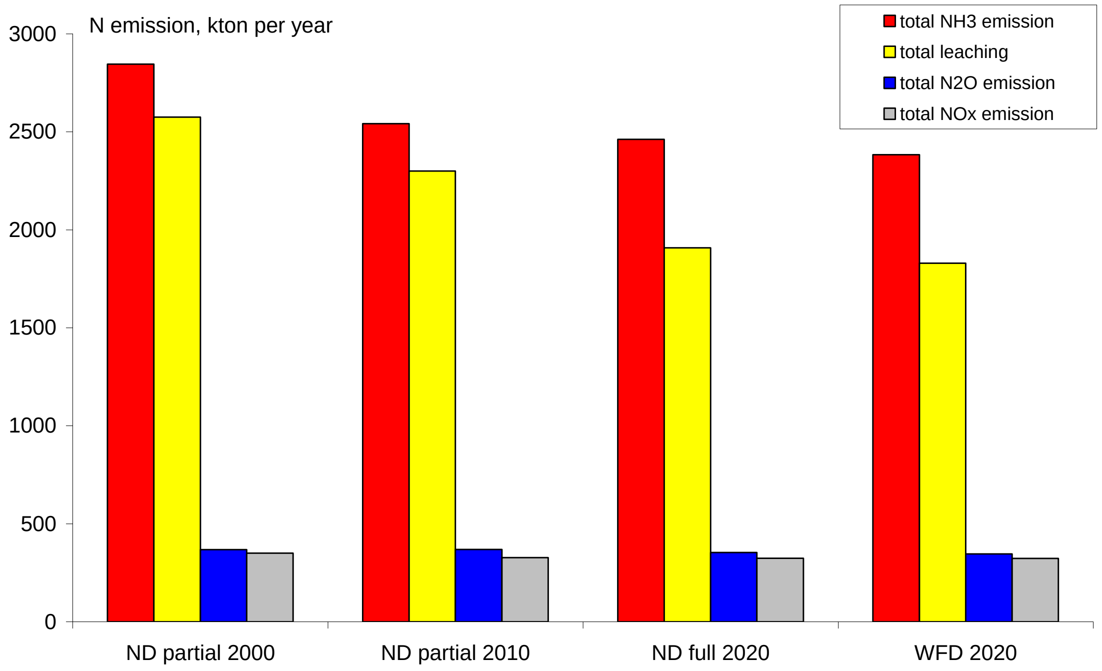

Figure 2.7. Gaseous N losses and N leaching losses from agriculture in the ND partial 2000 and 2010 scenarios, the ND full 2020 scenario and in WFD 2020 scenario. For explanation of scenarios see Table 2.6 and paragraph 2.4.

The emissions of NH_3, N_2O and NO_X and the leaching of N are similar in the ND partial 2000 scenario and in the RAINS A scenario (compare Tables 2.7-2.9 with Table 2.15-2.17). Hence, the reference 'ND partial 2000' in this paragraph is similar to the reference 'RAINS A 2000' in paragraph 2.7. Emissions of NH_3 in the ND full 2020 scenario are 14% lower compared to the reference year 2000, and in the WFD 2020 scenarios 16%. This projected decrease is half of the calculated decrease between RAINS optimized 2020 and RAINS A 2000 (Table 2.7). The RAINS optimized 2020 scenario is meant to achieve the objectives of the Thematic Strategy on Air Pollution (TSAP) in 2020. The results of the ND full 2020 scenario suggest that half of the targets of the TSAP for NH_3 emissions may be achieved through full implementation of the Nitrates Directive. However, full implementation of the ND with strict interpretation of Good Agricultural Practices and balanced fertilization may have significant effects for animal agriculture, as follows from the changes in the applied amounts of animal manure N and P (Tables 2.11 and 2.12).

Table 2.15. Ammonia emission in 2000 for EU-27 in kton NH_3, according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario.

Country	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton NH3	% change compared to ND partial 2000		
EU-27	3455	-11	-14	-16
Austria	51	-3	0	0
Belgium	76	0	-15	-17
Bulgaria	38	-14	-11	-11
Cyprus	5	-11	-10	-39
Czech. Rep	78	-9	-10	-10
Denmark	82	-11	-17	-17
Estonia	8	7	11	11
Finland	30	-15	-29	-29
France	607	-10	-16	-19
Germany	525	-20	-26	-26
Greece	47	-15	-19	-19
Hungary	71	-5	3	3
Ireland	114	-18	-27	-27
Italy	376	-5	-9	-14
Latvia	11	11	12	12
Lithuania	30	-2	6	6
Luxembourg	3	-6	-10	-10
Malta	1	63	75	-10
Netherlands	132	-20	-14	-20
Poland	278	1	1	0
Portugal	53	-8	-10	-26
Romania	135	-4	-4	-4
Slovakia	27	-3	1	1
Slovenia	18	4	0	-1
Spain	336	-10	-11	-20
Sweden	43	-7	-6	-6
United Kingdom	282	-19	-19	-19

Table 2.16. Nitrogen leaching losses in 2000 for EU-27 in kton N, according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario.

Country	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton N	% change compared to ND partial 2000		
EU-27	2575	-11	-26	-29
Austria	24	-27	-41	-41
Belgium	69	-5	-41	-44
Bulgaria	49	-13	-19	-19
Cyprus	4	6	5	-30
Czech. Rep	85	7	-10	-10
Denmark	65	-20	-37	-37
Estonia	5	21	-11	-11
Finland	10	-27	-51	-51
France	512	-12	-27	-30
Germany	367	-20	-42	-42
Greece	33	-23	-30	-30
Hungary	76	17	3	3
Ireland	79	-35	-57	-57
Italy	194	0	-18	-25
Latvia	9	29	8	8
Lithuania	26	15	-15	-15
Luxembourg	4	-15	-33	-33
Malta	1	79	88	-16
Netherlands	113	-35	-39	-49
Poland	227	4	-2	-4
Portugal	25	2	-4	-26
Romania	77	7	-4	-4
Slovakia	13	34	2	2
Slovenia	8	-10	-42	-43
Spain	202	-9	-17	-30
Sweden	13	-16	-29	-29
United Kingdom	284	-20	-36	-36

As expected, N leaching losses decrease greatly in the ND full 2020 and the WFD 2020 scenarios relative to the ND partial 2000 reference year (Table 2.16). Leaching losses decrease on average at EU-27 level by 26 and 29%, respectively, but there are large differences between Member States. The decrease in N leaching in the ND full 2020 scenario is much stronger than the projected decrease in N leaching according to the RAINS optimized 2020 scenario (Table 2.8), while the latter scenario had a much stronger effect on decreasing NH_3 emissions.

Emissions of N_2O (Table 2.17), CH_4 (Table 2.18) and NO_X (not shown) also decreased in the ND full 2020 and the WFD 2020 scenarios relative to the ND partial 2000 reference scenario. Mean decreases at EU-27 level were in the range of 4 to10% for N_2O, CH_4 and NO_X.

Table 2.17. Nitrous oxide emission in 2000 for EU-27 in kton N_2O-N, according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario.

Country	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton N	% change compared to ND partial 2000		
EU-27	368	0	-4	-6
Austria	5	-11	-14	-14
Belgium	9	0	-17	-19
Bulgaria	5	-6	0	0
Cyprus	0	29	32	0
Czech. Rep	8	17	19	19
Denmark	9	-1	-8	-8
Estonia	1	15	14	14
Finland	4	-14	-31	-31
France	67	-1	-7	-9
Germany	49	-2	-12	-12
Greece	8	-10	-13	-13
Hungary	8	32	34	34
Ireland	15	-17	-26	-26
Italy	31	7	1	-4
Latvia	1	18	18	18
Lithuania	3	12	16	16
Luxembourg	0	-8	-15	-15
Malta	0	59	69	-5
Netherlands	17	-16	-13	-20
Poland	28	6	6	5
Portugal	4	15	13	0
Romania	12	14	20	20
Slovakia	2	29	31	31
Slovenia	1	-4	-10	-10
Spain	33	4	2	-6
Sweden	5	-3	-5	-5
United Kingdom	40	-6	-9	-9

It must be noted that the measures of the Nitrates Directive are only taken in the so-called Nitrate Vulnerable Zones (NVZ). In countries in which only part of the area is NVZ, measures only affect the use of fertilizer and manure and the related N emissions in these NVZ. E.g. in Belgium, the amount of applied fertilizer in NVZ decreases with 35% in the period 2000 – 2020 (after full ND implementation), whereas in non-NVZ the applied amount of N fertilizer decreases only by 11% (Velthof et al., 2007). It must be noted that measures of ND may result in export of manure from NVZ to non-NVZ. This decreases N emissions in the NVZ, but may increase emissions in non-NVZ if the total amount of applied N in the non-NVZ is not adjusted to the additional manure. This is also a mechanism of pollution swapping: the emission in NVZ decreases but that in non-NVZ increases (see also Chapter 3). The risk of this type of pollution swapping can be minimized when in the non-NVZ balanced N fertilization is applied.

Table 2.18. Methane emission in 2000 for EU-27 in kton CH_4*, according to the ND partial 2000 scenario, and the calculated potential changes relative to 2000 for the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario.*

Country	ND partial 2000	ND partial 2010	ND full 2020	WFD 2020
	kton CH4	% change compared to ND partial 2000		
EU-27	9848	-8	-10	-10
Austria	181	-9	-10	-10
Belgium	249	-4	-9	-9
Bulgaria	89	-14	-14	-14
Cyprus	13	1	1	1
Czech. Rep	142	-7	-7	-7
Denmark	237	-3	-8	-8
Estonia	22	-1	-5	-5
Finland	90	-14	-36	-36
France	1558	-6	-6	-6
Germany	1372	-11	-17	-17
Greece	201	-2	-2	-2
Hungary	101	-5	8	8
Ireland	550	-17	-25	-25
Italy	986	-4	-7	-7
Latvia	30	0	-3	-3
Lithuania	81	-8	-10	-10
Luxembourg	13	-7	-15	-15
Malta	2	2	2	2
Netherlands	479	-12	-6	-6
Poland	517	-7	-10	-10
Portugal	176	9	3	3
Romania	339	-4	-4	-4
Slovakia	61	5	5	5
Slovenia	41	5	6	6
Spain	1028	-1	0	0
Sweden	142	-6	-6	-6
United Kingdom	1146	-23	-23	-23

In the assessments of the effects of full implementation of the Nitrates Directive, it is considered that some countries have a derogation, which allows to apply more than 170 kg N per ha as manure on grassland (see Annex of Velthof., 2007). A derogation may have effects on N emissions for countries and NUTS-2 regions with a high livestock density, such as the Netherlands, Belgium, Denmark, Germany and parts of France, Italy and Spain. The Netherlands is a case in point in this respect as it has been granted a derogation to apply 250 kg N from livestock manure on intensive grassland-based cattle farms. To estimate the possible effects of a derogation on emissions, an analysis was made for the Netherlands, by setting the maximum application of manure at 170 kg N per ha (i.e. there is no derogation). In the current scenario with full implementation of the Nitrates Directive in 2020 with a derogation, the average manure application (including manure from grazing animals) in the Netherlands is 207 kg N per ha agricultural land. Decreasing this amount to 170 kg N per ha (through manure treatment; i.e. the number of animals does not change and the manure is still produced, but not applied to the soil) decreases total NH_3 emissions in the Netherlands by about 5% compared to the ND full 2020 scenario. Decreasing the maximum manure application to 170 kg N per ha by decreasing the N excretion (through lowering of the number of animals) decreases the NH_3 emission by approximately 15%. The latter decrease is much larger because the NH_3 emission from housing and storage has also decreased. The effect of deleting the possibility of derogation on N leaching and N_2O emission are smaller than the effects on NH_3 emissions in the ND full 2020 scenario because a strict implementation of balanced fertilization was assumed. This means that a decrease in applied manure is counterbalanced by an increase in applied fertilizer, to avoid sub optimal fertilization. The leaching of fertilizer N is somewhat lower than that of manure N, because the N in fertilizer has a higher plant-availability efficiency factor.

Figure 2.8 – 2.11 show for the reference year 2000 (ND partial 2000) the calculated regional distributions in EU-27 of manure application rate, N surpluses, N leaching and N_2O emissions. These maps show similar patters of N pressures through manure N application and N surpluses, and N emissions to the environment.

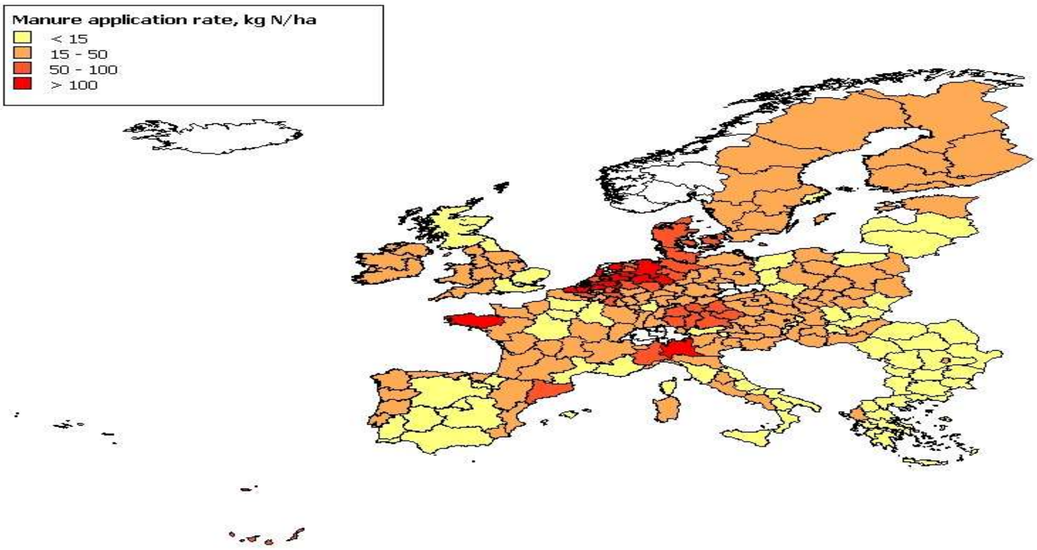

Figure 2.8. Regional distribution of manure applications at NUTS-2 level in 2000.

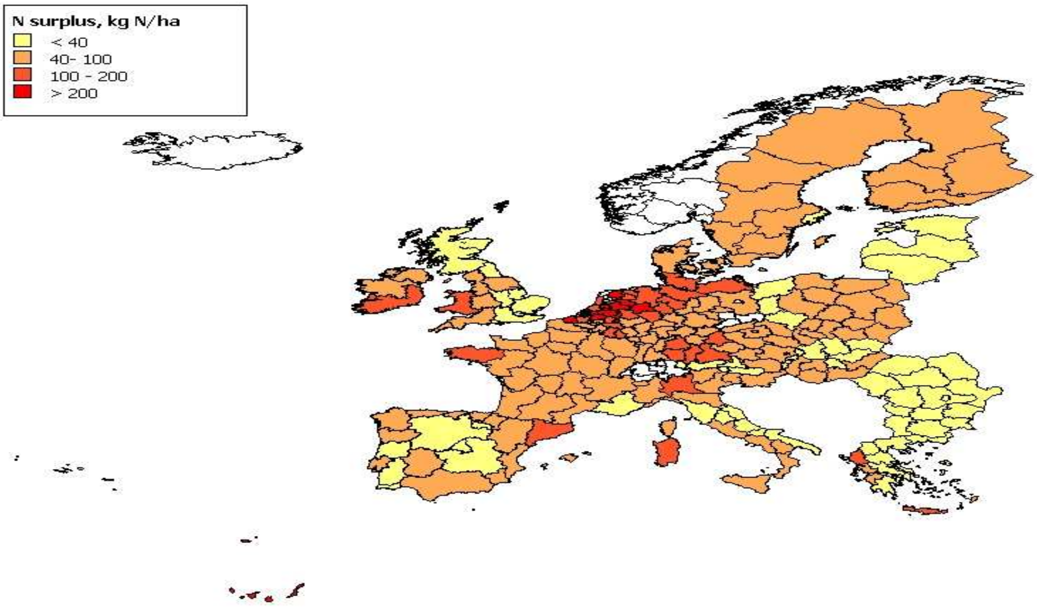

Figure 2.9. Regional distribution of N surpluses at NUTS-2 level in 2000.

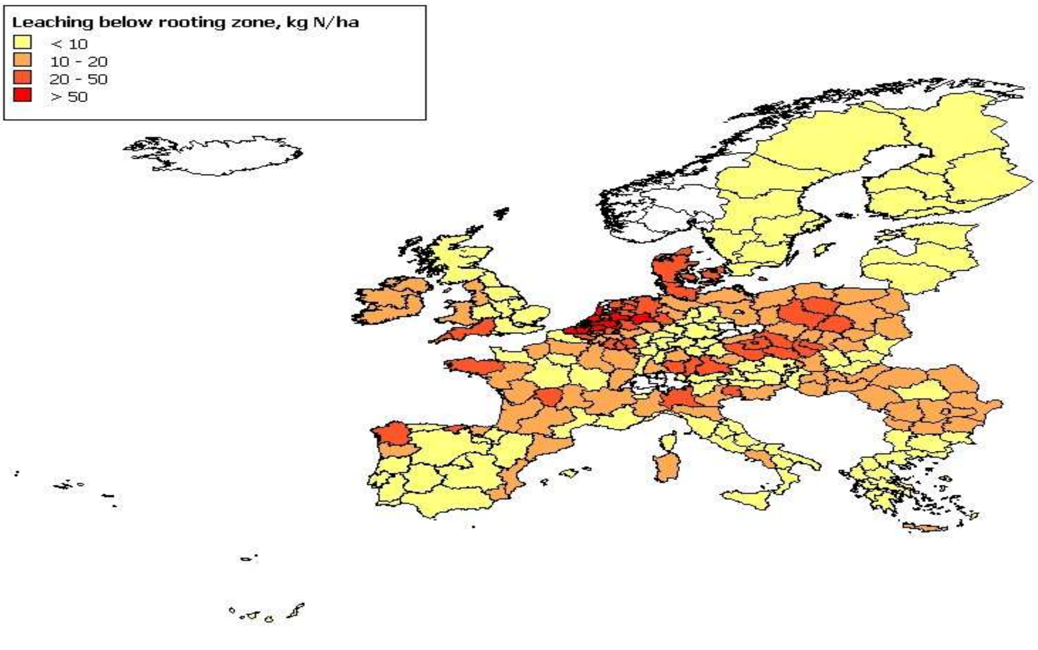

Figure 2.10. Regional distribution of N leaching losses at NUTS-2 level in 2000.

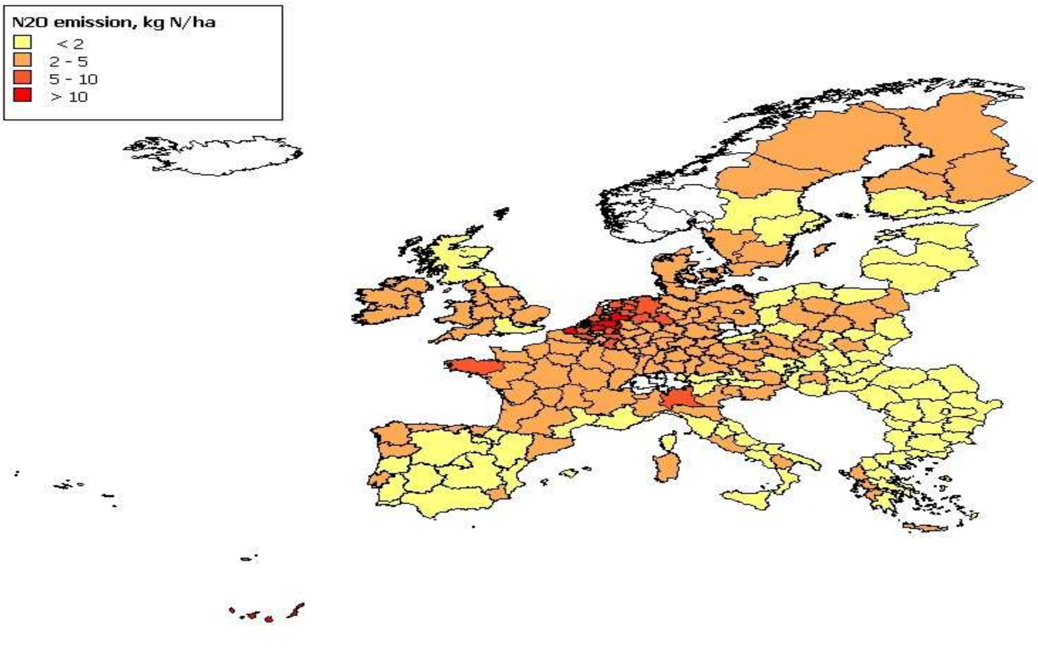

Figure 2.11. Regional distribution of nitrous oxide emissions at NUTS-2 level in 2000.

2.9. Conclusions and recommendations

With MITERRA-EUROPE, possible synergistic and antagonistic effects of the measures of the UNECE Working Group on Ammonia Abatement Technologies and of the Nitrates Directive and Water Framework Directive can be assessed in an integrated manner. Further, changes in the emissions of NH_3, N_2O, NO_x, and CH_4 to the atmosphere, and leaching of N to groundwater and surface waters, and on the P balance can be assessed on the EU-27 level, country level, and regional level (both NUTS-2 and Nitrate Vulnerable Zones). The effects of policies and measures can be quantitatively assessed and both ancillary benefits and trade offs of policies and measures can be identified. Hence, MITERRA-EUROPE can be used to fine-tune policy instruments and measures aimed at decreasing the emissions of N species from agriculture.

The results of the scenario analyses lead to the following conclusions:

- The NH_3 emission abatement measures of the UNECE Working Group on Ammonia Abatement Technologies are effective in decreasing NH_3 emission but some of these measures increase the emissions of N_2O and the leaching of N. The measures 'low-protein animal feeding' and 'N management' have the potential of inducing synergistic effects, i.e., decreasing all N losses simultaneously. When the NH_3 emission abatement measures are implemented as integrated package and emphasis is given to 'overall N management', the possible antagonistic effects may disappear (see also Chapter 3).
- The nitrate leaching abatement measures of the Nitrates Directive are effective in decreasing N leaching, but some have the potential to increase the emissions of NH_3 according literature. Assessments made by MITERRA-EUROPE indicate indeed that the measures of the Nitrates Directive are effective in decreasing N leaching and that the antagonistic effects are relatively small. Overall, the nitrate leaching abatement measures of the Nitrates Directive (especially balanced fertilization) have the potential of creating synergistic effects.
- The RAINS A 2020 scenario leads to a ~10 % decrease in NH_3 emission in EU-27 by 2020 relative to the reference year 2000, mainly due to a lower N fertilizer use and a less N excretion (due to less domestic animals). The leaching of N to groundwater and surface waters decreases by 9 %. Differences between countries are large.
- The RAINS optimized 2020 scenario lead to a ~21 % decrease in NH_3 emission in EU-27 by 2020 relative to the reference year 2000, mainly due to the implementation of 'cost-effective' NH_3 emission abatement measures. This decrease is less than the decrease (-29%) calculated by RAINS for the same scenario (see Aman et al., 2006b), because of differences in background scenario and abatement strategies. The leaching of N to groundwater and surface waters decreases by 10%.
- The Nitrates Directive scenarios, especially full implementation of the Nitrates Directive and the WFD scenario, have a strong effect on the N input via N fertilizer and animal manure, and hence on total N losses. The ND full 2020 and the WFD 2020 scenarios lead to a decrease in N leaching in EU-27 of 20 and 29 % relative to the reference year 2000, respectively. The NH_3 emission decrease by 14 and 16% in the ND full 2020 and the WFD 2020 scenarios, respectively.

- Though effective in decreasing N leaching and gaseous N (NH_3, N_2O and NO_X) emission, the ND full 2020 and the WFD 2020 scenarios have significant effects for agriculture. Strict implementation of the code of Good Agricultural Practice and balanced N fertilization according to the Nitrates Directive, and ‘equilibrium P fertilization’ (in the WFD scenario) will strongly decrease ‘the room for N and P fertilizer use and application of animal manure N and P’ in various regions in EU-27. Achieving a strong decrease in the application of animal manure N and P will require a combination of low-protein and low-P animal feeding, as well as manure treatment.
- The ND full 2020 and the WFD 2020 scenarios, as defined here, greatly contribute to achieving the targets of the Thematic Strategy on Air Pollution. As yet, the RAINS optimized 2020 scenario did not include the effects of the ND full 2020 and WFD 2020 scenarios. This suggests that new optimizations runs may be needed, taking the measures of the Nitrates Directive and the Water Framework Directive into account, to be able to calculate the most cost-effective combination of measures. Note that the additional costs of the RAINS optimized 2020 scenario relative to the RAINS 2020 scenario have been estimated at €1.6 billion per year for agriculture, equivalent to 2.6 million euro per kton NH_3 per year (Amann et al., 2006).
- Denitrification, with emission of N_2 is the largest N loss pathway in European agriculture, followed by NH_3 volatilization, and N leaching. Emissions of N_2O and NO_X contribute little to the total N loss (but have a significant environmental effect).
- At the suggestions of the reviewers and the Commission, new feedbacks were incorporated in MITERRA-EUROPE (coupling N deposition - NH_3 emissions; coupling crop yield – N input; coupling N uptake by the crop – N input). These feedbacks have made the model more robust but also more complex. Because of these feedbacks, the antagonistic effects of some NH_3 emission abatement measures and of some N leaching abatement measures reported here are smaller compared to the effects reported in the draft final report (21 January 2007 version).

The results of the assessments lead to the following recommendations:

- The discrepancy between the results of RAINS and MITERRA-EUROPE in the assessment of the effects of the RAINS optimized 2020 scenario demands further study.
- The strong effects of the ND full 2020 and WFD 2020 on N leaching, gaseous N emissions and on crop yield and N off take demand further study.
- Quantitative sensitivity analyses are needed to assess the effects of major uncertainties in the input and assumptions of MITERRA-EUROPE.

3. Analysis of International and European Policy Instruments

3.1. Introduction

This chapter summarizes the results of Task 2 'Analysis of International and European policy instruments' of the Ammonia Service Contract. It is based on the underlying Report in Annex 2[12]. The aim of this task is "*to analyze the existing International and European policy instruments aiming at reducing emissions of ammonia, nitrous oxide and methane to the atmosphere and nitrate to groundwater and surface waters*". Specifically, the study addresses the possible synergies and/or possible antagonisms in these policies, and provides suggestions and recommendations to ensure an optimal coherence between measures.

Currently, the use of animal manure and fertilizers and the emissions of N species from agriculture to the environment in the EU-27 are regulated directly or indirectly by four categories of EU policies and measures:

i. Air quality related Directives and climate change policy (Thematic Strategy on Air Pollution (TSAP), NEC Directive, IPPC Directive, Air Quality Directive, Kyoto Protocol);
ii. Water Framework Directive, including the Nitrates Directive and Groundwater Directive;
iii. Agenda 2000 and the reform of CAP, including Cross Compliance, Agri-Environmental and Rural Development regulations; and
iv. Nature conservation legislation, the Birds and Habitats Directives

The points of action of these instruments in agriculture are shown in Figure 3.1. Some of the instruments also (mainly) address industry, traffic and shipping, like the Air quality related Directives and climate change policy. In Agriculture, basically all instruments address the primary producers (the farmers) and landowners. The suppliers, processing industry, retailers and consumers are not addressed by the policy instruments, although they may notice the effects of the policies and measures indirectly.

The following policy instruments have been assessed qualitatively:

- Ammonia abatement measures of UNECE-CLTRAP, IPPC and NEC Directives;
- Nitrate leaching abatement measures of the Nitrate Directive (and Groundwater Directive and Water Framework Directive);
- Measures of the Birds and Habitats Directives;
- Cross-compliance measures;
- Measures of the Rural Development Regulation; and
- Measures to decrease N_2O and CH_4 emissions, according to the Kyoto Protocol.

This chapter summarizes the main findings of the assessments presented in Annex 2.

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[12] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen.

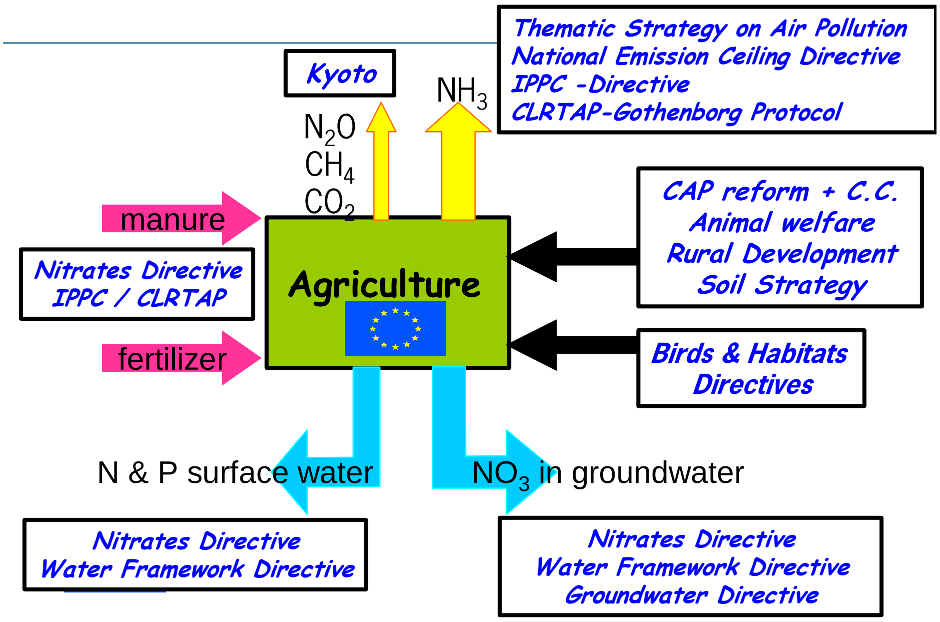

Figure 3.1. Overview of the EU policy instruments directly and indirectly acting on the use and losses of N in agriculture. The emission of NH_3 is regulated by the Thematic Strategy on Air Pollution (TSAP), National Emission Ceilings Directive (NEC), Convention on Long Range Transport of Atmospheric Pollutants (CLRTAP), and the Integrated Program on Pollution Control Directive (IPPC). Fertilizer N and animal manure N applications and N losses to groundwater and surface waters are regulated by the Nitrates Directives, Groundwater Directive, Water Framework Directive, IPPC and CLRTAP. The CAP reform, together with the Rural Development Regulations, Agri-Environmental measures and Cross Compliance measures, and the Birds and Habitats Directive and the Animal Welfare Directive will provide additional constraints to agricultural activities, and/or contribute to the enforcement of the aforementioned policy instruments, and hence on the cycling and loss of N.

3.2. Definition and mechanisms of 'pollution swapping'

Pollution swapping refers to a special side-effect of environmental policies and measures. In this study[13], we defined two types of pollution swapping, i.e., (i) the unwanted increase of another pollutant, and (ii) the transfer of an emission source to elsewhere. These two types of pollution swapping are distinguished in this study as:

- Type 1 swapping to other pollutants (i.e., decreasing the loss of one N species at the expense of other N species);
- Type 2 swapping to other areas (i.e., transferring the pollution potential from one area to another).

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[13] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen

Type 1 pollution swapping is generally seen as a response to governmental policies and measures that focus on one N loss form. Examples include:

- closed periods for spreading animal manure in autumn and winter to minimize nitrate leaching losses combined with spring and summer application to growing crops may exacerbate NH_3 emissions because of higher temperature and lower incidence of rainfall in summer compared to autumn and winter in some Member States;
- incorporation of animal manure into the soil to minimize NH_3 emissions may exacerbate direct N_2O emissions, because the anoxic manure contains easily degradable organic matter which is fuel the denitrifying micro-organisms in the soil;
- decreasing NH_3 losses from manure storage will contribute to manure with a relatively high N content, which increases the risk of nitrate leaching and direct N_2O emissions from soils following application (when the amount of applied manure is not adjusted for the increased N content);
- restricted grazing and zero-grazing, to decrease nitrate leaching from grazed pastures, may result in increased emissions of NH_3 and CH_4 from housing and manure storage systems emissions and following the application of manure to land; and
- no-till or minimum tillage systems, to encourage carbon sequestration in arable soils, may exacerbate nitrous oxide emissions, because of the increased wetness and organic carbon content in the top soil during the growing season.

The possibilities for type 1 pollution swapping are not always fully recognized and understood well, in part because of the narrow focus of research and policies, especially in the recent past, in part also because of the complexity of the N cycling and transformations in agricultural systems. The cause of type 1 pollution swapping can be most easily demonstrated via the so-called ‘hole in the pipe’ model (Figure 3.2). The ‘hole in the pipe’ model symbolizes the leaky N cycle in agricultural systems. There are inputs of N into these systems via e.g. fertilizers, animal manure, biological N fixation, atmospheric depositions (left side of the graph) and there are outputs from the systems, via harvested crop and livestock products. Within the system (visualized by the pipe), transformations and transfer processes take place, whereby a range of N species may escape (visualized via the holes in the pipe). Blocking one or two of the holes in the pipe usually leads to increased fluxes from other holes, unless the total input is decreased, and/or the total output via crop and livestock products is increased.

The reasoning given above does not preclude the assertion that leakages are (not) equally damaging to the environment and or human health. One may argue that losses via NH_3 volatilization are more damaging to the environment per mole of N than the leaching of NO_3 to groundwater and surface waters, or vice versa. However, this is outside the scope of this study. The only point to be made here is that the ‘law of mass conservation’ simply tells us that blocking one loss pathway will increase one or more other loss pathways, unless the N input is decreased or the N output via useful products is increased proportionally. Note also that N may be stored (temporally) in the soil (in the pipe), and thereby may contribute to a delay in swapping.

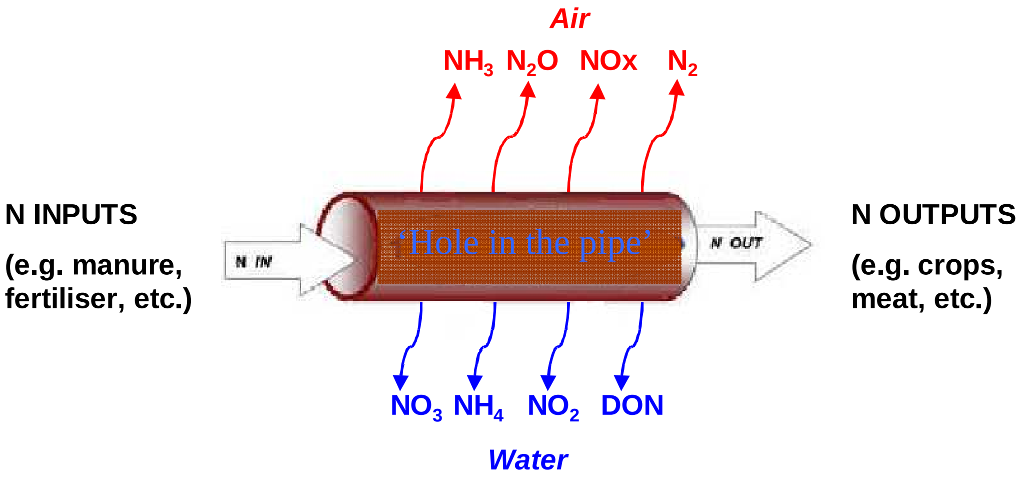

Figure 3.2. Nitrogen (N) emissions from agricultural systems to the air and water environments, visualized by the 'hole of the pipe' model. Inputs of N via fertiliser and animal manure, biological N fixation, and atmospheric deposition are positioned on the left-hand side, and outputs via crop harvest and livestock products on the right-hand side. Please note that the release of di-nitrogen (N_2) is often considered to be a benign emission relative to that of the other N species emissions, but that the emission of N_2 does result in the loss of N from the system to the environment and hence to a lower N use efficiency.

Type 2 pollution swapping (swapping pollution to other areas) is sometimes also called 'externalization' of N losses (and possible other environmental side effects). It occurs for example when policies limit the application of manure to agricultural land, and thereby force intensive livestock farms to transfer the surplus animal manure to arable farmers elsewhere. By doing so, also the risks of N losses via for example NH_3 and N_2O emissions are transferred to elsewhere. The transfer of manure and its emission potential is of course beneficial for the area of concern, but the total emissions of gaseous N emissions will not decrease (they may even increase due to the increasing handling actions). Hence, the N emission potential is simply transferred to other areas. Transfer of manure N from areas with high livestock density to areas with low livestock density can be effective if the manure N can be utilized effectively and does replace and thereby 'save' equal amounts of N from fertilizer.

A variant of type 2 pollution swapping (swapping pollution to other areas) may follow from zoning restrictions within the framework of the Nitrate Directive and especially the Birds and Habitats Directives (Natura 2000 areas). Zoning restrictions may expel farms from the designated areas to outside these areas, while the total production capacity does not diminish (as is the case when production rights and quota exist). In this case, the decreased environmental pressure within the designated areas decreases at the expense of increasing environmental pressures elsewhere. Of course, this can be highly beneficial when the vulnerability of the designated area is much higher than the area outside the designated area (the ‘pollutant’ may even become benign, for example when it contributes to decreasing N shortages in some areas), but the total emission does not decrease; it is simply transferred to other areas.

3.3. Categorization of measures according to their pollution swapping potential

The various measures of the policy instruments were categorized in six categories according to their pollution swapping potential and their effectiveness in decreasing emissions:

(i) *Mitigation or abatement of N species emissions* (e.g., low-emission storage and application of animal manure to decrease NH_3 emissions; no manure application in winter and the growth of cover crops to decrease nitrate leaching);

(ii) *Controlling N input* (e.g., low-protein animal feeding, balanced fertilization;

(iii) *Extensification of agricultural production and environmental protection* (e.g., in the framework of Rural Development Regulation 1692/2005, axis 2, and the Birds and Habitats Directives);

(iv) *Regulations on animal welfare* (e.g., minimal limits for the space and bedding material of animal housing systems, may effect animal feed use efficiency and emissions of NH_3, N_2O and CH_4);

(v) *Improving the competitiveness of agricultural sectors* (e.g., through modernization of farm buildings, improving infrastructure; may effect emissions of NH_3, N_2O and CH_4); and

(vi) *Spatial zoning* (e.g., restriction on farm activities near Natura 2000 areas and special obligations (Action Program measures) in Nitrate Vulnerable Zones).

On the basis of this categorization, a qualitative assessment was made. No distinction has been made between mandatory measures and (country-specific) voluntary measures. Also, it was assumed that the measures were implemented fully; hence the issue of penetration, adoption and feasibility of the measures in practice was not taken into account in this assessment.

3.4. Qualitative assessment of policies and measures

The results indicate that abatement measures for nitrate leaching (in the framework of Nitrates Directive) and ammonia emission (in the framework of UNECE-CLTRAP, and the IPPC and NEC Directives) may both contribute to type 1 ‘pollution swapping’. The potential of ammonia emission abatement measures to contribute to pollution swapping tends to be larger than that of the nitrate leaching abatement measures, when the measures are assessed individually (Tables 3.1 and 3.2). However, both policy instruments include integral control measures. The ammonia abatement measures listed in Table 3.1 have integral control measures in measures 1 (low-protein animal feeding) and 8 (Nitrogen management; balancing manure nutrients with other fertilizers to crop requirements). The nitrate leaching abatement measures listed in Table 3.2 have integral control measures in measure 8 (Rational fertilisation, e.g. split applications, fertilisation limitations). These integral control measures have the potential of creating synergistic effects. Hence, when the measures listed in Tables 3.1 and 3.2 are implemented jointly and in an integrated way, the potential of pollutions swapping is minimal.

Substitution of urea fertilizers by ammonium- and nitrate-based fertilizers will decrease NH_3 emission but may increase N_2O emissions and NO_3 leaching when the amount of N fertilizer applied is not adjusted to the increased effectiveness of ammonium- and nitrate-based fertilizers relative to urea-based N fertilizers. Incineration of poultry manure has the advantage of generating heat and electricity from the manure, but by doing so some of the nutrients in the manure are lost to the air (N, S), while some other nutrients (e.g. P, Ca, Mg) are transformed into forms that are less accessible to plant roots. Ashes of the incinerated manure may also be dumped in landfills, and thereby removing the residual nutrients from cycling in the biosphere for some time.

Table 3.1. Assessment of possible pollution swapping by Best Available Technique (BAT) measures taken within the framework of the IPPC, and in the Framework Advisory Code as developed by the Working Group on Ammonia Abatement of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP), in terms of increases (+), decreases (-) or neutral (~) effects on ammonia (NH_3), direct nitrous oxide (N_2O-d), indirect nitrous oxide (N_2O-i), methane (CH_4) and nitrogen oxides NO_x) emissions to the atmosphere and N leaching to groundwater and surface waters.

	Gaseous emission to the atmosphere					Leaching
BAT Measures	NH_3	N_2O-d	N_2O-i	CH_4	NO_x	N
1. Low Nitrogen Fodder (dietary changes)	–	–	–	~	–	–
2. Stable Adaptation by improved design and construction of the floor	–	+	–/+	~	+	+
3. Covered Manure Storage	–	+	–/+	~	+	+
4. Biofiltration (air purification)	–	–	–	~	–	–
5. Low Ammonia Application of Manure	–	+	–/+	~	+	+
6. Substitution of urea with ammonium nitrate	–	+	–/+	~	+	+
7. Incineration of poultry manure	–	–	–	~	–	–
8. Nitrogen management; balancing manure nutrients with other fertilizers to crop requirements	–	–	–	~	–	–

Volatilization of NH_3 occurs at an early stage in the sequence of processes following the excretion of faeces and urine by animals and or the application of urea and ammonium-based fertilizers (Figure 3.3). The emission of N_2O and the leaching of NO_3 occur at later stages. From this sequence of processes, it will become clear that measures that effect the emission of NH_3 will change the total amount of N at an early stage and thereby likely have an effect on the emission of N_2O and the leaching of NO_3 too. Conversely, it is less likely that measures that effect the leaching of NO_3 will effect the emission of NH_3.

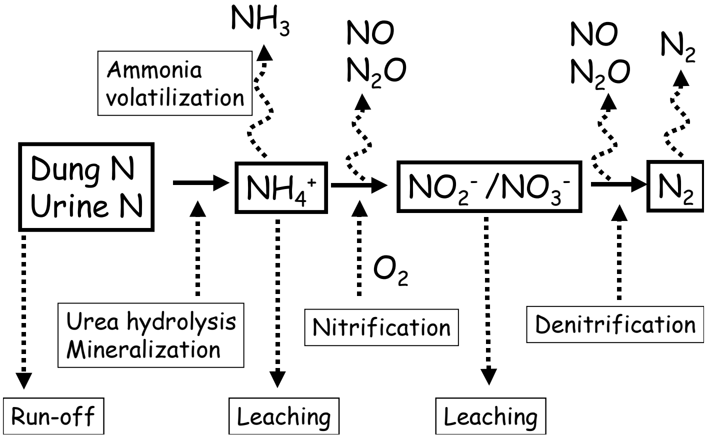

Figure 3.3. Sequence of N transformation processes, and the release and loss of various N compounds from dung and urine. Note that the uptake by the crop of NH_4^+ and NO_3^- is not included in this conceptual framework.

The sequence of processes shown in Figure 3.3 explains to some extent why the ammonia abatement measures listed in Table 3.1 likely have effect on nitrate leaching, and why the nitrate leaching abatement measures listed in Table 3.2 likely have little effect on emission of NH_3, unless the total N input is controlled too. A second reason that may explain why the NH_3 emission abatement measures likely have more effect on NO_3 leaching than the NO_3 leaching abatement measures have on NH_3 emission is the fact that the NH_3 abatement measures are more focused on technological measures and the NO_3 leaching abatement measures more on managerial measures. The technological measures to abate NH_3 emission are focussed on preventing the escape of NH_3 emission (trapping), while the managerial measures tend to focus on improving N utilization, i.e., preventing the leaching of NO_3 combined with balanced fertilization (finetuning of supply to demand by the crop).

Table 3.2. Assessment of possibility of pollution swapping of measures taken within the framework of the Nitrates Directive, in terms of increases (+), decreases (-) or neutral (~) effects on ammonia (NH_3), direct nitrous oxide (N_2O-d), indirect nitrous oxide (N_2O-i), methane (CH_4) and nitrogen oxides NO_x) emissions to the atmosphere and N leaching to groundwater and surface waters.

	Gaseous emission to the atmosphere					Leaching
Measures	NH_3	N_2O-d	N_2O-i	CH_4	NO_x	N
1. Prohibition of fertiliser application in winter	~	–	–	~	–	–
2. Prohibition of organic fertiliser application in winter	+	–	–	+	–	–
3. Restrictions for application on steeply sloping ground	~	~	~	~	~	–
4. Restrictions for application on soaked, frozen or snow-covered soils	~	–	+/~	+	–	–
5. Restriction for application near water courses (5-30 m)	–	–	–	~	–	–
6. Effluent storage	~	~	~	~	~	–
7. Manure storage (duration) (months)	+	~	+	+	~	~
8. Rational fertilisation (e.g. splitting, fertilisation limitations)	–	–	–	~	–	–
9. Crop rotation, permanent crop maintenance	~	~	~	~	~	–
10. Vegetation cover in rainy periods, winter	~	+	~	~	+	–
11. Fertilisation plans, spreading records	~	~	~	~	~	~
12. Application limits for animal manure (170 kg N/ha	–	–	–	~	–	–
13. Zero grazing*)	+	–	+/–	+	–	–
13. Other measures	?	?	?	?	?	?

*) Zero grazing is not a measure mentioned in the Nitrates Directive, but is in part an effect of the Nitrate Directive, as well as the effect of technological developments (e.g. milking robot).

Spatial zoning of Nitrate Vulnerable Zones in the context of the Nitrates Directive and of Nature 2000 within the context of the Birds and Habitats Directives may contribute to type 2 pollution swapping. In general, these Directives have regional effects, i.e. within and around the Nitrate Vulnerable Zones and Natura 2000 areas. The management plan measures of the Birds and Habitats Directives and the Action Plans of the Nitrates Directive may contribute to decreasing emissions of NH_3, N_2O and CH_4 and to decreasing NO_3 leaching as most of these measures put restrictions on agricultural activities. However, some measures may contribute to increasing the emissions of NH_3, N_2O and CH_4 and the leaching of NO_3 *elsewher*e (type 2 pollution swapping), as some farming activities may have to be transferred from around the Natura 2000 areas and the Nitrate Vulnerable Zones to elsewhere. There are no quantitative assessments available about the scale and extent of this type of pollution swapping. As the area involved in Natura 2000 in EU-25 is between 10 to 20%, the overall effect can be significantly.

Cross Compliance is meant to ensure respect of the Statutory Management Requirements, SMRs) and the maintenance of the land in Good Agricultural and Environmental Condition (GAEC) in response to area payments. Cross compliance will improve the implementation of Directives and good land management. Ensuring respect of the 'Environmental' Directives may amplify the single effects noted in Tables 3.1 and 3.2 but likely will not have additional pollution effects. Ensuring respect of the 'Animal Welfare' Directives may contribute to increased emissions of NH_3, N_2O and CH_4 from animal housing systems, because of the larger areas per animal and because of the use of bedding material (use of litter tend to increase the emissions of NH_3, N_2O and CH_4 from manure management). Quantitative assessments of the effects of such measures for the EU-25 are not available yet.

The assessment of the Rural Development Regulation 1698/2005 suggests that this regulation may have diverse effects on the emissions of NH_3, N_2O and CH_4 and the leaching of NO_3, depending on the relative importance of the axes. The term 'axis' is defined in the Regulation as "a coherent group of measures with specific goals resulting directly from their implementation and contributing to one or more of the objectives set out in Article 4 of the Regulation".
Axis 1 support will likely lead to decreasing emissions when the emphasis is on modernization, farm advice, implementing new standards and respecting Community standards for environmental protection. Conversely, when the modernisation of agricultural holdings improves the overall performance of the agricultural holding, including the production potential, total emissions may increase, depending of course on the type of modernization. Axis 2 support will lead to decreases in the emissions when the emphasis is on extensification and decreases in fertilizer use and livestock density. However, when the emphasis is on animal welfare support in animal housing, gaseous emissions will likely increase as the animal housing requirements for animal welfare lead to increasing emissions of NH_3, N_2O and $CH_{4.}$ Axis 3 support likely leads to a decrease in emissions of NH_3, N_2O and CH_4 and the leaching of NO_3.

There are a large number of possible measures that may decrease the emissions of N_2O and CH_4 from agriculture. A large number of these measures have been assessed and discussed in Annex 2.[14] However, there is as yet no formal policy in EU agriculture with specific targets to decrease N_2O and CH_4 emissions from agriculture.

3.5 Conclusions

- The NH_3 emission abatement measures of the UNECE – CLRTAP and the IPPC and NEC Directives do have the potential of type 1 pollution swapping because of the emphasis on technology and the early incidence of NH_3 emission in the sequence of N transformation processes. To minimize type 1 pollution swapping, the NH_3 emission abatement measures have to be combined simultaneously with N management at

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[14] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen.

system level, or with the NO_3 leaching abatement measures of the Nitrates Directive, with a strong emphasis on N input control.

- Greater emphasis on low-protein feeding within the context of NH_3 emission abatement measures does have the potential of synergistic effects on decreasing the emissions of NH_3 and N_2O and the leaching of NO_3.
- The NO_3 leaching abatement measures of the Nitrates Directive have the potential of both synergistic and antagonistic effects on decreasing the emission of NH_3 and N_2O. The synergistic effects seem to dominate, because of the emphasis on balanced N fertilization and N input control. Type 1 pollution swapping (increased NH_3 emission) may occur following the tendency in cattle farming systems to move to zero-grazing systems (to circumvent the leaching of NO_3 from animal droppings in pastures, but NH_3 emissions are larger from housing systems than from grazing systems). Type 1 pollution swapping (increased NH_3 emission) may also occur following a ban on the application of animal manure off the growing season; this ban contributes to a higher utilization of nutrients from manure by the crop and to less NO_3 leaching losses, but at the same time may contribute to increased emissions of NH_3 (and N_2O), because of higher temperature and possible lower incidence of rainfall during the growing season. The pollution swapping potential of the NO_3 leaching abatement measures of the Nitrates Directive can be minimized through joint implementation of NH_3 emission abatement measures of the UNECE – CLRTAP. This indicates again that NH_3 emission abatement measures have to be combined simultaneously with the NO_3 leaching abatement measures of the Nitrates Directive and vice versa to be able to effectively and efficiently decrease N losses from agriculture.
- Designation of Nitrate Vulnerable Zones and areas of special protection (Natura 2000) within the context of the Birds and Habitats Directives do have the potential of type 2 pollution swapping, i.e., transferring the environmental pressures resulting from agricultural activities from within and around the designated zones to elsewhere, outside the designated zones. This type of pollution swapping can be circumvented or minimized by simply stopping the agricultural productivity or by the implementation of N loss abatement measures. However, transferring hot spots of N emissions (e.g. intensive livestock operations) from areas sensitive to N deposition to areas that are much less sensitive to N deposition can greatly decrease the ecological impact of the N losses, depending in part on the background deposition and the critical load.
- All measures that lead to increased N-use efficiency at the system level decrease the N losses via the emission of NH_3 and N_2O and the leaching of NO_3 per unit of agricultural produce, but not necessarily the emissions per unit of surface area. Decreasing the losses per unit of surface area requires that increases in N-use efficiency are not counterbalanced by increases in production capacity, which may occur in Member States following, for example, the abolishment of the milk quota system.
- Cross Compliance measures, introduced following the CAP reform, ensures respect in practice of 19 Statutory Management Requirements (SMRs) and Good Agricultural and Environmental Condition (GAEC). Thereby, Cross Compliance measures have the potential to exacerbate synergistic and antagonistic effects on the abatement of N loss

pathways. The SMRs include the Nitrates Directive and the Birds and Habitats Directives, with their potentials of creating synergistic and antagonistic (type 1 and type 2 pollution swapping) effects. The SMRs also include animal welfare regulations which may contribute to an increase of the emission of NH_3 and N_2O and the leaching of NO_3 because of the regulations on the area and bedding material of animal housing systems, and the requirements on outside free-walk. Further, such animal welfare regulations may increase the animal feed conversion ratio (more feed is needed to produce 1 kg of animal produce) and thereby also increase emissions.

- The effects of the Rural Development Regulation on the emission of NH_3 and N_2O and the leaching of NO_3 from agriculture are diverse and complex. They have the potential of decreasing N losses and of creating synergistic effects on the emission of NH_3 and N_2O and the leaching of NO_3, depending on the measures that are being supported.
- Trends in agricultural development suggest that more livestock will fall under the regime of the IPPC Directive in near future, because of the effects of up-scaling in agriculture. This will make the impact of the IPPC directive for agriculture larger and calls for an increasing need of joint implementation of IPPC and Nitrates Directive measures. However, if the obligations of the IPPC are too strict from a farmers' point of view, there is the possibility that farm size will remain just under the threshold levels, depending also on the competitivess of larger-scale farms.

3.6 Recommendations

- The measures dealing with N input control in the Nitrates Directive (Balanced N fertilization) and the UNECE – CLRTAP and the IPPC and NEC Directives (protein content of the animal, integrated N management) should be the guiding and overall arching principle of the NH_3 and N_2O emission and NO_3 leaching control.
- The implementation and enforcement of the measures of the Nitrates Directive must be jointly with those of UNECE – CLRTAP and the IPPC and NEC Directives, so as to circumvent type 1 pollution swapping.
- In addition to NH_3 emission ceilings and limits, input limits for N from animal manure and NO_3 concentration in groundwater and surface waters, there is scope for formulating targets for N use efficiency for specified farming systems. Such targets for N use efficiency have the advantage of providing a measure for an integrated N input control and for the N loss to the environment.
- There is scope for introducing effective and efficient economic incentives to abate NH_3 and N_2O emissions and NO_3 leaching simultaneously, provided that N input control is the guiding and overall arching principle and that there is a well-balanced and joint implementation.
- Providing incentives via Rural Development measures to the N use efficiency for specified farming systems provides opportunities for rewarding those farmers that go beyond certain standard criteria and thereby decreasing N losses in an integrated way.
- A tax on N fertilizer (or on fossil energy sources) and / or on protein-rich animal feed stuffs may also contribute to N input control and to increasing N use efficiency, and thereby on decreasing N losses in an integrated way. However, a tax on N fertilizer

and/or protein-rich animal feed will also penalise farmers that use N fertilizer and protein-rich animal feed judiciously, and was therefore considered unfeasible in the recent past. With a greater priority in EU policy on climate change, fossil energy use and N emission control, new perspectives may emerge.

- Animal welfare regulations for animal housing should be combined with NH_3 and N_2O abatement measures and NO_3 leaching abatement measures
- In addition to spatial *zoning* of areas with high nature values and/or vulnerable to NO_3 leaching (within the context of the Nitrates Directive and the Birds and Habitats Directives), there is scope for spatial *planning* of N polluting agricultural activities in areas that are less vulnerable. This can be relevant also given the trends towards conglomerating large, specialized and intensive farms in areas with cost-specific advantages (which do not have necessarily nature or N cycling specific advantages).
- The role of the agro-complex (suppliers, farmers, processing industry and retailers) has so far received little or no attention in decreasing N losses from agriculture. This is surprising, as the agro-complex and especially suppliers, processing industry and retailers play a dominant role in (the development of) agriculture. It is suggested to explore the potentials of the agro-complex in improving N use efficiency and decreasing N losses from agriculture.
- So far, the leakages of the N species from the holes in the pipe have been considered equally (damaging). We recommend examining the potential ecological damage of each of the N species involved so as to making a rating among the N species.
- So far, the conclusions and recommendations are rather theoretical; joint sessions with farmers, advisers and policy makers should be organized to bring the messages down to earth and down to practice and policy.

4. In-depth Assessment of the most Promising Measures

4.1. Introduction

This chapter summarizes the results of Task 3 of the Ammonia Service Contract. The aim of this Task has been defined in the call for tender (see Annex 5) as *'(i) to identify a list of most promising (package of) measures to decrease the emissions of ammonia, nitrous oxide and methane to the atmosphere and nitrate to groundwater and surface waters, (ii) to select three (packages of) most promising measures after a dialogue with the Commission, and (iii) to make an in-depth assessment of the cost and impact of these (packages of) most promising measures".* In addition, the most effective European and/or national instruments should be identified to implement the most promising measures.

In order to be considered as promising, the (package of) measure should correspond to the following criteria, according to the call for tender (Annex 5):

(v) Co-beneficial effects for water, air, climate change and soil protection;
(vi) Feasible notably from an administrative and enforceability point of view;
(vii) Potentially acceptable by the farmers notably for what concerns costs and additional efforts at farm level;
(viii) Compatibility with the need for improved animal welfare'.

The call for tender mentioned that "the list of most promising measures will include at least adapted feeding strategies aiming at ensuring the same level of production with reduced nitrogen content in the feed and/or an adaptation of the feeding regime to the level of growth of the animals".

The results of this task have been reported in Annex 3[15]. This chapter summarizes the results, as follows. Paragraph 4.2 summarizes possible measures to decrease the emissions of ammonia, nitrous oxide and methane to the atmosphere and nitrate to groundwater and surface waters, and it provides a justification for the selected three packages of most promising measures. Paragraph 4.3 discusses the scenarios and assumptions in these scenarios

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[15] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. EuroCare, Bonn.

4.2. Possible measures to decrease emissions from agriculture to the environment

A large number of technical, structural and management-related measures for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems have been suggested in literature (e.g., Romstad et al., 1997; Hatch et al., 2004; Kuczybski et al., 2005; Cuttle et al., 2004; Mosier et al., 2004; Gairns et al., 2006; Weiske et al., 2006; Soliva et al., 2006). Many of these measures have been reviewed and qualitatively assessed in Task 2 and have been summarized in Chapter 3 and Annex 2[16] of this Report.

Measures for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems must be considered from a whole-farm perspective (Montenty et al., 2006; Weiske et al., 2006; Petersen et al., 2007). This is so, because farmers have to implement the measures within a certain farm setting and farm management. From a whole-farm perspective, it is convenient to distinguish three categories of measures:
(i) management-related measures,
(ii) technical and technological measures, and
(iii) structural measures.

Management-related measures include best management practices, i.e., improving the operational and tactical management of animal feeding, housing, manure, soils and crops. These measures increased knowledge and experience of farmers and therefore require training, advice and support by management tools. These types of measures do comply with the criteria of most promising measures indicated in paragraph 4.1.

Technical and technological measures often require investments in 'hardware', in machines, animal housing systems, manure storage and manure application techniques, anaerobic digesters and manure treatment, and air scrubbers. These measures are often costly and also require increased knowledge and experience of farmers and therefore require training, advice and support by management tools. Some of these types of measures may comply with the criteria of most promising measures indicated in paragraph 4.1, but quit a few are to costly.

Structural measures are least defined. A distinction can be made between large-scale structural changes and changes in the structure of farming systems. Large-scale structural changes include for example (i) changes in number, type, size of agricultural holdings and in the type and total volume of agricultural production, (ii) changes in the relative importance of production factors and resources (land, labor, capital, energy and management); and (iii) changes in the organization and vertical integration of food producing and food processing chains. These large-scale structural changes do not comply

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[16] Annex 2. Oenema, O. and G.L. Velthof 2007. Analysis of International and European Policy Instruments: Pollution Swapping. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 2. Alterra Report. Wageningen.

with the criteria of most promising measures indicated in paragraph 4.1, and are therefore not considered further. Farm-scale structural measures relate to changing the structure of the farm, for example from mixed to specialized farming systems, or from landless to mixed livestock systems. It may also relate to clustering and combining various crop and animal production systems to integrated novel systems that have low resource utilization and low emissions per unit of product produced. However, such structural measures (changes) require large capital investments (technical and social) and do not comply with the criteria of most promising measures indicated in paragraph 4.1, and are therefore also not considered further.

Summarizing, most promising measures as defined in the Ammonia Service Contract relate to management-related measures, and to technical and technological measures. Further, most promising measures must focus on input control, to circumvent or minimize the risk on pollution swapping (see Chapter 3). Hence, N input control and management-related and technical/technological measures form the building blocks of the most promising measures for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems.

Major sources of N in agriculture of EU-27 are N fertilizers (about 10 Tg per year), animal manure (produced about 9 Tg per year; applied to agricultural land about 5 Tg per year), biological N_2 fixation (about 1 Tg per year) and atmospheric N deposition (about 2 Tg). The N from animal manure is derived from animal feed and can be considered as recycled N. Part of this recycled N is derived from imported animal feed. Van Egmond et al., (2002) estimated the amount of N in imported animal feed in Europe at about 7 Tg per year. The N from atmospheric N deposition can be considered also as recycled N; about half is derived from NH_3 emitted from agriculture and the other half is largely derived from NO_X derived from combustion sources. Summarizing, the major sources of ‘new’ N in agriculture of EU-27 are N fertilizers (~ 10 Tg per year) and imported animal feed (~ 7 Tg per year). Hence, N input control as measure for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems, should focus on N fertilizer input and N input via animal feed. Lowering N input can only be considered as ‘most promising measure’ if crop yields and animal performance is not significantly decreased. Hence, lowering N input is only acceptable as most promising measure if the N use efficiency within agriculture is increased proportionally to keep the production level constant. Improving N use efficiency is therefore another building block of the most promising measures for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems.

Improving nitrogen (N) use efficiency in agriculture is considered to be the most promising and most integrated measure to decrease N losses from agriculture (Mosier et al., 2004; Hatch et al., 2004; Kuczybski et al., 2005; Cuttle et al., 2004; Gairns et al., 2006; Weiske et al., 2006; Soliva et al., 2006). Improving N use efficiency means that agriculture produce is made with less N (input) and that N losses are decreased. Improving N use efficiency often requires combination of various measures, including improved soil, crop and animal management, improved genetic potential of crops and animals, and emission abatement measures. Such packages of measures have to be implemented jointly with a decrease in N input and/or an increase in yield and N off take. Such a strategy has the potential of synergistic effects, i.e. decreasing the losses of all N species at acceptable economic costs, with minimal risk of pollution swapping (see Chapter 3).

Balanced N fertilization in crop production and low-protein animal feeding in animal production combined with low-emission storage, handling and application techniques for animal manure can be seen as the main vehicles to improve N use efficiency in EU agriculture. Balanced N fertilization is a measure of the Nitrates Directive, though only enforced in Nitrate Vulnerable Zones (NVZs). However, there is considerable discussion about the interpretation of ‘balanced fertilization’ and there is delay in the implementation of the Nitrates Directive (Zwart et al., 2007. As a consequence, ‘balanced N fertilization’ is not implemented in full in practice.

It this study, balanced N fertilization was implemented in a uniform way to all agricultural land in the EU-27, because of its synergistic effects through decreasing nitrate leaching and emissions of ammonia and nitrous oxide simultaneously. The Nitrates Directive in combination with the Water Framework Directive and the Groundwater Directive seem the most likely policy instruments to implement balanced fertilization beyond NVZs.

Low-protein animal feeding in animal production is common practice in some Member States, but is in the EU-27 only implemented legally on large pig and poultry farms in the EU-27 through the IPPC Directive (so-called IPPC farms). Low-protein animal feeding is also a measure of the Guidelines for ammonia abatement developed by the Working Group on Ammonia Abatement of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP). Improving the efficiency of N utilisation at the animal level requires both genetic improvement of the herd, a better description of feed, and higher quality feed with a proper balance of amino acids (and hence a low protein content). The first limitation for animal production and an efficient utilization of feed protein is an adequate supply and intake of feed energy and amino acids in proper ratios. Ensuring low-protein animal feeding in animal production in practice may be achieved by the IPPC Directive on IPPC farms but likely also through the Nitrates Directive. This Directive enforces a maximum application of N via animal manure of 170 kg per ha per year, and thereby exerts influence on lowering the N excretion per animal; the lower the N excretion per animal, the more animals can be kept per ha agricultural land. Alternatively, implementation of low-protein animal feeding in practice may be achieved through communicative and persuasive instruments, as the cost of low-protein animal feeding is relatively low (apart from the cost in training and capacity building)..

Low-emission storage, handling and application techniques for animal manure have been discussed for over a century (e.g., Erisman, 2000), and a large amount of convincing experimental evidence has been collected about the effectiveness of these techniques and measures (e.g., Burton and Turner, 2003; Web et al., 2003; Kuczybski et al., 2005; Rotz, 2004). In the EU-27, these techniques and measures are implemented on large pig and poultry farms in the EU-27 through the IPPC Directive (so-called IPPC farms), and described extensively in Reference Documents (European Commission, 2003). The Guidelines for ammonia abatement developed by the Working Group on Ammonia Abatement of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) also provides detailed instructions, and various Member States do recommend and/or enforce these techniques and measures in practice. However, these measures and techniques require capital investments and are therefore rather costly. The measures will decrease N losses from animal manure and have the potential benefit of replacing fertilizer N and thereby decreasing N losses associated with N fertilizer production and use. Anaerobic digestion of the animal manure during storage has the additional advantage of producing CH_4 to be used as biofuel. It encompasses the perspectives of minimizing emissions of odours, NH_3, N_2O and CH_4 during storage, and minimizing emissions of N_2O following application to land. The effectiveness of the manure as N fertilizer is also increased following application of the digested manure to land, but the digested manure has to be injected in the soil to minimize NH_3 losses following application (e.g., Burton and Turner, 2003).

Summarizing, the following set of measures have been selected as most promising measures for mitigating emissions of ammonia, nitrate, phosphorus, nitrous oxide, methane and carbon dioxide from agricultural systems (see also Annex 3[17]):

(i) Improving N use efficiency in animal production and lowering the N excretion of livestock through low-protein animal feeding, improved herd management and genetic improvement of the herd;
(ii) Improving N use efficiency in crop production and lowering N input in agriculture through balanced N fertilization and improved crop and soil management; and
(iii) Combination of (i) and (ii) plus enforced implementation of technical measures to decrease NH_3 emissions.

4.3. Description of the scenarios

As indicated in Chapter 2.3, scenarios are narratives of alternative future environments, or hypotheses of the future, specifically designed to highlight the risks and opportunities. The most promising measures discussed above have been assessed though ‘scenario analyses’. It has been assumed that the most promising measures are implemented in practice by 2020, and the effects of the implementation of the most promising measures have been analyzed in terms on emission decrease, investments and income foregone. This paragraph explains ‘the translation of the most promising measures in scenarios’. An overview of the scenarios analysed in this task is presented in Table 2.3.

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[17] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. EuroCare, Bonn.

The ND full 2020 scenario was used as reference scenario for the analyses of the most promising measures. This scenario has been described in detail in paragraph 2.3. The ND full 2020 scenario is based on the "National Projections" baseline scenario for the revision of the NEC Directive, but in addition includes a strict interpretation of balanced N fertilization in NVZs. This baseline was chose as reference at the suggestion of the European Commission.

4.3.1. Description of the low-protein animal feeding scenarios

As regards low-protein animal feeding, there is empirical and theoretical evidence in the literature that the protein content of the animal feed can be lowered, at least on some animal farms, but there is no consensus about the degree of lowering. Two lines of reasoning have been applied in this study to arrive at an estimate of the windows or opportunity for decreasing the N excretion by livestock in EU-27. The first line of reasoning is based on the current N excretion levels in the RAINS database and the theoretical/practical limits based on animal physiology as indicated in literature. Taking the mean N excretion values per animal type of the RAINS database as point of departure is based on the fact that RAINS is used as instruments for assessing current and future gaseous N emissions in EU-27. The N excretion values in the RAINS database are based on country specific information provided by experts and are regularly updated. As indicated in Annex 3[18] to this report, the gap between the apparent mean N excretion per animal type of the RAINS database and the current theoretical/practical limits is rather small. This suggest that the scope of lowering the protein content of the animal feed in current practice is relatively small, in the range of 10% to maximal 20% (Annex 3).

The second line of reasoning is based on statistical/empirical data from practice. For example, data presented in Figure 4.1 indicates that the N excretion of fattening pigs on specialized farms in the Netherlands ranged from ~10 to ~15 kg per pig place per year, and that the P excretion (expressed as P_2O_5 excretion) ranged from 3 to 6 kg per year in 1999-2000. The scatter suggests that there may be some errors involved in the recording of the data, but the variation also indicates that there is scope for (further) lowering of the N and P excretion of fattening pigs on many farms by 10 – 30 % (Hubeek and de Hoop 2004).

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[18] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. EuroCare, Bonn

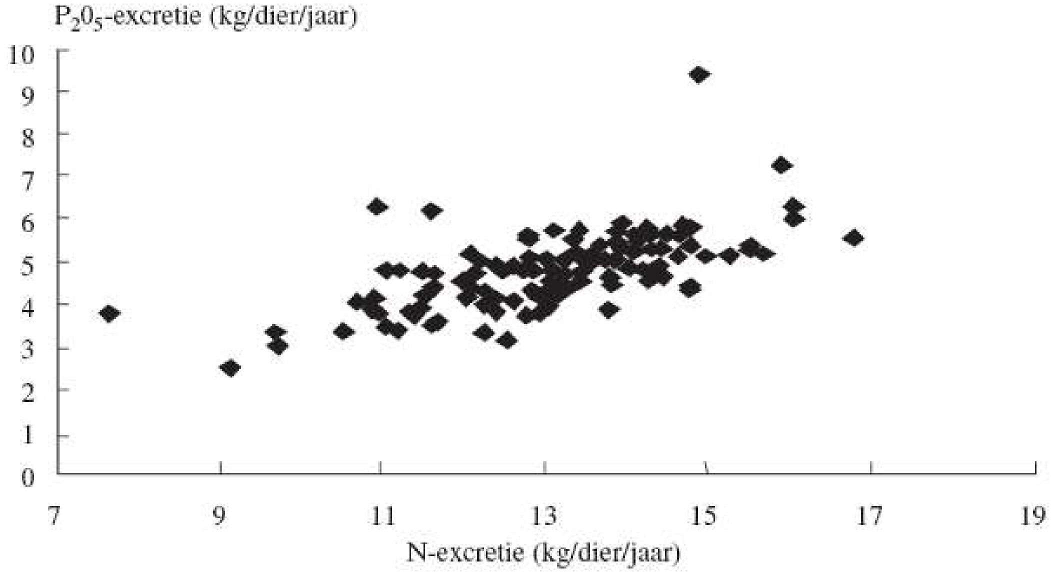

Figure 4.1. Relationship between the mean excretion of N and P (in P_2O_5) by fattening pigs at farm level in 1999-2000, for specialized fattening pig farms in The Netherlands. (Source FADN database, Hubeek and de Hoop, 2004).

A similar variation between Member States in mean N excretion of cattle, pigs and poultry has been observed on the basis of data statistics of the animal feed imports, domestic forage and fodder production, and the number of animals and their energy and protein requirements derived from the CAPRI database. The CAPRI database also indicates that there is a significant variation between Member States in mean excretion, suggesting that there is scope for lowering the protein content of the animal feed in at least some countries by 10 to 20% (Figure 4.2).

As yet, it remains unclear which line of reasoning provides the most accurate assessment of the scope for low-protein animal feeding in the EU-27. Therefore, both lines of reasoning were used for scenario analyses. The first line of reasoning was used in the scenarios assessed by MITERRA-EUROPE (see Chapter 2). Based on the desk study presented in Annex 3, it was assumed that the N excretion of dairy cattle, other cattle, pigs and poultry, as presented in the RAINS database can be decreased by on average 10% through a combination of low-protein animal feeding, and improved animal management, improved genetic potential of the herds and less replacement cattle[19]. As a way of sensitivity analysis, a variant with 20% lower N excretion was included.

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[19] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. EuroCare, Bonn

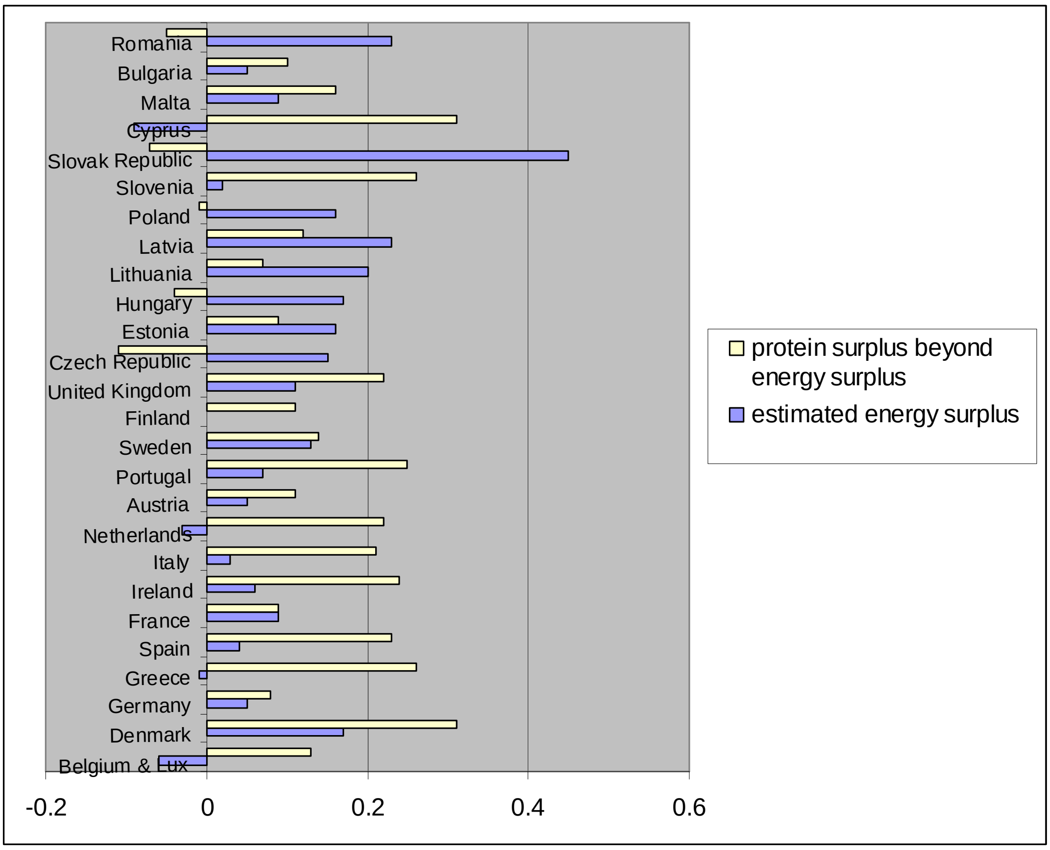

Figure 4.2. Protein surplus and energy surplus in animal production in European countries according to the CAPRI database (Annex 3[20]).

As regards implementation of the low-protein animal feeding, two variants were considered, i.e., (i) on IPPC farms only, and (ii) on 'all' farms in EU-27, but the percentage implementation was different for different Member States (Table 4.1). These percentages were based on the general idea that the management of animal feeding is more advanced in the EU-15 Member States than in the new Member States.

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[20] Annex 3. Witzke, P. and O. Oenema, 2007. Assessment of Most Promising Measures. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 3. EuroCare, Bonn

Table 4.1. Level of implementation (level of penetration, in %) of 'low-protein feeding' for dairy cattle, other cattle, pigs and poultry for each country included in the analysis for the years 2000, 2010 and 2020. Note that the year 2000 has been used as reference year (zero level implementation), though it is acknowledged that various farms have implemented some level of low-protein feeding already (see also text).

	2000				**2010**				**2020**			
Country	Dairy cattle	Other Cattle	Pigs	Poultry	Dairy cattle	Other cattle	Pigs	Poultry	Dairy cattle	Other cattle	Pigs	Poultry
AT	0	0	0	0	33	17	33	33	100	50	100	100
BG	0	0	0	0	17	8	17	17	50	25	50	50
BL	0	0	0	0	33	17	33	33	100	50	100	100
CR	0	0	0	0	25	13	25	25	75	38	75	75
CY	0	0	0	0	25	13	25	25	75	38	75	75
CZ	0	0	0	0	25	13	25	25	75	38	75	75
DE	0	0	0	0	33	17	33	33	100	50	100	100
DK	0	0	0	0	33	17	33	33	100	50	100	100
EE	0	0	0	0	17	8	17	17	50	25	50	50
EL	0	0	0	0	33	17	33	33	100	50	100	100
ES	0	0	0	0	33	17	33	33	100	50	100	100
FI	0	0	0	0	33	17	33	33	100	50	100	100
FR	0	0	0	0	33	17	33	33	100	50	100	100
HU	0	0	0	0	25	13	25	25	75	38	75	75
IR	0	0	0	0	25	13	25	25	75	38	75	75
IT	0	0	0	0	33	17	33	33	100	50	100	100
LT	0	0	0	0	17	8	17	17	50	25	50	50
LU	0	0	0	0	33	17	33	33	100	50	100	100
LV	0	0	0	0	17	8	17	17	50	25	50	50
MT	0	0	0	0	33	17	33	33	100	50	100	100
NL	0	0	0	0	33	17	33	33	100	50	100	100
PL	0	0	0	0	33	17	33	33	100	50	100	100
PT	0	0	0	0	33	17	33	33	100	50	100	100
RO	0	0	0	0	17	8	17	17	50	25	50	50
SE	0	0	0	0	33	17	33	33	100	50	100	100
SI	0	0	0	0	25	13	25	25	75	38	75	75
SK	0	0	0	0	25	13	25	25	75	38	75	75
TK	0	0	0	0	8	4	8	8	25	13	25	25
UK	0	0	0	0	33	17	33	33	100	50	100	100

The second line of reasoning was used in the scenarios assessed by CAPRI. Here, the percentage decrease in N excretion was assessed by CAPRI, on the basis of the protein excess in the animal feed per Member States. Hence, country-specific and animal-type-specific assessments were made of the perspectives for lowering N excretion. However, because inaccurate recordings of feed quantities in the official data statistics might distort the nutrient balancing in CAPRI, safeguards have been introduced to prevent an exaggerated assessment of the avoidable protein excess:

- In case that both an energy surplus and a protein surplus is estimated it is assumed that the energy surplus is either indicative of general waste in feed use of the agricultural systems concerned (affecting both energy and protein), which is difficult to tackle or it is indicative of statistical problems. The ‘avoidable’ protein surplus has to be reduced in this case.

- A full removal of the observed protein surplus would imply that all farms in a country operate on the technology frontier of most efficient feeding practice, including, for example in the pig sector, multiphase feeding with fine tuned supplements of all amino acids in insufficient supply from the core feed ingredients. This is only achievable in experimental situations and evidently unrealistic for the vast majority of all farms.

Furthermore it is proposed that low protein feeding be promoted through a combination of advisory services and financial incentives from agri-environmental measures. A 100% penetration will be difficult to achieve in this way. Table 4.1 above assumed that the knowledge level would develop sufficiently to achieve this in EU 15 countries but that in other countries penetration would be smaller. The energy surplus bars in Figure 4.2 support the assessment that surplus feeding may still be significant in current agriculture of the New Member States. If surplus feeding is significant there is also a large potential to avoid this through simple measures which can be implemented easily such as a reasonable assessment of the farmers own fodder. Hence, penetration rates in New Member States may be just as high as in EU15 countries. Prevalence of inefficiency also applies to non dairy cattle production such that applicability of low nitrogen feeding may again be higher than indicated in Table 4.1 above if inefficiency may be reduced. For this analysis we have to acknowledge that future penetration rates are quite uncertain. In the CAPRI simulations we have used a uniform penetration rate of 75% for all countries and activities therefore, which is about the average in 2020 from Table 4.1, but gives a larger weight to the nitrogen saving ‘potential’ as opposed to the current ‘knowledge’ aspect. All these considerations are built into the following table (Table 4.2).

Table 4.2. Achievable decrease in protein supply in animal feeding, as a function of the initial protein surplus and the calculated energy surplus for the 10% reduction scenario

initial protein surplus →	*0.0%*	*10.0%*	*20.0%*	*30.0%*	*50.0%*
initial energy surplus ↓					
0.0%	0.0%	4.0%	8.0%	12.0%	20.0%
5.0%	0.0%	3.8%	**7.5%**	11.3%	18.9%
20.0%	0.0%	3.2%	6.5%	9.7%	16.1%
30.0%	0.0%	2.9%	5.9%	8.8%	14.7%
50.0%	0.0%	2.5%	5.0%	7.5%	12.5%

Table 4.2 is applied to all countries and animal activities such that the differences in the initial estimate of the protein surplus determine the percentage decrease applied. For the typical case (see Figure 4.2) of a protein surplus of 20% combined with an estimated energy surplus of 5% we obtain a decrease of 7.5% which is downscaled from the full 10% decrease due to the assumed 75% penetration rate. For the 20% decrease scenario a similar table has been used giving an effective decrease of about 13.5% for the typical case (protein surplus = 20%, energy surplus = 5%). This acknowledges that penetration is likely to be a bit smaller if the measure is more ambitious.

4.3.2. Description of the economic cost analyses

The implementation of low-protein animal feeding may cause different types of cost:

- Additional feed cost for optimised low protein compound feeds apply mainly on highly efficient farms.
- Additional costs for handling facilities related to several types of feed on a farm may apply if multi phase feeding is introduced.
- Additional time input of the farmer for improved planning of feed use will often be the main cost in New Member States and the 'other cattle' sector

In particular the time input is difficult to assess both in terms of hours as well as in terms of an appropriate wage rate (opportunity cost). For the CAPRI simulations we had to apply a workable hypothesis covering all countries and animal activities. The first idea underlying this hypothesis is that the costs are increasing if the relative decrease of the protein surplus increases. This relative decrease is simply the ratio of the decrease in protein supply from Table 4.2 to the initial protein surplus. It is assumed that additional costs go to infinity as the relative decrease approaches one (because perfect efficiency is unattainable) and that they are zero for a zero relative decrease. Furthermore the additional cost is expressed as a mark up of initial feed cost to incorporate differences between animal types and countries. The free parameter in the approximating formula has been chosen to give about 1.65 € per fattened pig or 27 € per dairy cow in terms of additional feed cost under typical circumstances[21]. These costs are somewhat lower than in the December simulations in RAINS (about 3.3 € Euro per fattened pig, 55 € dairy cow) in view of the ongoing downward revision in RAINS. This is supported by information from German DVT representatives (FEFAC member) and from Dutch feed experts suggesting that the cost in RAINS may be somewhat exaggerated for current technologies and prices.

For the strong reduction scenario the effective cut attains 80% of the initial surplus which would bring farmers closer to the technological frontier (BAT). The additional costs would strongly increase therefore and amount to 10 € per fattened pig or 160 € per cow. Even though this strong decrease is unlikely to be implemented in full it is nonetheless of interest for a sensitivity analysis.

4.3.3. Description of the balanced fertilization scenario

The scope for improving N use efficiency in crop production and lowering N input in agriculture through balanced N fertilization was explored on the basis of the degree of balanced fertilization in the various Member States according to the results of MITERRA-EUROPE calculations. Currently, there is no consensus in literature about the definition of 'balanced fertilization'. In this study, balanced fertilization was defined in its most 'straight' form:

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[21] The formula is: c * relative cut / (1-relative cut) where c = 0.05. For a relative cut of 40% as in the first line of Table 4.2, we obtain a percentage increase of feed cost of 3.3% or 1.65 € if feed cost is 50 € (typical for fattening of pigs) or 27 € if feed cost is 800 € (case of dairy cows).

Σ (input of available N from all sources) = Σ (N demand by the crop).

The procedure for assessing balanced fertilization has been described in detail in Chapter 2 and in Annex 1. The concept applied here is similar to the concept described in Chapter 2; the only difference is that balanced fertilization in the scenario ND full 2020 is applied to NVZs only, while it is considered applicable to all agricultural land in the current scenario (Balfert 2020). The assessment of balanced N fertilization was made by both MITERRA-EUROPE and CAPRI. Because MITERRA-EUROPE and CAPRI use slightly different approaches and definitions for balanced N fertilization, the results of both models may be seen as sensitivity analyses too.

In the CAPRI model, balanced fertilization implies basically an 80% decrease of the initial ‘overfertilisation’ (available N input / N output), taking into account that balanced fertilisation is already part of action programs for NVZ. This is a somewhat simplified and moderated version compared to the MITERRA-EUROPE calculations. However balanced fertilisation would require more careful establishments of fertiliser plans, more frequent soil analyses, perhaps split applications of fertiliser and more demanding crop management in general to bring about the increase in efficiency implied by a reduction in fertiliser input while maintaining output. Conceptually we should assess and value these additional management efforts which are not feasible however. Instead, we assumed a flat rate cost of 25 € per ha for a full elimination of overfertilisation (20 € for an 80% cut) which was meant to cover these management efforts. Different wage cost may have suggested to use higher costs in EU15 countries. However, the ‘knowledge argument’ from above could motivate that the required efforts would be higher in the New Member States. In view of transparency and lack of quantitative information we opted for the uniform flat rate assumption.

4.3.4. Description of the optimal combination scenario

The combination of balanced fertilization with a set of low-emission manure techniques for animal manure storage and application is considered to be the most optimal and far reaching scenario. The concept of balanced N fertilization applied here is similar to that described in chapter 4.3.2. Following consultation with the Commission, the National Projections baseline scenario for the revision of the NEC Directive, but optimized to achieve the targets of the Thematic Strategy in 2020 (RAINS optimized 2020 scenario) was chosen as feasible set of low-emission manure storage and application techniques. Hence, the ‘optimal combination scenario’ is a combination of RAINS optimized 2020 and Balfert 2020 and is the most far-reaching scenario.

The cost data for the optimised 2020 scenario are from RAINS except for the case of low nitrogen feeding and balanced fertilisation where the above assumptions have been applied in CAPRI.

An overview of the scenarios analyzed in Task 3 of the Ammonia Service Contract is presented in Table 4.3.

Table 4.3. Overview of the scenarios analyzed in Task 3 of the Ammonia Service Contract

Scenarios	**Description**
1. ND full 2020 (Reference scenario)	National Projections baseline scenario for the revision of the NEC Directive, 2020, plus full (strict) implementation of the N leaching abatement measures in extended areas of Nitrate Vulnerable Zones (Annex 1).
2. LNF 10%, all farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to all farms.
3. LNF 10%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to IPPC farms only
4. LNF 20%, all farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to all farms
5. LNF 20%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to IPPC farms only
6. Balfert 2020	ND full 2020 (see above) plus strict implementation of balanced N fertilization on all farms, irrespective of NVZs
7. Optimal Combination, 2020	Rains optimized 2020 (see Table 2.6) plus Balfert 2020

4.4. Results of the scenario analyses by MITERRA-EUROPE.

A total of 6 scenarios and the reference scenario (ND full 2020) have been analysed in this study (Table 4.3). Low-protein animal feeding has effect on the N excretion and thereby on the amount of N in animal manure. Balanced N fertilization (Balfert 2020) may have effect on the N fertilizer use and on the amount of manure N applied to agricultural land.

Table 4.4 shows the mean changes in the N inputs in agriculture of the EU-27. The LNF 10%, 2020 scenario decreases the amount of N in animal manure applied to land at EU-27 level by 7%, when applied on all farms, and by 1% when applied on IPPC farms only. Doubling the target for low-protein animal feeding to 20% decreases the amount of manure N by 13% and 3%, when applied on all farms and IPPC farms only, respectively. Balfert 2020 scenario and the Optimal Combination 2020 scenario have a drastic effect on the amount of manure N, especially in countries with no or a small area of NVZ in 2020 (see Table 2.5). Fertilizer N input is not significantly affected by the LNF 10% and LNF 20% scenarios, but is greatly affected by the Balfert 2020 and the Optimal Combination 2020 scenarios. Again, the decreases are largest in countries with no or a small area of NVZ in 2020.

As discussed also in Chapter 2, the strict interpretation of balanced fertilization has large influence on the N input via N fertilizer and animal manure N (Table 4.4). The decreases in animal manure N in the Balfert 2020 scenario do not pertain to the manure from grazing animals (N excretion by grazing animals does not decrease in the Balfert scenario). In practice, decreasing the N input via fertilizer N and applied animal manure N to grazed grasslands, as in the Balfert 2020 scenario, will likely decrease the protein content of the herbage. However, such a feedback is not yet included in MITERRA-EUROPE. As a result, the projected relative decreases of the amounts of manure N in the Balfert and Optimal Combination scenarios are likely too large.

The decrease in applied N via animal manure (Table 4.4) implicitly assumes that some manure N has to be disposed elsewhere. As discussed also in Chapter 2, the decrease in animal manure N brought about by balanced fertilization will require a combination of low-protein animal feeding and manure treatment. This suggest that full implementation of ‘balanced N fertilization’, as defined here, will need at the same time implementation of ‘low-protein animal feeding’ to be able to decrease the N excretion by the animals to the level that the manure N can be ‘absorbed’.

The projected decreases in applied animal manure N in the Optimal Combination 2020 scenarios are larger than the projected decreases in fertilizer N. This is opposite to the changes projected for the ND full 2020 and WFD 2020 scenarios discussed in Chapter 2, and the Balfert 202 scenario. The relative strong decrease in manure N relative to fertilizer N is in part related to the assumptions in MITERRA-EUROPE, in part also to the fact that NH3 emission abatement measures in the Optimal Combination 2020 scenarios contribute to increased N contents of the animal manure. As a consequence, less animal manure can be applied within the concept of Balfert 2020 in the Optimal Combination 2020 scenario.

Evidently, the results of the Balfert 2020 and the Optimal Combination scenarios are very sensitive to the assumptions made in the calculation of the N input. Some preliminary sensitivity analyses have been made, but there is a clear need for further exploring the influence of assumptions and factors in these scenarios analyses.

Table 4.4. Main N flows in agriculture in EU-27 in 2020 according to the ND full 2020 scenario, and the calculated potential changes relative to the ND full 2020 scenario for the LNF 10% on all farms scenario, the LNF 10% on IPPC farms scenario, the LNF 20% on all farms scenario, the LNF 20% on IPPC farms scenario, the Balfert 2020 scenario and the optimal combination scenario.

N source	ND full 2020	LNF 10% all	LNF 10% IPPC	LNF 20% all	LNF 20% IPPC	Balfert 2020	Optimal combination
	kton N	% change compared to ND full 2020					
Total N excretion	9887	-6	-1	-13	-3	0	-8
Applied N fertilizer	9212	1	0	3	0	-9	-7
Applied manure N	4341	-7	-1	-13	-3	-6	-13
N excreted during grazing	3271	-4	0	-8	-1	0	-6
N deposition	1896	-2	0	-5	-1	0	-7
Biological fixation	823	0	0	0	0	0	0

Because of the changes in the amounts of excreted N and in the applications of manure N and fertilizer N to agricultural land, leaching losses decrease significantly (Table 4.5). Total decreases in leaching are largest in the Optimal Combination 2020 scenario. Note that the LNF scenarios have a relative large influence on the leaching losses from manure storage.

Table 4.5. Total N leaching losses from agriculture to groundwater and surface waters in EU-27 according to the ND full 2020 scenario, and the calculated potential changes relative to the ND full 2020 scenario for the LNF 10% on all farms scenario, the LNF 10% on IPPC farms scenario, the LNF 20% on all farms scenario, the LNF 20% on IPPC farms scenario, the Balfert 2020 scenario and the optimal combination scenario.

Leaching pathway	ND full 2020	LNF 10% all	LNF 10% IPPC	LNF 20% all	LNF 20% IPPC	Balfert 2020	Optimal combination
	kton N	% change compared to ND full 2020					
Manure storage	160	-7	-2	-15	-4	0	-8
Surface runoff	657	-2	0	-4	-1	-6	-8
Small surface water and groundwater	1025	-4	-1	-8	-2	-15	-19
Large surface water	66	-5	-1	-9	-2	-14	-18
Total	1908	-4	-1	-7	-2	-11	-14

The decrease in N input via animal manure and fertilizer in the LNF, Balfert and Optimal Combination 2020 scenarios have a strong effect on the emissions of NH_3, N_2O, NO_X and

CH_4 to the atmosphere and the leaching of N to groundwater and surface waters. Figure 4.3 provides an overview of the changes in the emissions of NH_3, N_2O and NO_X and the leaching of N in these scenarios. Decreases in emissions and leaching are large for the scenarios LNF 20% on all farms 2020, Balfert 2020, and Optimal Combination 2020. Effects of the scenarios LNF 10% and LNF 20% applied to IPPC farms in 2020 only are relatively small.

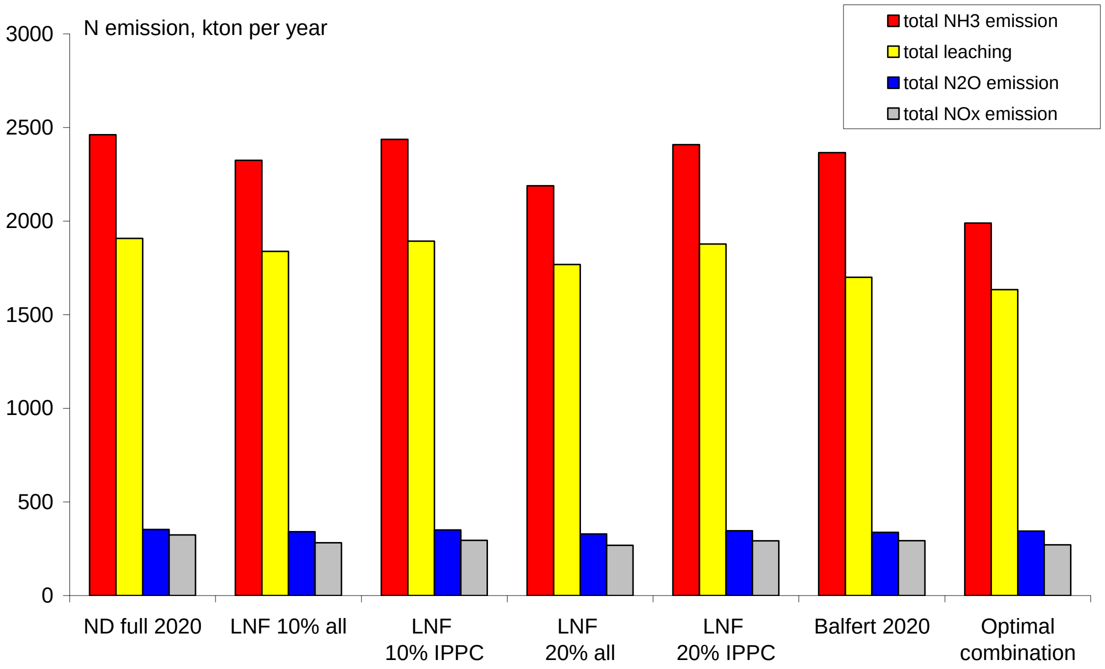

Figure 4.3. Gaseous N losses and N leaching losses from agriculture in the ND full 2020 reference scenario and the LNF, Balfert 2020 and Optimal combination 2020 scenarios. For explanation of scenarios see Table 4.2 and paragraph 4.3.

In Task 3, the ND full 2020 scenario was chosen as the reference scenario. Emissions of NH_3 in the ND full 2020 scenario are 14% lower compared to the reference year 2000 (Table 2.15). The estimated total NH_3 emission from agriculture in this scenario are 2989 kton per year in the EU-27 (Table 4.6), which is roughly ~300 kton NH_3 per year above the calculated emission level in the EU-27 (see Aman et al., 2006b) to achieve the targets of the Thematic Strategy on Air Pollution for NH_3 (see Table 2.3).

The LNF 10% 2020 scenario decreases the emissions of NH_3 at EU-27 level by 6% relative to the ND full 2020 reference scenario, when applied on all farms, and by 1% when applied on IPPC farms only. Doubling the target for low-protein animal feeding to 20% decreases the emissions of NH_3 by 11% and 2%, when applied on all farms and IPPC farms only, respectively (Table 4.6). Clearly, the projected 10% decrease in the emissions of NH_3 in the LNF 20% 2020 on all farms, relative to the ND full 2020 scenario, greatly contributes to achieving the target of the Thematic Strategy on Air Pollution.

The Balfert 2020 scenario and the Optimal Combination 2020 scenario also have large effects on the emissions of NH_3 (Table 4.6) especially in countries with no or a small area of NVZ in 2020 (see Table 2.5). Balfert 2020 decreases the emissions of NH_3 by 4% and the Optimal Combination 2020 scenarios by 19%. Again, the decreases are largest in countries with no or a small area of NVZ in 2020

Table 4.6. Ammonia emission from agriculture in EU-27 in kton NH_3, according to the ND full 2020 scenario, and the calculated changes relative to the ND full 2020 scenario for the LNF 10% on all farms scenario, the LNF 10% on IPPC farms scenario, the LNF 20% on all farms scenario, the LNF 20% on IPPC farms scenario, the Balfert 2020 scenario and the optimal combination scenario.

Country	ND full 2020	LNF 10% all	LNF 10% IPPC	LNF 20% all	LNF 20% IPPC	Balfert 2020	Optimal combination
	kton NH3	% change compared to ND full 2020					
EU-27	2989	-6	-1	-11	-2	-4	-19
Austria	51	-8	0	-15	0	0	-29
Belgium	65	-6	-1	-13	-1	0	-11
Bulgaria	33	-3	0	-5	0	0	-6
Cyprus	5	-6	-3	-11	-5	-25	-39
Czech. Rep	70	-4	-3	-9	-7	-1	-12
Denmark	68	-4	1	-12	0	0	-29
Estonia	9	-4	-3	-8	-6	0	-17
Finland	21	-7	0	-14	-1	0	-14
France	507	-6	-1	-10	-1	-6	-26
Germany	390	-6	-1	-13	-2	0	-11
Greece	38	-4	-1	-7	-2	-11	-26
Hungary	73	-5	-3	-10	-6	-4	-28
Ireland	83	-4	0	-8	-1	0	-19
Italy	341	-5	-1	-11	-3	-5	-18
Latvia	13	-4	-1	-7	-2	0	-29
Lithuania	31	-3	-1	-6	-2	0	-22
Luxembourg	3	-6	0	-12	0	0	-28
Malta	2	-5	0	-10	0	-30	-34
Netherlands	114	-7	-1	-14	-2	0	-11
Poland	281	-6	-1	-13	-2	-8	-21
Portugal	48	-6	-2	-13	-3	-14	-34
Romania	129	-3	0	-6	0	0	-7
Slovakia	27	-5	-3	-11	-6	0	-14
Slovenia	18	-5	0	-10	-1	0	-36
Spain	299	-6	-1	-11	-2	-9	-26
Sweden	41	-8	-1	-15	-2	-2	-11
United Kingdom	228	-6	-2	-12	-4	-1	-15

The N leaching losses decrease in all scenarios examined in this task (Table 4.7). The LNF 10% 2020 scenario decreases N leaching losses at EU-27 level by 4% relative to the ND full 2020 reference scenario, when applied on all farms, and by 1% when applied on

IPPC farms only. Doubling the target for low-protein animal feeding to 20% decreases the N leaching losses by 7% and 2%, when applied on all farms and IPPC farms only, respectively. The Balfert 2020 scenario and the Optimal Combination 2020 scenario have large effects on the N leaching losses, especially in countries with no or a small area of NVZ in 2020. Balfert 2020 decreases the N leaching losses by 11% and the Optimal Combination 2020 scenarios by 14% relative to the reference scenario ND full 2020.

Table 4.7. Leaching losses of N from agriculture in EU-27 in kton N, according to the ND full 2020 scenario, and the calculated potential changes relative to the ND full 2020 scenario for the LNF 10% on all farms scenario, the LNF 10% on IPPC farms scenario, the LNF 20% on all farms scenario, the LNF 20% on IPPC farms scenario, the Balfert 2020 scenario and the optimal combination scenario.

Country	ND full 2020	LNF 10% all	LNF 10% IPPC	LNF 20% all	LNF 20% IPPC	Balfert 2020	Optimal combination
	kton N	% change compared to ND full 2020					
EU-27	1908	-4	-1	-7	-2	-11	-14
Austria	14	-6	0	-12	0	0	-7
Belgium	41	-4	0	-9	-1	0	-5
Bulgaria	40	-2	0	-4	0	-2	-6
Cyprus	4	-4	-2	-7	-4	-37	-40
Czech. Rep	77	-3	-3	-7	-6	-3	-7
Denmark	41	-3	0	-11	-1	0	-2
Estonia	5	-5	-4	-11	-9	0	-10
Finland	5	-2	0	-3	0	0	-1
France	372	-3	0	-6	-1	-16	-19
Germany	215	-2	0	-4	-1	0	-3
Greece	23	-2	0	-4	-1	-13	-14
Hungary	78	-3	-2	-5	-3	-16	-18
Ireland	34	-7	0	-15	-1	0	-13
Italy	159	-4	-1	-7	-2	-13	-16
Latvia	10	-3	-1	-7	-2	-1	-7
Lithuania	22	-3	-1	-6	-2	0	-5
Luxembourg	3	-3	0	-5	0	0	-2
Malta	1	-4	0	-8	0	-46	-48
Netherlands	69	-5	-1	-10	-2	0	-5
Poland	222	-5	-1	-9	-1	-24	-27
Portugal	24	-6	-2	-11	-3	-27	-29
Romania	74	-4	0	-7	0	-1	-9
Slovakia	13	-5	-4	-11	-7	0	-7
Slovenia	5	-2	0	-5	0	0	1
Spain	168	-4	-1	-9	-2	-21	-23
Sweden	9	-5	-1	-9	-1	-8	-13
United Kingdom	181	-4	-1	-7	-2	-6	-10

The N_2O emissions (Table 4.8) decrease also in all scenarios examined in this task. The LNF 10% 2020 scenario decreases the emissions of N_2O at EU-27 level by 4% relative to the ND full 2020 reference scenario, when applied on all farms, and by 1% when applied on IPPC farms only. Doubling the target for low-protein animal feeding to 20% decreases the emissions of N_2O by 7% and 2%, when applied on all farms and IPPC farms only, respectively. The Balfert 2020 scenario decreases the emissions of N_2O by 4% and the Optimal Combination 2020 scenarios by 3% relative to the reference scenario ND full 2020.

Table 4.8. Nitrous oxide emissions from agriculture in EU-27 in kton N_2O-N, according to the ND full 2020 scenario, and the calculated potential changes relative to the ND full 2020 scenario for the LNF 10% on all farms scenario, the LNF 10% on IPPC farms scenario, the LNF 20% on all farms scenario, the LNF 20% on IPPC farms scenario, the Balfert 2020 scenario and the optimal combination scenario.

Country	ND full 2020	LNF 10% all	LNF 10% IPPC	LNF 20% all	LNF 20% IPPC	Balfert 2020	Optimal combination
	kton N	% change compared to ND full 2020					
EU-27	354	-4	-1	-7	-2	-4	-3
Austria	4	-5	0	-10	0	0	10
Belgium	7	-4	-1	-8	-1	0	-1
Bulgaria	5	-2	0	-3	0	0	-4
Cyprus	1	-4	-3	-8	-5	-24	-22
Czech. Rep	9	-3	-3	-7	-6	-1	-2
Denmark	8	-3	0	-8	-1	0	5
Estonia	1	-3	-3	-6	-5	0	-1
Finland	3	-3	0	-5	-1	0	3
France	62	-4	0	-7	-1	-6	0
Germany	43	-3	-1	-6	-1	0	-2
Greece	7	-1	0	-3	-1	-7	-4
Hungary	11	-3	-2	-7	-4	-8	0
Ireland	12	-3	0	-6	-1	0	-2
Italy	31	-4	-1	-8	-3	-5	-5
Latvia	1	-3	-1	-5	-1	0	11
Lithuania	3	-2	-1	-4	-2	0	6
Luxembourg	0	-3	0	-6	0	0	8
Malta	0	-4	0	-9	0	-35	-39
Netherlands	15	-5	-2	-11	-4	0	-3
Poland	30	-5	-1	-10	-2	-12	-12
Portugal	5	-5	-1	-10	-3	-12	-2
Romania	15	-2	0	-5	0	0	-5
Slovakia	3	-4	-3	-7	-5	0	-2
Slovenia	1	-3	0	-6	0	0	14
Spain	34	-4	-1	-8	-2	-10	-4
Sweden	5	-4	-1	-8	-2	-5	-8
United Kingdom	36	-4	-1	-7	-3	-2	-3

The CH_4 emissions from agriculture (not shown) were only slightly (changes < 1%) affected in scenarios examined in this task. The non-response is related to the facts that the number of (ruminant) animals do not change in the LNF 2020, Balfert 2020and Optimal Combination 2020 scenarios, relative the reference scenario ND full 2020, and that MITERRA-EUROPE does not account for possible effects of low-protein animal feeding on CH_4 emissions.

Table 4.9. Relative surpluses of manure N, in per cent of the total N excretion per Member State, in the ND partial 2010 and ND full 2020 scenarios and the WFD 2020 scenario. These relative amounts of manure N have to be treated and/or removed (see text).

	Surplus amount of manure N, %						
Country	ND full	LNF 10%	LNF 10%	LNF 20%	LNF 20%	Balfert	Optimal
Austria	-2	-1	-2	-1	-2	-2	-1
Belgium	-21	-18	-21	-16	-20	-21	-18
Bulgaria	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	-28	-28
Czech. Rep	0	0	0	0	0	0	0
Denmark	-6	-2	-6	0	-5	-6	-4
Estonia	0	0	0	0	0	0	0
Finland	-10	-9	-10	-9	-10	-10	-10
France	-13	-12	-13	-9	-12	-18	-17
Germany	-7	-6	-7	-5	-7	-7	-6
Greece	-4	-4	-4	-4	-4	-13	-13
Hungary	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0
Italy	-1	-1	-1	-1	-1	-5	-5
Latvia	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0
Malta	0	0	0	0	0	-41	-41
Netherlands	-14	-13	-14	-12	-14	-14	-13
Poland	0	0	0	0	0	-1	-1
Portugal	0	0	0	0	0	-18	-18
Romania	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0
Slovenia	-8	-7	-8	-7	-8	-8	-9
Spain	0	0	0	0	0	-10	-10
Sweden	0	0	0	0	0	-2	-2
United Kingdom	0	0	0	0	0	0	0

As indicated before, strict implementation of the ND full 2020 and Balfert 2020 has consequences for the amounts of animal manure that can be disposed properly within NVZs and outside the designated NVZs in Member States of the EU-27 (see also Table 4.4). The amounts of animal manure that can be applied depend also on the types of crops and on the N demand by the crops. Table 4.9 provides an overview of the relative surpluses of manure N in the Member States in the EU-27 for the various scenarios. Note that the surpluses are relative to the amounts of N excreted, which may differ between different scenarios. In the ND full scenario, relatively large relative surpluses are observed for Belgium and the Netherlands, but also for France Finland and Germany. The latter countries have regionally surpluses of manure N. Relative manure surpluses decrease in the LNF scenarios, because of less N in the animal manure, relative to the reference scenario ND full 2020. In the Balfert 2020 scenario, relative large surpluses emerge for some Member States with no or small NVZs. Please note that the results for Malta and Cyprus are at odd, because of inconsistency in the statistical data.

Summarizing, the results of the scenarios analysed in this chapter clearly indicate that both low-protein animal feeding and balanced N fertilization and an optimal combination of NH_3 emission abatement techniques with balanced N fertilization have synergistic effects and decrease the emissions of N_2, NH_3, N_2O and NO_x to the atmosphere and of N leaching to groundwater and surface waters simultaneously. Hence, no pollution swapping occurs. Further, balanced N fertilization has larger effects on N losses via leaching and denitrification than on N losses via the emissions of NH_3, N_2O and NO_x. Low-protein animal feeding has a rather steady and constant effect on all N loss pathways. It decreases the amount of N in animal manure (Table 4.4).

Implementation of balanced N fertilization as defined in this study decreases N fertilizer use (Table 4.4), and in some areas also the amounts of applied manure N. As indicated before, it is assumed that the decrease of applied manure N is ‘treated and taken out of agriculture’ or ‘not produced to low-protein animal feeding’. Evidently, these assumptions have large implications for agriculture. In general, lowering the amount of manure N via low-protein animal feeding has lower costs than treatment and disposal of the manure N to elsewhere. However, lowering the protein-content of the animal feed requires investments in knowledge and feed technology.

4.5. Results of the scenario analyses by CAPRI

The scenarios indicated in Table 4.3 have also been calculated with CAPRI except for the scenario 'LNF 20% applied to IPPC farms only'. The scenario 'LNF 20% applied to IPPC farms only' is considered to be somewhat "optimistic" (unrealistic) on a relatively short term, because it may be expected that IPPC farms are already quite efficient in the current situation (near the technical limit).

The CAPRI results provide an integrated assessment of economic and environmental impacts. Both, the economic and environmental impacts of a scenario are presented in one table. The impacts will be given for:

- Agricultural income;
- Gaseous emissions (NH_3, N_2O, CH_4) to the atmosphere and leaching of N to groundwater and surface waters; and
- Other affected variables of interest (mineral fertiliser, selected activity levels).

In the following discussion we focus on the impacts of the most promising measures relative to the ND full 2020 scenario and give results in terms of absolute changes and percentage changes as both can be interesting depending on the question.

The implementation of **balanced fertilization** (Balfert 2020) in the whole area has only effects in areas not covered by NVZs. As a consequence this is manly a regional extension of the ND full 2020 scenario to additional areas. Overall the CAPRI simulation gives a 9% decrease in EU27 mineral fertilizer use compared to the ND full reference situation. Impacts on mineral fertiliser use in Member States tend to be larger (i) the smaller the initial NVZ share, (ii) the larger the initial overfertilisation, and (iii) the smaller the share of mineral fertiliser in total N supply Table (4.10).

In terms of regional variation we have to admit that the data situation in Cyprus and Malta is quite difficult and that the percentage declines of 86% and 51% in Table 4.10 are overstated. CAPRI does include some safeguards in the form of minimum requirements from mineral fertilizer but these safeguards turned out to have loopholes for the particular situation of these countries.

Agricultural income is expected to decline by about 1.5% or 3.1 billion €. Acknowledging the uncertainties in these simulations this gives for a Euro of income loss about 50 g less leaching, 20 g less NH_3 emissions and 6 g less N_2O emissions.

Table 4.10: Simulation results of CAPRI for the scenario balanced fertilization (Balfert 2020) vs. ND full 2020

Absolute change Balfert vs. ND full 2020

	agric income [m €]	'other' costs [m €]	'net' dir cost [m €]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-3058	3877	3103	-888	-1	-53	-1	-19	-157
Austria	0	0	-1	0	0	0	0	0	0
Belgium	12	22	-11	-25	0	-1	0	-1	-7
Bulgaria	-136	198	140	-40	0	-2	0	-1	-9
Cyprus	2	5	-6	-7	-1	0	0	0	-1
Czech. Rep	-95	118	97	-41	0	-2	0	-1	-11
Denmark	2	0	-1	0	0	0	0	0	0
Estonia	-26	27	26	-1	0	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0
France	-358	500	366	-127	0	-6	0	-3	-28
Germany	2	0	-4	0	0	0	0	0	0
Greece	-180	199	182	-22	0	-1	0	0	-2
Hungary	-110	139	114	-36	0	-1	0	-1	-6
Ireland	-4	2	4	-1	0	0	0	0	0
Italy	-359	436	356	-95	0	-9	0	-2	-16
Latvia	-42	47	43	-5	0	0	0	0	-1
Lithuania	2	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0
Netherlands	-2	0	-1	0	0	0	0	0	0
Poland	-506	605	526	-142	0	-10	0	-3	-25
Portugal	-115	140	116	-25	0	-1	0	-1	-3
Romania	-529	576	527	-47	0	-3	0	-1	-10
Slovakia	-31	37	33	-6	0	0	0	0	-1
Slovenia	0	0	0	0	0	0	0	0	0
Spain	-482	660	491	-209	-1	-16	0	-4	-27
Sweden	-37	53	37	-13	0	0	0	0	-1
United Kingdom	-67	113	67	-46	0	-1	0	-1	-8

Percentage change Balfert vs. ND full 2020

	agric income [%]	'other' costs [%]	'net' dir cost [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-1.5	11.2	2.6	-8.6	0.0	-1.8	0.0	-2.6	-15.0
Austria	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0
Belgium	0.3	5.5	-0.3	-19.4	0.0	-0.7	0.0	-3.2	-14.4
Bulgaria	-5.1	76.9	14.3	-20.1	0.0	-4.3	0.0	-7.5	-49.6
Cyprus	0.5	11.2	-3.1	-86.4	-2.4	-10.5	-1.5	-16.3	-43.4
Czech. Rep	-5.4	22.5	6.1	-12.3	0.0	-4.8	0.0	-6.2	-36.5
Denmark	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Estonia	-12.4	84.5	16.2	-5.6	0.1	-0.6	0.1	-2.0	-7.7
Finland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
France	-1.1	8.1	1.6	-5.9	0.0	-1.2	0.0	-2.2	-16.1
Germany	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Greece	-1.7	82.1	10.1	-11.5	0.0	-2.6	0.0	-4.0	-20.9
Hungary	-2.8	14.6	3.9	-8.2	0.0	-2.0	0.1	-3.4	-24.5
Ireland	-0.1	0.3	0.1	-0.3	0.0	0.0	0.0	0.0	-0.4
Italy	-1.0	13.8	3.1	-12.9	0.0	-2.5	0.0	-3.5	-20.3
Latvia	-16.3	66.1	19.1	-11.3	0.0	-3.1	0.0	-3.3	-23.3
Lithuania	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malta	0.5	5.1	-1.1	-51.0	0.0	0.0	0.0	-11.1	-15.8
Netherlands	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1
Poland	-5.9	183.1	11.6	-14.3	-0.1	-4.0	-0.1	-4.8	-29.7
Portugal	-2.9	11.5	3.8	-24.4	0.0	-2.5	-0.1	-4.9	-26.3
Romania	-9.4	41.4	13.2	-9.8	0.0	-3.2	0.0	-3.4	-26.6
Slovakia	-4.6	12.0	4.5	-5.5	0.0	-1.3	0.0	-2.3	-13.9
Slovenia	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Spain	-1.2	43.2	4.3	-27.0	0.0	-4.9	0.0	-6.2	-27.1
Sweden	-2.4	5.8	1.7	-7.8	0.0	-0.3	0.0	-2.6	-23.4
United Kingdom	-0.7	2.7	0.7	-5.6	0.0	-0.6	0.0	-1.4	-6.6

The regional variation of agricultural income effects in the scenario balanced fertilization relative to the ND full 2020 reference is shown in the Figure 4.4. It is evident that the percentage losses are lowest where NVZs were enforcing balanced fertilization already in the reference situation (green = gains in income, losses increasing with red colour). Other factors such as the economic weight of the crop sector operate to modify these impacts but appear to be less important than the initial NVZ share.

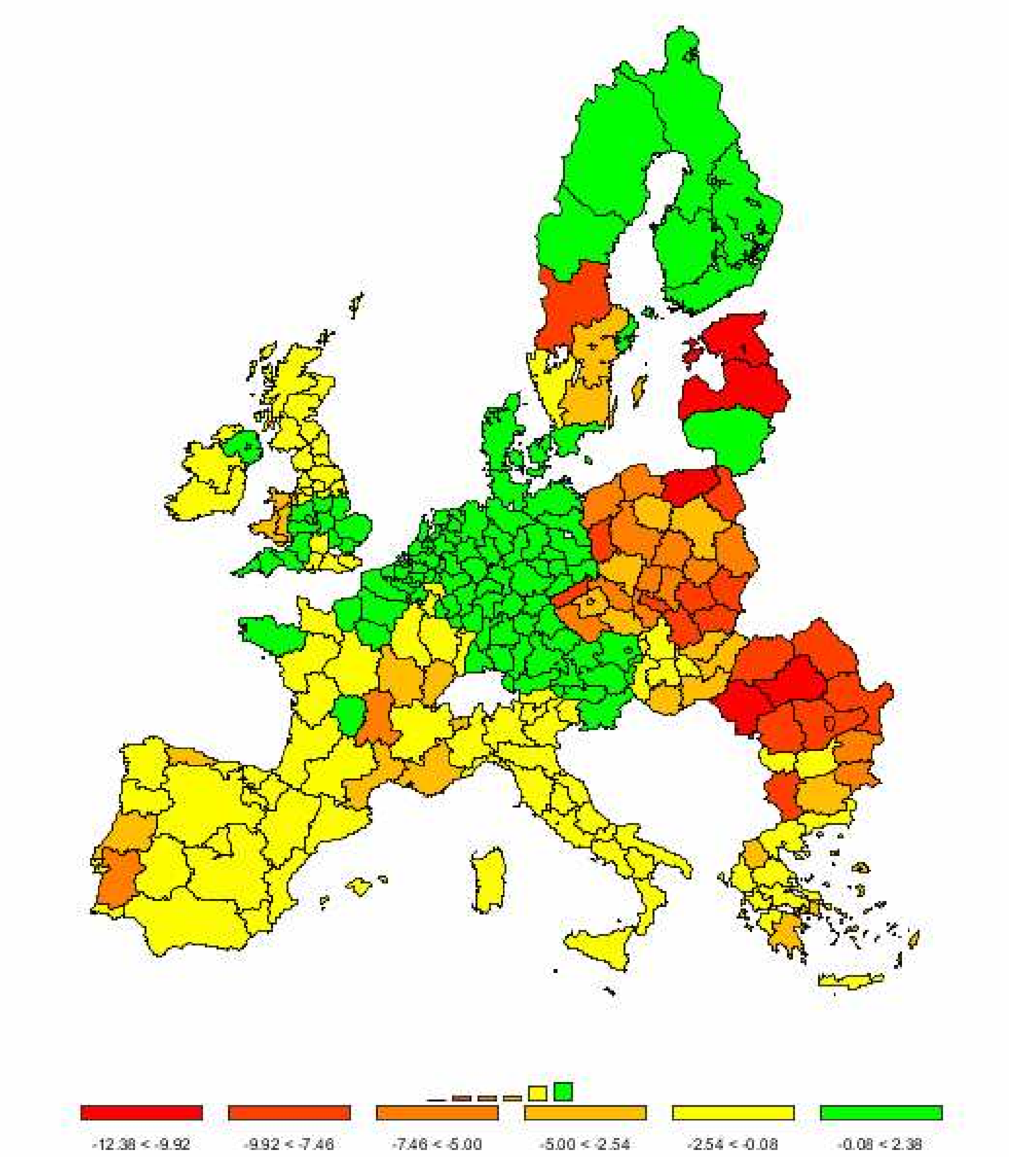

Figure 4.4. Regional variation of percentage income effects for scenario BALFERT relative to ND full 2020. (Bars illustrate the distribution)

Table 4.11 gives the changes of main components of agricultural income for scenario Balfert 2020.

Table 4.11. Contributions to agricultural income according to CAPRI simulations for the scenario balanced fertilization (Balfert 2020) vs. ND full 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [change]	Unit value EAA [change]	Quantity [change]
European Union 27						
Production value	426383			0.0%		
Cereals	35863	106	339507	0.0%	0.2%	-0.2%
Other non fodder	157162	252	624354	0.0%	0.0%	0.0%
Fodder	18944	9	2144968	0.1%	0.0%	0.1%
Meat	74266	1616	45947	0.0%	0.0%	0.0%
Other Animal products	59045	271	217684	-0.1%	-0.1%	0.0%
Other output	81103	164	494052	0.1%	0.1%	0.0%
Inputs	261324			1.2%		
Fertiliser	39283	819	47951	-1.7%	0.0%	-1.7%
Feedingstuff	72481	47	1545314	-0.1%	-0.2%	0.1%
Other input	149560	281	532491	2.6%	2.1%	0.5%
European Union 15						
Production value	370370			0.0%		
Cereals	26627	111	240085	0.0%	0.0%	0.0%
Other non fodder	140660	263	534942	0.0%	0.0%	0.0%
Fodder	15813	9	1767083	0.1%	0.0%	0.1%
Meat	64587	1682	38401	0.0%	0.0%	0.0%
Other Animal products	50905	276	184382	-0.1%	-0.1%	0.0%
Other output	71777	173	413886	0.0%	0.0%	0.0%
Inputs	224756			0.7%		
Fertiliser	31818	850	37423	-1.4%	0.0%	-1.4%
Feedingstuff	63094	48	1325855	-0.1%	-0.1%	0.1%
Other input	129845	289	448615	1.6%	1.3%	0.3%
European Union 12						
Production value	56013			0.0%		
Cereals	9236	93	99422	-0.1%	0.4%	-0.5%
Other non fodder	16502	185	89412	0.0%	0.1%	-0.1%
Fodder	3131	8	377885	0.1%	0.1%	0.0%
Meat	9679	1283	7546	0.0%	0.1%	-0.1%
Other Animal products	8140	244	33302	-0.1%	0.0%	0.0%
Other output	9326	116	80166	0.3%	0.4%	-0.1%
Inputs	36567			4.1%		
Fertiliser	7465	709	10528	-2.9%	-0.1%	-2.8%
Feedingstuff	9387	43	219458	-0.1%	-0.3%	0.2%
Other input	19715	235	83876	8.7%	7.4%	1.3%

It is evident that the impacts of this scenario are estimated to be quite small both in the crop and livestock sector. The impact on fertiliser is much smaller than the 9% reduction mentioned above first because non nitrogen fertilisers are not directly affected and more importantly because the fertiliser value and quantity given in Table 4.11 includes the imputed value *plant available manure* (both on the input and output side). The increase in ‘other input’ mainly derives from our assumptions on additional management effort needed to bring about this change in agricultural farming practice.

The change in agricultural income is one component of the total change in ‘economic welfare’ (Table 4.12).

Table 4.12: Contributions to the change in conventional economic welfare according to CAPRI simulations for the scenario balanced fertilization (Balfert 2020) vs. ND full 2020 [million €]

	EU27	EU15	EU12
Total	-3056	-1559	-1497
Consumer money metric	-26	-9	-17
Agricultural income	-3058	-1588	-1470
Premiums	12	1	11
Agricultural Output	52	38	15
Output crops	27	37	-10
Output animals	25	0	25
Output rest	0	0	0
Agricultural Input	3123	1626	1496
Crop specific Input	-679	-456	-223
Animal specific Input	-42	-37	-5
Other Input	3844	2119	1725
'Net' direct cost	3103	1603	1500
Profit of dairies	-1	-1	0
Profit of other processing	34	36	-2
Tariff revenues	-2	-6	4
FEOGA first pillar	3	-8	11

In this scenario, consumers, the processing industry and the budget are hardly affected such that the total welfare effect is almost equal to the impact on agriculture. Note that the budget impacts do not include estimated for the required additional efforts of the public advisory system such that the above welfare cost is underestimated to some extent. However, note also that the benefits of this and other scenarios in terms of reduced emissions have not been monetised. Finally the row ‘net’ direct cost shows that in this scenario the total welfare effects are almost identical to the ‘net’ direct cost, i.e. the additional costs for higher managerial effort net of the savings in fertiliser cost. This is to be expected if the price effects are very small.

Low-protein animal feeding as measure to decrease N excretion will be promoted through agri-environmental programs and additional advisory work. It is assumed that farmers do not compensate the decrease in N supply to crops, following the decrease in the N content of the animal manure, through increased application of mineral fertilizers. Everything else equal, mineral N fertilizer use would be more or less constant therefore following implementation of low-protein animal feeding.

However, increased efficiency in protein use also implies that protein need is decreasing which would lead to some substitution among fodder types. Protein rich feed decreases in use and some others also increase. Among the protein rich feed is grass which is partly replaced with other feedstuffs such that grass production would become less intensive. This indirect effect from reduced demand for protein rich grass is the main reason why mineral fertilizer use would actually decline somewhat in the low protein scenarios.

Increased efficiency has also the effect that, in particular in ruminant feeding, some expensive feedstuffs may be replaced with cheaper ones such that there would be some savings on protein rich feedstuffs. Remember that the CAPRI simulations try to capture not only optimization of feeding practice in the intensive pigs and poultry sectors but also the avoidance of 'waste' in some form on cattle farms. For those there would be an increase in management efforts (included under the heading of 'feed related' cost) but at the same time there would be some cost savings, provided the change in feeding practice will come about. As current inefficiency is more widespread in the cattle sector, these cost saving effects tend to benefit the cattle sector, whereas intensive livestock farming is already operating closer to the technological limit. These differences change the relative profitability in the livestock sector. For a decline in the protein surplus from 10% to 5% (which may hold for the pig sector in a country) we would apply the same mark-up of feed cost as for a decline from 30% to 15% because the relative cut of the surplus is the same (50%). However the efficiency gain would benefit the cattle sector. As a consequence we see in many countries a small increase of beef production and at the same time a decline in pork production (Table 4.13). Correspondingly EU prices of beef are slightly decreasing (-2.0% in LNF10 all) while pork prices are increasing (+4.7%).

Total excretion is evidently decreasing in the LNF scenarios which makes the largest contribution to the improvement in the nitrogen balance (-830 ktons or -7% in LNF10 all for EU27) but the above mentioned decline in mineral fertiliser use adds another 210 ktons. Total ammonia emissions are expected to decline by 7% whereas leaching is declining by 12% under LNF10 all. The latter effect on leaching is larger than according to MITERRA-EUROPE, among other reasons because mineral fertilizer is slightly increasing on aggregate in MITERRA-EUROPE (+1%) whereas it is somewhat decreasing in CAPRI (-2% on aggregate). Some differences also stem from the definition of leaching in the tables which does not include the runoff parts in CAPRI which are included in Miterra-Europe[22].

The regional differences among countries in the LNF scenarios are first of all due to the different initial protein and energy surplus situations as estimated in the CAPRI database (see Figure 4.2) because these determine the relative cut factors applied to each animal. However changes in activity level may modify these 'first round' effects. In the case of the Czech Republic we see from Figure 4.2 that for some activities there will not be any surplus at all and thus not a cut in protein supply (which does not hold for the cattle sector). If excretion is increasing here, this is because producers benefit from the price increases without suffering from large cost increases such that they will tend to increase production. In other cases some decline in production contributes to the reduction in excretions in particular if both beef and pork production would decline (Spain, Portugal). The exceptional decline in mineral fertilizer use in Ireland is due to the importance of grassland in this country. The 13% decline under 'LNF10 all' in Cyprus is probably also attributable to a peculiar data situation.

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[22] Runoff is included in CAPRI but it is not aggregated with leaching below the rooting zone.

Table 4.13. Simulation results of low nitrogen feeding (LNF 10% 2020, all farms) vs. ND full 2020.

Absolute change LNF10 all vs. ND full 2020

	agric income [m €]	'net' dir cost [m €]	beef prod [kton]	pork prod [kton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-6425	6267	72	-450	-208	-827	-203	53	-35	-120
Austria	-61	115	2	5	0	-16	-4	2	-1	-1
Belgium	-124	205	-3	9	-2	-17	-3	-3	-1	-4
Bulgaria	-65	41	-1	0	-5	-7	-2	0	0	-1
Cyprus	-24	17	0	-5	0	-3	-1	-1	0	0
Czech. Rep	-70	45	3	-2	-6	0	0	3	0	-1
Denmark	-116	68	1	-125	2	-29	-7	-2	-1	-5
Estonia	-8	6	0	0	0	-1	0	0	0	0
Finland	-98	88	-2	-2	0	-5	-1	-2	0	0
France	-976	965	-8	7	-6	-111	-25	-1	-4	-14
Germany	-880	832	2	-213	-11	-113	-34	-3	-4	-15
Greece	-196	173	2	0	-12	-14	-3	1	-1	-1
Hungary	-154	130	-1	-22	-3	-10	-3	0	0	-1
Ireland	-578	606	56	-18	-70	-22	-7	38	-3	-9
Italy	-714	667	4	-10	6	-103	-28	-17	-4	-10
Latvia	-3	4	0	0	-5	-1	-1	1	0	-1
Lithuania	-35	17	0	0	-3	-5	-1	0	0	-2
Malta	-2	3	0	0	0	0	0	0	0	0
Netherlands	-147	261	1	-17	-2	-31	-6	0	-1	-6
Poland	-378	272	0	-15	-8	-48	-16	-5	-2	-6
Portugal	-152	145	-2	-7	-1	-24	-6	-2	-1	-2
Romania	-339	177	6	2	-2	-8	-2	3	0	-1
Slovakia	-11	10	0	-1	-1	-3	-1	0	0	-1
Slovenia	-14	20	-1	1	0	-4	-1	0	0	0
Spain	-842	842	-9	-33	-25	-157	-30	-5	-6	-18
Sweden	-80	114	4	4	6	-11	-3	4	0	0
United Kingdom	-358	443	19	-8	-62	-85	-19	40	-5	-22

Percentage change LNF10 all vs. ND full 2020

	agric income [%]	'net' dir cost [%]	beef prod [%]	pork prod [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-3.2	5.2	0.8	-1.9	-2.0	-8.0	-6.8	0.5	-4.8	-11.6
Austria	-2.0	5.0	1.3	1.0	0.2	-7.4	-7.0	1.0	-4.4	-12.7
Belgium	-3.5	6.1	-1.1	0.8	-1.7	-5.3	-4.4	-1.0	-4.1	-7.2
Bulgaria	-2.5	4.2	-1.0	0.0	-2.5	-5.1	-4.2	-0.1	-3.2	-8.0
Cyprus	-6.1	8.9	-1.8	-27.3	5.6	-13.0	-14.4	-3.0	-8.7	-10.0
Czech. Rep	-4.0	2.8	6.1	-0.4	-1.7	0.1	-0.6	3.7	-1.0	-2.9
Denmark	-3.6	1.7	0.6	-6.5	1.2	-8.3	-8.2	-1.3	-5.3	-11.5
Estonia	-4.0	3.7	-0.8	-0.6	-0.5	-7.4	-6.3	-0.7	-4.0	-7.4
Finland	-7.5	4.1	-2.3	-1.2	0.4	-6.9	-6.0	-2.2	-3.0	-8.1
France	-2.9	4.2	-0.4	0.3	-0.3	-6.8	-4.9	-0.1	-3.1	-7.9
Germany	-4.9	4.2	0.1	-4.6	-0.6	-7.8	-7.0	-0.2	-4.0	-12.5
Greece	-1.9	9.6	3.3	-0.4	-6.2	-8.7	-8.4	0.8	-6.2	-13.1
Hungary	-4.0	4.5	-1.6	-2.7	-0.7	-5.6	-4.3	-0.5	-2.2	-4.8
Ireland	-21.9	19.7	8.5	-6.6	-26.6	-4.2	-6.1	6.7	-9.1	-32.2
Italy	-1.9	5.7	0.4	-0.6	0.8	-11.5	-8.1	-2.0	-6.5	-13.4
Latvia	-1.2	1.9	-2.0	0.9	-9.6	-5.0	-7.0	5.5	-6.6	-21.2
Lithuania	-5.3	2.5	0.6	-0.4	-2.8	-7.9	-6.2	-0.3	-3.4	-14.4
Malta	-2.8	11.8	-2.6	-3.2	0.0	-9.7	-9.2	-1.4	-11.1	-5.3
Netherlands	-1.4	3.8	0.4	-1.3	-1.0	-7.0	-6.8	0.1	-5.5	-8.4
Poland	-4.4	6.0	-0.2	-0.8	-0.8	-8.4	-6.2	-1.2	-3.4	-7.3
Portugal	-3.8	4.8	-1.7	-1.9	-0.9	-11.9	-10.7	-0.9	-8.1	-14.5
Romania	-6.0	4.4	2.2	1.1	-0.3	-2.9	-1.8	1.0	-1.2	-2.3
Slovakia	-1.6	1.3	0.9	-0.4	-0.8	-6.8	-5.3	0.9	-2.5	-7.0
Slovenia	-2.5	6.0	-2.6	4.8	-2.0	-7.9	-6.6	0.4	-5.8	-16.6
Spain	-2.1	7.4	-1.0	-0.9	-3.2	-11.5	-9.5	-0.4	-8.3	-17.6
Sweden	-5.3	5.1	2.6	1.8	3.5	-7.5	-7.4	3.0	-2.7	-1.6
United Kingdom	-3.6	4.4	2.9	-1.4	-7.7	-8.2	-8.8	3.5	-6.6	-18.1

Figure 4.5 shows the regional distribution of income effects against the ND full reference. It is evident that agriculture rarely gains from the LNF scenario. Exceptions are possible if countries are little affected by increasing feed and management cost but benefit from the general price increase on meat markets.

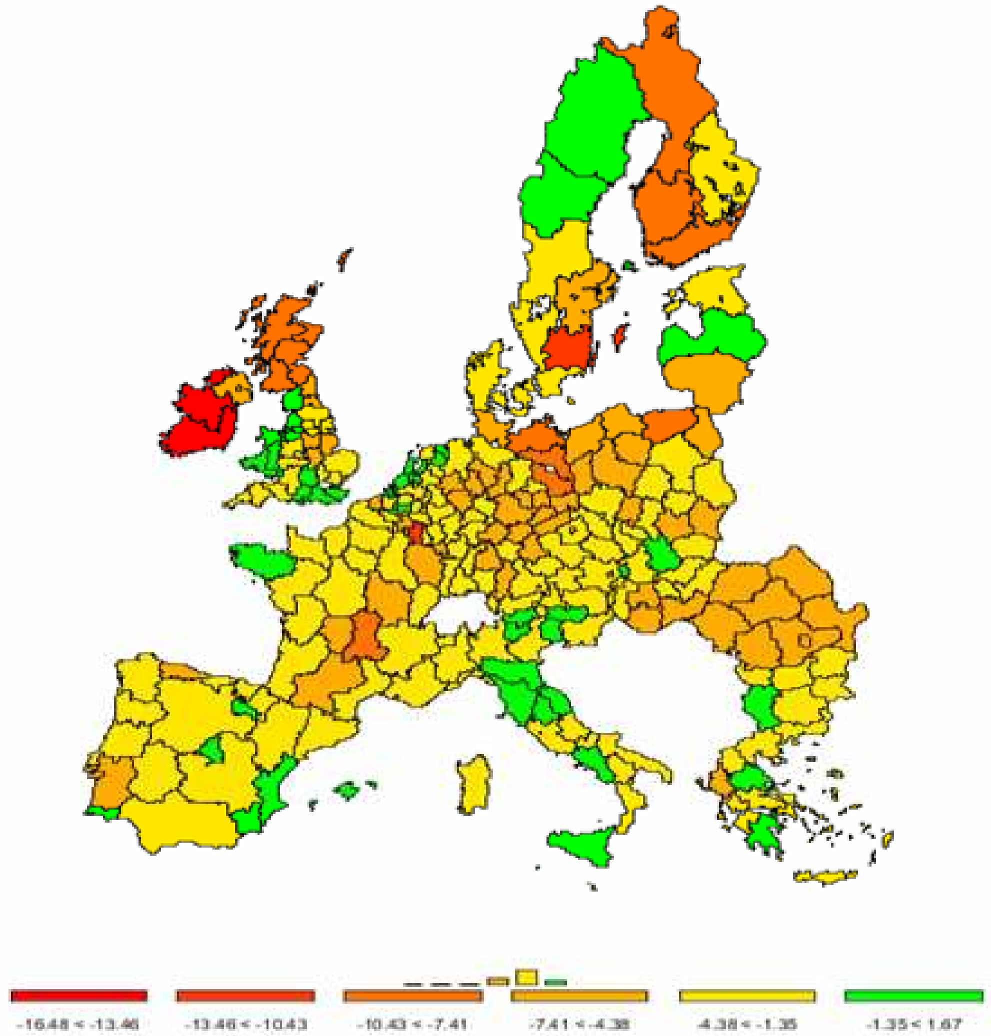

Figure 4.5. Regional variation of percentage income effects for scenario LNF10, all farms, relative to ND full 2020. (Bars illustrate the distribution)

Table 4.14 gives the changes of main components of agricultural income from scenario LNF10.

Table 4.14: Contributions to agricultural income according to CAPRI simulations for the low nitrogen reduction target of 10% in all farms (LNF10, all) vs. ND full 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	426383			-0.2%		
Cereals	35863	106	339507	-6.6%	-6.0%	-0.7%
Other non fodder	157162	252	624354	0.1%	-0.3%	0.4%
Fodder	18944	9	2144968	-1.9%	0.6%	-2.4%
Meat	74266	1616	45947	1.4%	2.6%	-1.2%
Other Animal products	59045	271	217684	2.1%	2.0%	0.1%
Other output	81103	164	494052	-0.9%	0.3%	-1.1%
Inputs	261324			2.1%		
Fertiliser	39283	819	47951	-1.1%	0.0%	-1.1%
Feedingstuff	72481	47	1545314	-7.5%	-6.2%	-1.4%
Other input	149560	281	532491	7.6%	6.9%	0.6%
European Union 15						
Production value	370370			-0.2%		
Cereals	26627	111	240085	-6.1%	-5.6%	-0.6%
Other non fodder	140660	263	534942	0.1%	-0.2%	0.3%
Fodder	15813	9	1767083	-1.8%	0.7%	-2.5%
Meat	64587	1682	38401	1.3%	2.6%	-1.3%
Other Animal products	50905	276	184382	2.2%	2.1%	0.1%
Other output	71777	173	413886	-1.0%	0.2%	-1.2%
Inputs	224756			2.1%		
Fertiliser	31818	850	37423	-1.1%	0.1%	-1.2%
Feedingstuff	63094	48	1325855	-7.5%	-6.1%	-1.5%
Other input	129845	289	448615	7.5%	6.8%	0.7%
European Union 12						
Production value	56013			-0.6%		
Cereals	9236	93	99422	-8.1%	-7.1%	-1.0%
Other non fodder	16502	185	89412	0.4%	-0.5%	0.9%
Fodder	3131	8	377885	-2.2%	-0.1%	-2.1%
Meat	9679	1283	7546	2.4%	2.9%	-0.5%
Other Animal products	8140	244	33302	1.4%	1.5%	-0.1%
Other output	9326	116	80166	0.5%	1.3%	-0.8%
Inputs	36567			2.1%		
Fertiliser	7465	709	10528	-0.8%	0.0%	-0.8%
Feedingstuff	9387	43	219458	-7.7%	-6.9%	-0.8%
Other input	19715	235	83876	7.9%	7.2%	0.6%

The LNF scenarios have stronger market impacts because feed demand would be reduced, at least in terms of quantities. As a consequence cereal prices decline by about 6% which contributes to the loss in agricultural income. On the input side we see a decline in the demand for feedingstuff which implies some savings in cost. However, feed quality and quality of management has to increase which is covered under ‘other input’ giving on balance an increase in costs to agriculture.

The change in agricultural income is one component of the total change in 'economic welfare' (Table 4.15)

Table 4.15: Contributions to the change in conventional economic welfare according to CAPRI simulations for the low nitrogen reduction target of 10% in all farms (LNF10) vs. ND full 2020 [million €]

	EU27	EU15	EU12
Total	-11505	-9899	-1606
Consumer money metric	-2841	-2507	-334
Agricultural income	-6425	-5323	-1103
Premiums	8	-2	10
Agricultural Output	-968	-620	-348
Output crops	-2576	-1835	-741
Output animals	1608	1215	393
Output rest	0	0	0
Agricultural Input	5465	4701	765
Crop specific Input	-426	-359	-67
Animal specific Input	-6080	-5434	-646
Other Input	11971	10493	1478
'Net' direct cost	6267	5526	741
Profit of dairies	36	31	5
Profit of other processing	-1974	-1813	-161
Tariff revenues	56	59	-3
FEOGA first pillar	356	346	10

In this scenario significant market impacts have to be expected as mentioned above. In addition to the impacts on agriculture there is a loss in consumer welfare. Furthermore the processing industry, in particular for processing of oilseeds would also be affected by decreasing prices for protein rich feedstuffs. Impacts on the budget are moderate and mainly derive from additional export subsidies on cereals and meat. As under the BALFERT scenario we have to note that the budget impacts do not include estimates for additional advisory efforts and at the same time do not of the public advisory system such that the above welfare cost are underestimated to some extent. However, note also that the benefits of this and other scenarios in terms of reduced emissions have not been monetised. Due to significant impacts on consumers and the processing industry the overall welfare effects considerably exceed the 'net' direct cost of low nitrogen feeding. In the case of low nitrogen feeding these costs are mainly for higher quality of feed and management but net of some savings in quantities and also mineral fertiliser.

Moving to the partial implementation of LNF for IPPC farms only (with extended coverage according to '*IPPC2 2020*' in section 5 of the main report) we find much weaker impacts in general but basically a quite similar picture in qualitative terms (Table 4.16).

Table 4.16: Simulation results of low nitrogen feeding (LNF 10% 2020, IPPC farms) vs. ND full 2020

Absolute change LNF10 IPPC2 vs. ND full 2020

	agric income [m €]	'net' dir cost [m €]	beef prod [kton]	pork prod [kton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-397	1196	17	-88	-27	-106	-35	16	-6	-15
Austria	26	9	0	2	-1	0	0	0	0	0
Belgium	-4	37	0	0	0	-1	0	0	0	0
Bulgaria	7	-3	0	1	-1	0	0	0	0	0
Cyprus	-3	3	0	-2	0	-1	0	0	0	0
Czech. Rep	-10	20	1	0	-2	0	0	1	0	-1
Denmark	-5	16	0	-26	0	-6	-1	0	0	-1
Estonia	-2	2	0	0	0	-1	0	0	0	0
Finland	4	12	0	2	0	0	0	0	0	0
France	51	129	3	7	-4	-2	-1	3	0	-1
Germany	-56	197	3	-18	-2	-17	-5	1	-1	-2
Greece	-1	14	0	0	-1	0	0	0	0	0
Hungary	-38	53	0	-9	0	-4	-1	0	0	0
Ireland	-42	51	4	-9	-5	1	0	4	0	0
Italy	-124	176	-1	-23	0	-19	-7	-1	-1	-2
Latvia	0	1	0	0	0	0	0	0	0	0
Lithuania	-2	3	0	0	0	-1	0	0	0	0
Malta	0	0	0	0	0	0	0	0	0	0
Netherlands	-10	47	0	-1	0	-6	-1	0	0	-1
Poland	-8	48	0	4	-1	-6	-2	0	0	-1
Portugal	-15	29	0	2	0	-2	-1	0	0	0
Romania	9	2	1	2	-1	1	0	1	0	0
Slovakia	-2	5	0	0	0	-2	-1	0	0	0
Slovenia	4	2	0	0	0	0	0	0	0	0
Spain	-118	205	1	-21	-4	-22	-7	1	-1	-2
Sweden	2	16	0	1	1	-1	0	0	0	0
United Kingdom	-61	121	3	0	-6	-17	-6	5	-1	-3

Percentage change LNF10 IPPC2 vs. ND full 2020

	agric income [%]	'net' dir cost [%]	beef prod [%]	pork prod [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-0.2	1.0	0.2	-0.4	-0.3	-1.0	-1.2	0.2	-0.8	-1.4
Austria	0.8	0.4	0.2	0.5	-0.9	0.1	0.1	0.2	-0.1	-0.4
Belgium	-0.1	1.1	0.1	0.0	-0.3	-0.3	-0.3	0.0	-0.4	-0.5
Bulgaria	0.3	-0.3	0.2	0.2	-0.4	0.2	0.1	0.1	-0.1	-0.2
Cyprus	-0.8	1.5	-0.1	-9.2	1.0	-2.9	-4.5	-0.5	-2.2	-1.8
Czech. Rep	-0.6	1.3	2.2	0.1	-0.7	-0.4	-0.5	1.4	-0.5	-1.7
Denmark	-0.2	0.4	0.3	-1.3	0.2	-1.7	-1.8	-0.2	-1.3	-2.3
Estonia	-1.0	1.3	0.0	-0.4	0.0	-3.0	-2.6	-0.2	-2.0	-2.6
Finland	0.3	0.5	0.3	0.8	-0.1	-0.2	-0.2	0.0	-0.2	-0.5
France	0.2	0.6	0.2	0.3	-0.2	-0.1	-0.2	0.1	-0.2	-0.3
Germany	-0.3	1.0	0.3	-0.4	-0.1	-1.2	-1.1	0.1	-0.8	-1.9
Greece	0.0	0.8	0.0	-0.2	-0.3	-0.1	-0.3	0.1	-0.2	-0.4
Hungary	-1.0	1.8	-0.3	-1.0	0.0	-2.4	-1.8	-0.3	-0.8	-1.7
Ireland	-1.6	1.6	0.7	-3.2	-1.8	0.1	-0.3	0.7	-0.4	-1.3
Italy	-0.3	1.5	-0.1	-1.4	0.0	-2.2	-1.9	-0.1	-1.4	-2.4
Latvia	-0.1	0.6	-0.4	0.1	-0.6	-0.9	-0.9	0.2	-0.5	-1.7
Lithuania	-0.3	0.5	0.4	-0.4	-0.2	-0.9	-0.8	0.0	-0.4	-1.3
Malta	0.3	1.3	-0.9	-1.4	0.0	-0.4	0.0	0.0	0.0	0.0
Netherlands	-0.1	0.7	0.1	-0.1	0.2	-1.3	-1.4	0.0	-1.6	-1.3
Poland	-0.1	1.1	0.0	0.2	-0.1	-1.0	-0.7	-0.1	-0.5	-0.9
Portugal	-0.4	1.0	0.0	0.5	-0.4	-1.1	-1.4	0.2	-1.1	-1.4
Romania	0.2	0.0	0.3	0.9	-0.2	0.3	0.2	0.2	0.0	-0.1
Slovakia	-0.2	0.7	0.2	-0.3	0.0	-4.4	-3.2	0.1	-1.6	-3.9
Slovenia	0.6	0.6	-0.3	0.8	-0.4	0.1	0.3	0.0	0.0	0.0
Spain	-0.3	1.8	0.1	-0.6	-0.5	-1.6	-2.2	0.1	-1.6	-2.0
Sweden	0.1	0.7	0.3	0.5	0.5	-1.0	-1.0	0.2	-0.7	0.0
United Kingdom	-0.6	1.2	0.4	0.0	-0.7	-1.6	-3.0	0.4	-1.5	-2.1

Figure 4.6 shows the regional distribution of income effects against the ND full reference. It is evident that the income losses to agriculture are much smaller if the application is limited to IPPC farms only. Note that regional heterogeneity within Member States is not due to different shares of IPPC farms on which we do not have information. It is mainly driven by differences in production structure and possibly differences in the estimated initial protein surplus.

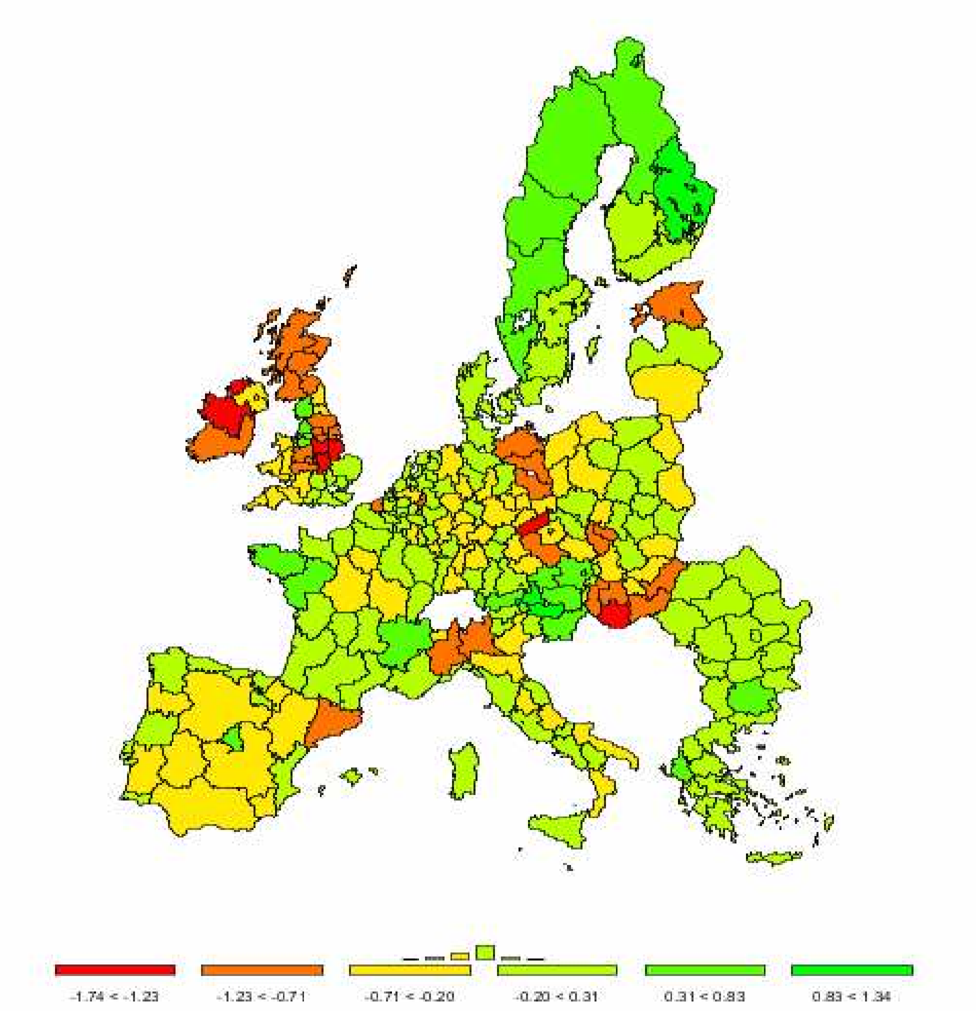

Figure 4.6. Regional variation of percentage income effects for scenario LNF10 IPPC farms only, relative to ND full 2020. (Bars illustrate the distribution)

Table 4.17 gives the changes of main components of agricultural income from scenario LNF10, IPPC farms only.

Table 4.17: Contributions to agricultural income according to CAPRI simulations for the low nitrogen reduction target of 10% in IPPC farms (LNF10 IPPC) vs. ND full 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	426383			0.2%		
Cereals	35863	106	339507	-1.0%	-0.8%	-0.1%
Other non fodder	157162	252	624354	0.1%	0.0%	0.1%
Fodder	18944	9	2144968	-0.2%	0.1%	-0.2%
Meat	74266	1616	45947	0.6%	0.9%	-0.3%
Other Animal products	59045	271	217684	0.9%	0.9%	0.0%
Other output	81103	164	494052	-0.1%	0.1%	-0.2%
Inputs	261324			0.4%		
Fertiliser	39283	819	47951	-0.1%	0.0%	-0.1%
Feedingstuff	72481	47	1545314	-1.1%	-1.0%	-0.1%
Other input	149560	281	532491	1.3%	1.2%	0.1%
European Union 15						
Production value	370370			0.2%		
Cereals	26627	111	240085	-1.0%	-0.8%	-0.1%
Other non fodder	140660	263	534942	0.1%	0.0%	0.1%
Fodder	15813	9	1767083	-0.2%	0.1%	-0.2%
Meat	64587	1682	38401	0.6%	1.0%	-0.4%
Other Animal products	50905	276	184382	0.9%	0.9%	0.0%
Other output	71777	173	413886	-0.1%	0.1%	-0.2%
Inputs	224756			0.4%		
Fertiliser	31818	850	37423	-0.1%	0.0%	-0.1%
Feedingstuff	63094	48	1325855	-1.1%	-1.0%	-0.2%
Other input	129845	289	448615	1.3%	1.2%	0.1%
European Union 12						
Production value	56013			0.2%		
Cereals	9236	93	99422	-0.9%	-0.8%	-0.2%
Other non fodder	16502	185	89412	0.2%	0.1%	0.1%
Fodder	3131	8	377885	-0.3%	0.0%	-0.2%
Meat	9679	1283	7546	1.1%	1.0%	0.1%
Other Animal products	8140	244	33302	0.5%	0.5%	0.0%
Other output	9326	116	80166	0.1%	0.1%	0.0%
Inputs	36567			0.4%		
Fertiliser	7465	709	10528	-0.1%	0.0%	-0.1%
Feedingstuff	9387	43	219458	-1.1%	-1.1%	-0.1%
Other input	19715	235	83876	1.3%	1.1%	0.2%

The LNF scenario has weaker market impacts if it is limited to IPPC farms. Meat prices are only expected to increase by 1% rather than 2.7 % under ‘LNF10 all’ and cereal prices would only drop by 0.8% rather than 6% in EU27. On the input side we see the counteracting changes for feeding stuff and ‘other input’ which incorporates the ‘quality mark up’.

The change in agricultural income is one component of the total change in 'economic welfare' (Table 4.18)

Table 4.18: Contributions to the change in conventional economic welfare according to CAPRI simulations for the low nitrogen reduction target of 10% in IPPC farms (LNF10) vs. ND full 2020 [million €]

	EU27	EU15	EU12
Total	-2437	-2160	-277
Consumer money metric	-1450	-1271	-179
Agricultural income	-397	-352	-45
Premiums	16	15	1
Agricultural Output	696	597	99
Output crops	-210	-156	-54
Output animals	906	752	154
Output rest	0	0	0
Agricultural Input	1109	964	145
Crop specific Input	-42	-36	-6
Animal specific Input	-894	-796	-98
Other Input	2045	1796	249
'Net' direct cost	1196	1059	137
Profit of dairies	14	12	2
Profit of other processing	-541	-494	-46
Tariff revenues	13	22	-8
FEOGA first pillar	77	76	1

In this scenario market impacts are weaker than under LNF10 (all) as mentioned above. Nonetheless there is a loss in consumer welfare and a loss in the processing industry. Impacts on the budget are quite small, disregarding expenditure for additional advisory efforts. The 'net' direct cost capture only apart of the total economic cost of the measure as changes market prices pass on the loss to other market participants and enforce economic adjustments involving welfare cost. Nonetheless even the 'net' direct cost give already a more encompassing cost indicator than agricultural income effects alone.

With a further implementation of LNF towards a 20% target many effects discussed earlier would be strengthened of course. However, there are also new aspects. In this scenario all meat prices would increase (12% for beef, 18% for pork) such that there would be a significant burden to final consumers. A large part of the additional cost of the measures would thus be passed on to consumers. Whereas the economic impacts of this scenario are important this evidently holds as well for the environmental gains (Table 4.19).

It will be recognized that the impacts on excretion and hence all derived environmental effects are stronger in these CAPRI simulations than in the MITERRA-EUROPE results from above. This is mainly because the CAPRI simulations tend to cover the efficiency gains in the non dairy cattle and sheep sectors as well but some adjustments of activity levels also contribute to the differences.

Table 4.19: Simulation results of low nitrogen feeding (LNF 20% 2020, all farms) vs. ND full 2020

Absolute change LNF20 all vs. ND full 2020

	agric income [m €]	'net' dir cost [m €]	beef prod [kton]	pork prod [kton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-8962	17788	-113	-1274	-330	-1909	-436	-368	-80	-250
Austria	-81	368	2	-8	3	-39	-9	-6	-1	-1
Belgium	-379	759	-17	-59	-1	-39	-8	-7	-1	-7
Bulgaria	-75	117	-4	5	-8	-13	-3	-1	-1	-3
Cyprus	-43	50	0	-7	1	-5	-1	-1	0	0
Czech. Rep	-83	120	8	5	-12	2	0	7	0	-2
Denmark	-105	259	-14	-380	5	-55	-13	-9	-2	-9
Estonia	-9	17	0	0	0	-2	-1	0	0	0
Finland	-297	326	-12	-10	3	-14	-3	-8	0	0
France	-1279	3079	-145	-51	5	-257	-55	-83	-9	-30
Germany	-1159	2641	-86	-374	-14	-235	-68	-53	-8	-29
Greece	-644	285	31	0	-1	-49	-5	-27	-2	-2
Hungary	-270	348	0	-53	-7	-18	-6	0	-1	-2
Ireland	-61	554	188	-34	-107	-145	-29	-28	-8	-22
Italy	-1602	2245	-1	-136	7	-231	-64	-77	-8	-21
Latvia	4	12	-1	1	-9	-3	-1	2	0	-2
Lithuania	-39	48	2	1	-10	-7	-2	2	-1	-3
Malta	-2	5	0	-1	0	0	0	0	0	0
Netherlands	-315	901	-37	-69	2	-72	-14	-6	-3	-12
Poland	-554	715	6	-9	-18	-78	-27	-6	-4	-11
Portugal	-235	380	-5	-12	-5	-70	-16	-38	-3	-4
Romania	-552	412	12	12	-5	-12	-3	7	-1	-2
Slovakia	7	33	1	2	-2	-5	-1	0	0	-1
Slovenia	-19	59	-4	4	0	-7	-2	-1	0	-1
Spain	-1344	3006	-77	-107	-29	-309	-60	-30	-11	-32
Sweden	-114	324	5	29	15	-24	-6	0	-1	0
United Kingdom	290	725	32	-23	-144	-221	-41	-7	-13	-53

Percentage change LNF20 all vs. ND full 2020

	agric income [%]	'net' dir cost [%]	beef prod [%]	pork prod [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-4.4	14.7	-1.3	-5.5	-3.2	-18.6	-14.6	-3.6	-10.8	-24.1
Austria	-2.7	15.9	1.1	-1.7	3.3	-18.2	-16.2	-2.7	-11.2	-21.9
Belgium	-10.8	22.5	-5.5	-5.2	-1.0	-12.1	-11.3	-2.5	-8.9	-15.0
Bulgaria	-2.8	11.9	-2.7	1.2	-3.9	-9.1	-7.3	-0.3	-5.4	-13.8
Cyprus	-11.2	26.5	-2.5	-44.2	11.3	-23.4	-25.7	-6.0	-16.3	-17.2
Czech. Rep	-4.8	7.5	16.3	1.2	-3.6	1.7	-0.4	7.3	-1.5	-5.3
Denmark	-3.3	6.5	-11.5	-19.9	3.0	-15.9	-15.7	-4.8	-9.8	-21.3
Estonia	-4.5	10.5	2.0	0.6	-1.2	-13.2	-11.2	-1.7	-6.6	-13.5
Finland	-22.8	15.2	-15.6	-5.2	2.6	-17.6	-15.5	-9.5	-7.7	-15.7
France	-3.9	13.6	-7.7	-1.9	0.3	-15.8	-11.0	-3.9	-7.0	-17.2
Germany	-6.5	13.2	-7.4	-8.0	-0.8	-16.3	-13.8	-4.5	-8.2	-24.2
Greece	-6.1	15.9	55.6	0.1	-0.5	-31.3	-16.7	-14.9	-14.8	-29.1
Hungary	-7.0	11.9	1.2	-6.5	-1.6	-10.2	-8.2	-0.5	-4.2	-9.0
Ireland	-2.3	18.0	28.5	-12.1	-40.8	-28.0	-25.5	-4.9	-29.9	-77.1
Italy	-4.3	19.2	-0.1	-8.0	1.0	-25.6	-18.5	-8.9	-14.8	-27.5
Latvia	1.6	5.2	-3.8	5.8	-18.1	-10.5	-13.3	8.2	-12.9	-41.6
Lithuania	-5.9	7.4	6.6	1.2	-8.9	-10.6	-10.2	3.4	-7.1	-30.7
Malta	-2.7	23.0	-3.4	-23.6	3.9	-21.2	-19.7	-5.9	-22.2	-15.8
Netherlands	-3.0	13.1	-11.1	-5.3	1.2	-16.4	-16.0	-1.7	-12.9	-17.4
Poland	-6.5	15.8	3.1	-0.5	-1.8	-13.9	-10.5	-1.5	-5.8	-13.0
Portugal	-5.9	12.5	-3.7	-3.3	-5.0	-34.2	-29.4	-16.8	-25.4	-36.2
Romania	-9.8	10.3	4.3	5.4	-1.1	-4.7	-3.0	2.2	-2.3	-5.0
Slovakia	1.1	4.5	6.7	1.6	-1.9	-11.4	-8.7	0.9	-4.3	-12.4
Slovenia	-3.4	17.9	-13.0	11.9	-1.4	-16.0	-12.9	-2.5	-11.1	-30.6
Spain	-3.3	26.4	-8.0	-3.0	-3.8	-22.5	-18.7	-2.3	-15.8	-31.6
Sweden	-7.5	14.5	3.5	12.7	9.3	-17.1	-15.3	0.2	-6.6	-5.5
United Kingdom	2.9	7.1	4.8	-4.2	-17.9	-21.3	-18.7	-0.7	-16.6	-43.2

Figure 4.7 shows the regional distribution of income effects against the ND full reference. There is a great regional heterogeneity, partly due to different productions structure and initial protein surplus. The relatively high loss in Finland is mainly a basis effect: Compared to many other countries Finish agriculture is not very profitable, for example measures in terms of agricultural income relative to total revenue (about 30%). A certain squeeze from additional cost may cause a large relative drop in income when starting from a low level.

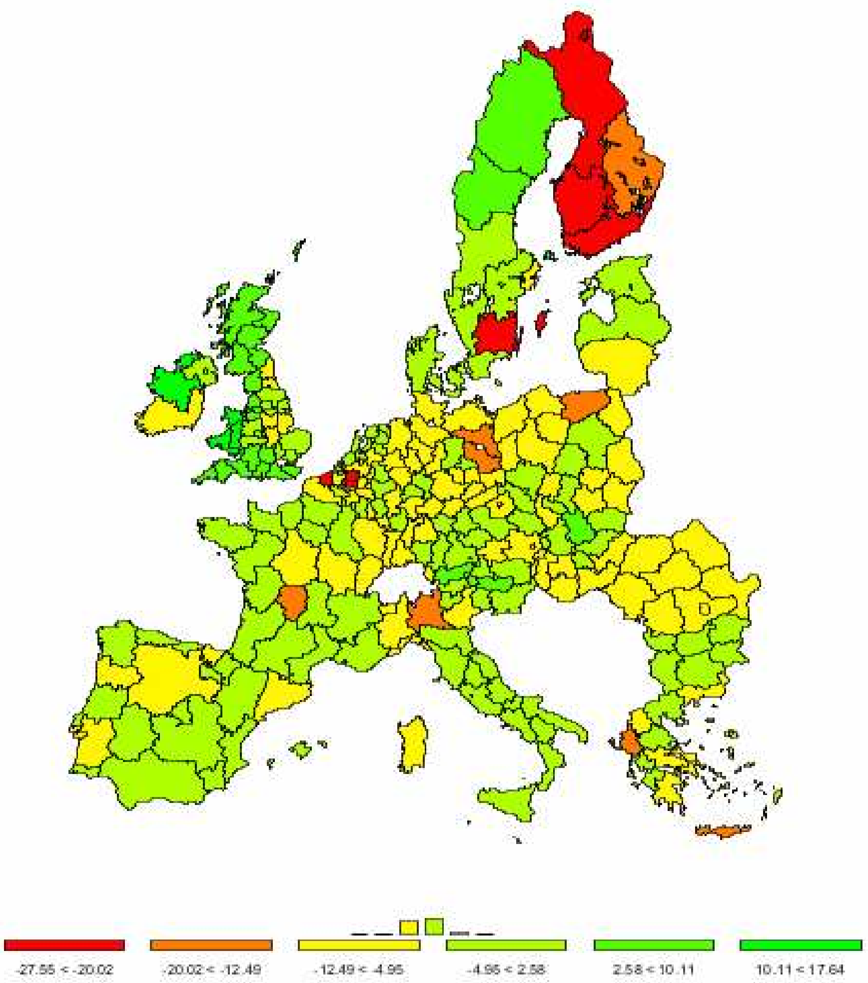

Figure 4.7. Regional variation of percentage income effects for scenario LNF20 all relative to ND full 2020.

Table 4.20 gives the changes of main components of agricultural income from scenario LNF20.

Table 4.20: Contributions to agricultural income according to CAPRI simulations for the low nitrogen reduction target of 20% in all farms (LNF20) vs. ND full 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	426383			4.9%		
Cereals	35863	106	339507	-13.0%	-12.6%	-0.5%
Other non fodder	157162	252	624354	0.5%	-0.4%	0.8%
Fodder	18944	9	2144968	-5.7%	2.5%	-8.0%
Meat	74266	1616	45947	10.8%	15.9%	-4.4%
Other Animal products	59045	271	217684	8.6%	9.2%	-0.6%
Other output	81103	164	494052	15.8%	23.7%	-6.4%
Inputs	261324			11.4%		
Fertiliser	39283	819	47951	-3.2%	0.1%	-3.3%
Feedingstuff	72481	47	1545314	-15.4%	-9.6%	-6.4%
Other input	149560	281	532491	28.3%	30.3%	-1.6%
European Union 15						
Production value	370370			5.5%		
Cereals	26627	111	240085	-11.7%	-12.0%	0.3%
Other non fodder	140660	263	534942	0.3%	-0.2%	0.5%
Fodder	15813	9	1767083	-5.9%	3.1%	-8.8%
Meat	64587	1682	38401	10.7%	17.0%	-5.4%
Other Animal products	50905	276	184382	8.9%	9.7%	-0.7%
Other output	71777	173	413886	17.5%	27.1%	-7.5%
Inputs	224756			12.3%		
Fertiliser	31818	850	37423	-3.5%	0.2%	-3.7%
Feedingstuff	63094	48	1325855	-15.7%	-9.1%	-7.3%
Other input	129845	289	448615	29.8%	32.9%	-2.3%
European Union 12						
Production value	56013			0.9%		
Cereals	9236	93	99422	-16.6%	-14.7%	-2.2%
Other non fodder	16502	185	89412	1.8%	-0.7%	2.6%
Fodder	3131	8	377885	-4.7%	-0.2%	-4.5%
Meat	9679	1283	7546	11.6%	10.8%	0.7%
Other Animal products	8140	244	33302	6.4%	6.4%	0.0%
Other output	9326	116	80166	2.7%	3.4%	-0.7%
Inputs	36567			5.9%		
Fertiliser	7465	709	10528	-1.8%	0.0%	-1.7%
Feedingstuff	9387	43	219458	-13.5%	-12.4%	-1.3%
Other input	19715	235	83876	18.1%	15.5%	2.3%

The LNF20 scenario has even stronger market impacts than LNF10. Especially meat production decreases clearly (-4.6%). Price increases from animal products compensate for the decrease in quantity such that the total production value is increasing. Price effects on cereals are strong as well. On the input side we see a marked decline in the demand for feeding stuff which implies again some savings in cost. However, feed quality and quality of management has to increase which is covered under ‘other input’ giving on balance a sizeable increase in costs to agriculture (+11.4%).

The change in agricultural income is one component of the total change in 'economic welfare' (Table 4.21).

Table 4.21. Contributions to the change in conventional economic welfare according to CAPRI simulations for the low nitrogen reduction target of 20% in all farms (LNF20) vs. ND full 2020 [million €]

	EU27	EU15	EU12
Total	-31372	-27716	-3656
Consumer money metric	-16966	-15316	-1650
Agricultural income	-8962	-7325	-1637
Premiums	-8	-29	21
Agricultural Output	20883	20370	513
Output crops	-5015	-3640	-1375
Output animals	25898	24011	1888
Output rest	0	0	0
Agricultural Input	29837	27667	2171
Crop specific Input	-1189	-1055	-134
Animal specific Input	1996	2959	-963
Other Input	29030	25763	3268
'Net' direct cost	17788	15852	1937
Profit of dairies	239	213	27
Profit of other processing	-5716	-5256	-460
Tariff revenues	566	482	84
FEOGA first pillar	535	514	21

Welfare effects from LNF20 would be clearly stronger than from LNF10. Agricultural income has further decreased but consumers losses have increased more than fivefold. Together with a stronger loss on other processing (due to less feed demand of oilcakes) this would lead to a tripled reduction in conventional total welfare compared to LNF10. The two caveats from above, ignorance of additional administrative cost and lack of monetised environmental benefits apply as usual. Finally it may be seen again that 'net' direct costs as a simpler indicator of economic costs fail to capture the full size of welfare cost but are nonetheless more inclusive than agricultural income effects.

The most ambitious package analysed by our models combines balanced fertilization, low nitrogen feeding (10% target for all farms) and the ammonia measures considered for the Thematic Strategy (**Optimal combination**). Excretion would decline by 8% according to CAPRI but the key contribution would come from a decline of mineral fertilizer by 13% which is even larger than under balanced fertilization alone because the effect of lower protein demand on grass production is added on top (Table 4.22). Reduced nitrogen supply combines with targeted ammonia measures to reduce ammonia emissions by 19%. Leaching would also be alleviated significantly by -26% (where the difference to the lower leaching impact according to MITERRA-Europe is partly due to the exclusion of runoff from the leaching result in CAPRI). Finally we have to repeat our caveat on the data situation in Malta and Cyprus which contributed to exaggerated effects on mineral fertilizer in these countries.

Table 4.22: Simulation results of a combined low nitrogen feeding, balanced fertilization and ammonia measures from TS explorations (optimal combination) vs. ND full 2020

	agric income [m €]	'net' dir cost [m €]	beef prod [kton]	pork prod [kton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-10831	11446	27	-535	-1295	-862	-558	17	-19	-266
Austria	-147	196	1	-3	-9	-17	-16	1	1	-1
Belgium	-94	230	-3	19	-28	-16	-6	-2	-1	-10
Bulgaria	-200	184	-1	1	-45	-7	-3	0	-1	-10
Cyprus	-27	13	0	-7	-7	-3	-1	-1	0	-1
Czech. Rep	-181	161	0	-3	-48	-1	-5	2	-1	-12
Denmark	-334	218	0	-214	-8	-35	-26	-4	0	-4
Estonia	-35	34	0	0	-2	-1	-1	0	0	0
Finland	-121	114	-2	-1	-1	-5	-3	-2	0	0
France	-1533	1658	-11	-4	-196	-116	-121	-6	5	-39
Germany	-964	1078	-17	-170	-19	-115	-44	-11	-3	-15
Greece	-474	410	1	-10	-35	-17	-11	0	0	-3
Hungary	-288	277	-1	-18	-45	-10	-12	-1	0	-8
Ireland	-869	899	43	-25	-81	-31	-16	28	-2	-10
Italy	-1132	1205	2	-13	-116	-105	-72	-19	-3	-25
Latvia	-58	57	0	-1	-11	-2	-2	1	0	-2
Lithuania	-67	50	0	-1	-6	-6	-5	-1	0	-2
Malta	-1	3	0	0	0	0	0	0	0	0
Netherlands	-135	314	1	0	-5	-30	-9	0	-1	-6
Poland	-899	861	-2	-14	-161	-48	-42	-7	-3	-30
Portugal	-301	303	-3	-10	-31	-26	-16	-4	0	-4
Romania	-857	705	6	4	-49	-8	-4	3	-1	-11
Slovakia	-41	46	0	-1	-8	-3	-2	0	0	-2
Slovenia	-59	54	-3	0	-3	-6	-7	-2	0	0
Spain	-1446	1548	-7	-69	-256	-159	-94	-3	-3	-42
Sweden	-113	165	4	7	-8	-10	-3	4	-1	-1
United Kingdom	-456	663	20	0	-121	-83	-37	41	-4	-30

Percentage change Opt combination vs. ND full 2020

	agric income [%]	'net' dir cost [%]	beef prod [%]	pork prod [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-5.3	53.2	0.3	-2.3	-12.5	-8.4	-18.6	0.2	-2.6	-25.6
Austria	-4.8	29.1	0.7	-0.6	-10.1	-8.0	-28.5	0.6	7.4	-11.0
Belgium	-2.7	99.6	-1.1	1.7	-22.2	-5.0	-8.5	-0.8	-3.4	-20.4
Bulgaria	-7.5	107.8	-1.0	0.2	-22.3	-5.1	-8.5	-0.1	-10.5	-57.0
Cyprus	-7.0	142.8	-3.1	-44.6	-88.4	-16.2	-36.9	-4.9	-21.7	-55.2
Czech. Rep	-10.4	43.3	1.0	-0.7	-14.3	-1.1	-11.3	2.1	-5.4	-38.9
Denmark	-10.5	53.9	-0.3	-11.2	-4.4	-10.1	-32.0	-2.2	0.8	-9.9
Estonia	-16.5	141.7	-0.9	-0.8	-7.7	-7.3	-14.2	-0.4	-2.6	-14.4
Finland	-9.3	20.0	-2.1	-0.4	-1.0	-6.7	-13.9	-1.9	3.9	-7.6
France	-4.6	45.1	-0.6	-0.2	-9.2	-7.1	-24.3	-0.3	4.0	-22.1
Germany	-5.4	38.0	-1.4	-3.6	-1.1	-8.0	-9.1	-0.9	-3.2	-12.4
Greece	-4.5	233.9	2.1	-8.5	-18.5	-10.6	-32.3	-0.2	-4.3	-31.9
Hungary	-7.5	45.8	-2.9	-2.2	-10.2	-5.7	-17.3	-0.7	-0.5	-28.6
Ireland	-32.9	116.4	6.6	-9.0	-30.8	-5.9	-14.5	5.0	-7.8	-34.9
Italy	-3.0	60.0	0.2	-0.7	-15.7	-11.6	-20.8	-2.3	-5.4	-32.3
Latvia	-22.4	96.4	-2.1	-4.3	-22.6	-5.8	-23.2	5.1	-5.8	-43.1
Lithuania	-10.2	47.0	-0.7	-1.3	-5.3	-9.3	-20.8	-1.8	0.1	-14.7
Malta	-1.5	84.6	-1.7	-1.1	-51.0	-9.3	-9.2	-0.9	-11.1	-26.3
Netherlands	-1.3	17.9	0.2	0.0	-2.5	-6.8	-9.7	0.0	-3.7	-8.1
Poland	-10.5	389.6	-1.1	-0.7	-16.2	-8.5	-16.2	-1.6	-5.3	-36.0
Portugal	-7.5	43.0	-2.3	-2.7	-29.9	-12.9	-30.8	-1.9	-2.7	-39.9
Romania	-15.3	60.5	2.2	1.7	-10.2	-2.9	-5.0	1.0	-4.6	-28.7
Slovakia	-6.0	24.8	1.6	-0.5	-7.0	-6.6	-12.6	1.1	-2.9	-20.4
Slovenia	-10.4	98.2	-10.6	-0.9	-15.6	-12.6	-40.4	-4.3	12.1	-14.0
Spain	-3.6	182.7	-0.8	-1.9	-33.0	-11.6	-29.4	-0.3	-4.4	-41.5
Sweden	-7.4	22.9	2.6	2.9	-4.7	-7.3	-8.7	3.1	-5.0	-24.7
United Kingdom	-4.6	29.6	2.9	0.0	-15.0	-8.0	-17.0	3.6	-5.2	-24.3

Figure 4.8 shows the regional distribution of income effects against the ND full reference. It is evident that the income effects are quite negative for most regions.

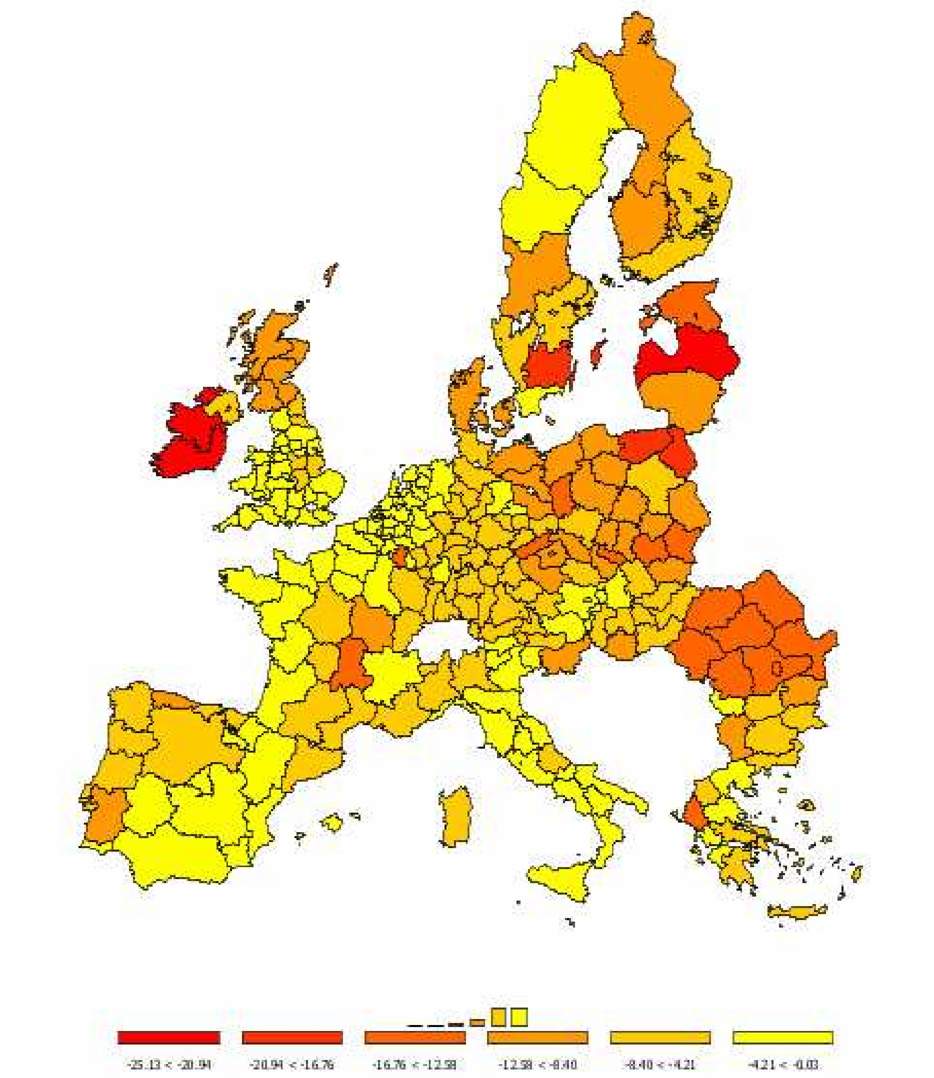

Figure 4.8. Regional variation of percentage income effects for scenario 'Optimal combination' relative to ND full 2020. (Bars illustrate the distribution)

Table 4.23 gives the changes of main components of agricultural income from the scenario ‘Optimal combination’.

Table 4.23. Contributions to agricultural income according to CAPRI simulations for combined low nitrogen feeding, balanced fertilization and ammonia measures from TS explorations (optimal combination) vs. ND full 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	426383			0.1%		
Cereals	35863	106	339507	-6.8%	-6.0%	-0.8%
Other non fodder	157162	252	624354	0.1%	-0.2%	0.4%
Fodder	18944	9	2144968	-1.9%	0.6%	-2.5%
Meat	74266	1616	45947	2.4%	4.0%	-1.5%
Other Animal products	59045	271	217684	2.1%	2.1%	0.0%
Other output	81103	164	494052	0.1%	1.7%	-1.5%
Inputs	261324			4.3%		
Fertiliser	39283	819	47951	-2.8%	0.0%	-2.9%
Feedingstuff	72481	47	1545314	-8.0%	-6.5%	-1.5%
Other input	149560	281	532491	12.2%	11.0%	1.1%
European Union 15						
Production value	370370			0.2%		
Cereals	26627	111	240085	-6.3%	-5.8%	-0.5%
Other non fodder	140660	263	534942	0.1%	-0.2%	0.3%
Fodder	15813	9	1767083	-1.8%	0.7%	-2.5%
Meat	64587	1682	38401	2.3%	4.1%	-1.7%
Other Animal products	50905	276	184382	2.2%	2.2%	0.0%
Other output	71777	173	413886	0.0%	1.7%	-1.6%
Inputs	224756			3.9%		
Fertiliser	31818	850	37423	-2.6%	0.0%	-2.6%
Feedingstuff	63094	48	1325855	-8.0%	-6.4%	-1.7%
Other input	129845	289	448615	11.3%	10.3%	0.9%
European Union 12						
Production value	56013			-0.4%		
Cereals	9236	93	99422	-8.3%	-6.8%	-1.6%
Other non fodder	16502	185	89412	0.5%	-0.3%	0.8%
Fodder	3131	8	377885	-2.2%	-0.1%	-2.1%
Meat	9679	1283	7546	3.0%	3.7%	-0.6%
Other Animal products	8140	244	33302	1.4%	1.6%	-0.3%
Other output	9326	116	80166	1.1%	2.1%	-0.9%
Inputs	36567			6.8%		
Fertiliser	7465	709	10528	-3.8%	-0.1%	-3.7%
Feedingstuff	9387	43	219458	-7.9%	-7.1%	-0.9%
Other input	19715	235	83876	17.8%	15.5%	2.0%

The market impacts are in part an overlay of the impacts from scenarios LNF10 (all farms) and BALFERT, but the ammonia measures contribute to the additional cost in the livestock sector and tend to reduce supply and increase prices. Meat prices are therefore increasing by 4.1% rather than 2.7 % under ‘LNF10 all’ but the drop in cereal prices is very similar to the LNF10 scenario. On the input side we may observe a decline in expenditure on fertiliser and feedstuffs which is more than compensated by the additional costs for ‘other input’.

The change in agricultural income is one component of the total change in ‘economic welfare’ (Table 4.24).

Table 4.24. Contributions to the change in conventional economic welfare according to CAPRI simulations for combined low N feeding, balanced fertilization and ammonia measures from TS explorations (optimal combination) vs. ND full 2020 [million €]

	EU27	EU15	EU12
Total	-16959	-13589	-3370
Consumer money metric	-3954	-3485	-469
Agricultural income	-10831	-8119	-2713
Premiums	-2	-24	21
Agricultural Output	536	783	-247
Output crops	-2600	-1843	-757
Output animals	3136	2625	510
Output rest	0	0	0
Agricultural Input	11365	8878	2487
Crop specific Input	-1120	-828	-292
Animal specific Input	-5835	-5179	-656
Other Input	18320	14885	3436
'Net' direct cost	11446	9001	2445
Profit of dairies	37	32	5
Profit of other processing	-1993	-1816	-177
Tariff revenues	69	64	4
FEOGA first pillar	288	267	21

In this scenario market impacts would be most significant of course. There is a loss in consumer welfare and a sizeable loss to the processing industry, in particular for processing of oilseeds. Impacts on the budget are moderate. The two caveats from above, ignorance of additional administrative cost and lack of monetised environmental benefits apply as usual. As market impacts are smaller than under the LNF20 scenario (Table 4.21) the ‘net’ direct cost better reflects total welfare cost than above.

The key results from the CAPRI simulations are summarized in Table 4.25

Table 4.25: Simulation results of low nitrogen feeding, balanced fertilization and ‘optimal combination’ measures vs. ND full 2020 in EU27

	agric income [m €]	consumer welfare [m €]	total econ welfare [m €]	total NH3 loss [kton]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
BALFERT	-3058	-26	-3056	-53	-1	-19	-157
LNF10 all	-6425	-2841	-11505	-203	53	-35	-120
LNF10 IPPC	-397	-1450	-2437	-35	16	-6	-15
LNF20 all	-8962	-16966	-31372	-436	-368	-80	-250
Opt combination	-10831	-3954	-16959	-558	17	40	-266

	abatement relative to welfare cost estimate			
	NH3 [g / €]	CH4 [g / €]	N2O [g / €]	leaching [g / €]
BALFERT	17	0	6	51
LNF10 all	18	-5	3	10
LNF10 IPPC	14	-7	2	6
LNF20 all	14	12	3	8
Opt combination	33	-1	-2	16

With all caveats due to the significant uncertainties it appears that balanced fertilization achieves significant improvements on leaching at moderate cost whereas progress on ammonia emissions would be quite moderate.

Low nitrogen feeding is less efficient in terms of reduced leaching but it is an important ingredient of an overall strategy if sizable ammonia abatement is to be achieved. It is evident that a great part of the economic loss is born by consumers. Price increases of 10% and more have been projected under the ambitious variant of low nitrogen feeding and the size of these price increases is part of the uncertainties. Among other influences they hinge on the unknown degree of consumer preferences for EU produced meat which determine the amount of pass through of additional cost in the livestock sector. With greater substitutability the economic losses would fall more on agriculture than on consumers. When comparing the moderate (10%) goal with the more ambitious objective of a 20% reduction the simulation results conform to intuition: Achieving a more ambitious target involves a more than proportionate increase in cost.

The optimal combination is shown to yield significant contributions at economic cost between those of the BALFERT and LNF scenarios for leaching and at lowest cost for ammonia. Apparently the mix of ammonia targeting measures selected for the RAINS simulations was quite efficient in economic terms. This should be the case as economic efficiency was guiding the selection procedure for the RAINS model.

The economic costs do not encompass estimates of the additional administrative cost in EU and national administrations and advisory services. On the other hand the term total welfare cost should not be read as implying that the overall economic balance is negative: As we have not tried to put monetary values on the abatements achieved it is possible and even likely that the overall balance would be positive. There economic welfare cost indicated are meant in a quite narrow sense therefore and refer only to the conventional welfare components.

4.6. Discussion and conclusions

Implementation of low-protein animal feeding has multiple beneficial environmental effects. Our analyses indicates that a decrease of 10% in the protein content of the animal feed on all farms will lower the NH_3 emissions by 6% and the N leaching and emissions of N_2O by 4% relative to the ND full 2020 reference scenario. This indicates that low-protein animal feeding has synergistic effects. Decreasing the protein content of the animal feed by 20% would further decrease the NH_3 emissions by 11% and the N leaching and emissions of N_2O by 7% relative to the ND full 2020 reference scenario. Hence, the effects of the decreases in protein content are suggested to be linear.

Balanced N fertilization (Balfert 2020) also has multiple beneficial environmental effects. Full implementation of balanced fertilization in this study (removing 'over-fertilization') was equivalent to decreasing the N input via N fertilizer by on average 9% and that via animal manure by up to 6% (see Table 4.4), relative to the ND full 2020 reference scenario. Balanced fertilization (Balfert 2020) decreases the NH_3 emissions by 4%, N leaching by 11% and the emissions of N_2O by 4% relative to the ND full 2020 reference scenario. However, balanced fertilization as applied in this study is not without cost for the farmer. It may increase the risk of a decrease in crop yield. Furthermore, areas with high livestock density may be forced to lower the N content of the animal manure through low-protein animal feeding or may have to treat the manure, to be able to implement balanced fertilization and to utilize the nutrients in the animal manure efficiently. The balanced N fertilization measure has considerable perspectives for decreasing the N loading of the environment, but when applied too strict it can have considerable agronomic and economic effects. Further sensitivity analyses are needed.

Combined implementation of an optimal set of NH_3 emission abatement measures (RAINS optimized 2020) and balanced fertilization ('Optimal Combination 2020') has also large effects. It decreases the NH_3 emission by another 19% relative to the ND full 2020 reference scenario to a level of ~ 2350 kton NH_3 from agriculture in EU-27. This level is similar to (or less than) the target levels (~ 2450 kton for EU-25 and ~2650 kton for EU-27; Aman et al., 2006b) needed to achieve the objectives of the Thematic Strategy on Air Pollution in 2020. In addition, the Optimal Combination 2020 scenario decreases mean N leaching by 14% and mean N_2O emissions by 3% relative to the ND full 2020 reference scenario. However, the Optimal Combination 2020 scenario is not without cost for the farmer. The annual cost of the NH_3 emission abatement measures have been estimated at € 1.6 billion per year for the EU-25, in addition to the cost already associated with current legislation. Further, relatively large amounts of manure N have to be 'neutralized' through a combination of low-protein animal feeding and manure treatment and manure disposal in some regions, at considerable additional costs.

The results of the MITERRA-EUROPE and CAPRI simulations agree rather well. Though the activity data are based on similar sources, the modelling concepts are different. CAPRI is an economic optimization model, while MITERRA-EUROPE largely is an empirical factor model. Both models arrive at the conclusion that the identified most promising measures can contribute greatly to the decrease in the emissions of NH_3 and N2O to the air and the leaching of N to groundwater and surface waters. The small differences between the MITERRA-EUROPE and CAPRI simulations can be seen as a contribution to sensitivity analyses.

The scope for lowering the total N excretion of animals in the EU-27 by 10 to 20% is based on the following combination of measures:

- lowering the protein content of animal feed, with or without additions of specific amino acids and improved phase feeding;
- improvement of the genetic potential of the herds, i.e., increasing the milk yield per cow and the growth rate of pigs, poultry and beef animals; and
- lowering the replacement rate of dairy cattle, increasing the growth rate of young dairy stock and lowering the age of the young stock at first calving.

Considerable investments in demonstration, training farmers and research are needed to be able to achieve an overall lowering of the protein content of the animal feed by on average 10-20%. The genetic improvements mentioned above would have to be on top of the baseline increase in productivity. As it is unclear whether such improvements will come about it may be questioned whether the 20% decrease is technically feasible on the majority of farms.

In this study, it is assumed that lowering the N excretion by 10% through low-protein animal feeding decreases the NH_3 emissions proportionally (i.e., by 10%). However, there is a considerable amount of empirical and theoretical evidence that lowering of the N excretion by 10% through low-protein animal feeding decreases the NH_3 emissions more than proportionally (Kulling et al., 2001; 2003; Broderick, 2003; Flachowsky and Lebzien, 2005; Jondreville and Dourmad, 2005; Mateos et al., 2005; Misselbrook et al., 2005; Velthof et al., 2005). In addition, the metabolizable energy and the cation composition of the diets affect the pH of the urine and the animal manure and thereby the NH_3 emissions too. This suggests that more precise animal diet prescriptions and more precise model formulation for assessing the effects of diet composition on NH_3 emissions are needed, to be able to fully capture the variance in practice in the relationships between animal feed composition, manure composition and NH_3 emissions.

In addition to diet composition, high-technological measures, such as the use of antibiotics, antimicrobial agents, and certain growth hormones could be used to lower NH_3 emissions, but these measures are not considered here, because of animal welfare reason (these measures do not satisfy the criterion of ‘most promising’, as indicated in the call for tender (Annex 5)).

The available data do not allow to making a more precise estimate of the potential for decreasing the N excretion by animals in the EU-25+, than the suggested rough mean of 10-20%. The accuracy of the estimated potential decrease in N excretion is on the one hand constrained by our limited knowledge of the animal physiology and especially the animal nutrition (the minimum requirement for amino acids), and on the other hand by our limited knowledge of current practice. The current information in RAINS indicates that (i) there is little variation in practice as regards the mean N excretion of dairy cattle, other cattle, pigs and poultry among countries, and (ii) that the N excretion of these main livestock categories in the various countries is not (excessively) high. Hence, on the basis of the RAINS database, there is only limited scope for decreasing N excretion. In practice, there appears to be a large variation between farms in the N excretions of for example dairy cattle, pigs and poultry, suggesting room for lowering N excretion on at least some farms (e.g., Hubeek and De Hoop, 2004). This variation between farms is averaged out in the Member States means, and it is not always clear how the Member States arrived at these means. The RAINS data also indicate that there is very limited scope for regional differentiation in the scope for decreasing N excretion (but there is scope for regional differentiation in the level of implementation (see Table 4.1).

The suggested decrease of the N excretion by animals by roughly 10-20% in the next 10 to 15 years will be achieved only with proper incentives, including

- training and advising farmers;
- demonstration trials and demonstration farms;
- covenants with animal feed industry and farmers;
- research for improving the requirement of animals for amino acids and the diagnosis of amino acids in diets.

The Nitrates Directive exerts a strong implicit incentive to lower the N excretion rate of livestock through its Code of Good Agricultural Practice, which states that the maximum application rate of N via animal manure is 170 kg N per ha per year. This application limit indirectly also limits livestock density and N excretion rate of the livestock (the lower the N excretion per animal, the more animals can be kept per unit agricultural land). Evidently, this incentive is most applicable to countries and regions with a relatively high livestock density.

For making more accurate assessments of the prospects for lowering N excretion through further lowering of the protein content in the animal feed, it is recommended that a thorough survey is being made of the animal feeding practices and animal performances in the EU-27. A uniform methodology must be applied for estimating the regional variation in N excretion by animals. The current N excretion values in RAINS are based on estimates by country specialists, and it is unclear whether these estimates reflect indeed the variation that occurs in practice. This holds as well for the projected number of animals for the next decades. More precise estimates of the regional variation in N excretion will also allow making more accurate estimates of the potential for decreasing N excretion by animals.

Our results indicate that balanced fertilization is a possible most promising measure. There is scope for improving the N use efficiency in crop production by more efficient use of animal manure and fertilizers and hence by a lower fertilizer N input. This holds especially for the intensively managed crop production systems (including forage production) in many EU-15 Member States. Our estimate indicates that N input in EU agriculture can be decreased. Mosier et al (2004) suggested that increases in NUE of about 10-30 relative to present levels appear feasible in many regions, through fine-tuning of the N management. However, strict implementation of balanced fertilization has the risk of lowering crop yield and quality. Because of the risks involved of balanced

N fertilization, it would be worthwhile to explore the possibilities of using support to those farmers that go beyond a less strict interpretation of balanced fertilization via the Rural Development Regulation. This has been anticipated already in the CAPRI simulations where the decrease of the overfertilisation factor has been large but less than 100% to acknowledge that farmers may be reluctant to reduce fertiliser input if the decline of yields cannot be avoided anymore through more precise application.

There are various reports from EU Member States indicating that significant improvements have been made (and can be made further) in N use efficiency and in decreasing N surpluses in agriculture through a combination of measures. Denmark is a typical example in this case. The N use efficiency in Danish agriculture has increased steadily during the last 10 to 20 years. The success of the Danish case has been ascribed to two factors, namely (i) mandatory fertilizer and crop rotation plans, with limits on the amount of plant available N to be applied to different crops, and (ii) the statutory norms for the fraction of manure N assumed to be plant available. These two instruments have been enforced stepwise between 1991 and 2004, and have been designed in close dialogue with farmers and farmers associations. The regulations are supported by extensive information materials, demonstration, extension and education. Also, extensive research programs have been supported (Dalgaard, 2006). Rather similar success stories have been reported for the Netherlands (Van Grinsven et al., 2005).

The lessons to be learned from the Danish case and other cases is that a steady lowering of N surpluses and a steady increase of the N use efficiencies can be made only following the implementation of sound policies and measures, including the training of farmers and extension services, and supported by extensive research programs. Mosier et al (2004) state that improvements in NUE require knowledge intensive N management practices and are brought about by:

- increased yields and more vigorous crop growth, associated with greater stress tolerance of modern crop varieties;
- improved management of production factors other than N (tillage, seed quality, plant density, weed and pest control, balanced fertilization of other nutrients than N; and
- improved N fertilizer and animal manure management, to better match the amount and timing of applied N to crop N demand.

Prerequisites for implementing such practices are that they must be simple and user friendly, involve little extra time, provide consistent gains in NUE and yield and are cost-effective. Optimizing the timing, quantity and availability of applied N is the key to achieving a high NUE. They require suitable policies and significant long-term investments in research, extension and education. The policies and investments need to be regional specific, because of the different agricultural practices and priorities in different countries.

There are possible future developments which may hinder a possible decrease in the protein content of the animal feed and in the N fertilizer input in agriculture. This hindrance is related to the development of the use of bio fuels. The increasing demand for biofuels will compete to some extend with the demand for high-quality animal feed, because there is hardly land unused in the world. It has been suggested that an increasing supply of low-quality by-products from the production of biodiesel and ethanol will become available on the market. These by-products (DDGS) of the biofuel industry are poor in energy and rich in protein and fiber (but have low-quality protein), after the energy has been distilled and removed. As a consequence, the protein content of the animal feed may have the tendency to increase again in the near future, when these trends become noticeable. Also, the increasing acreage of biofuels will likely contribute to intensification of agricultural production (on a smaller area, because of the land used for biofuel production). This further intensification of the agricultural production on a smaller area may contribute to increased N emissions per unit of utilized agricultural area, even though the total N emissions from agricultural production may not increase necessarily.

There are also possible developments which may hinder the possible decrease in the total N fertilizer application rate. The current interest in biofuel has increased the area of rapeseed considerably in some countries (e.g. Germany), and this increase in area has contributed to an increase in N fertilizer use. Fertilizer statistics experts from the European Fertilizer Manufacturers Association (EFMA) expect a further increase in the area of crops used for biofuels in EU-27 and a concomitant increase in the sales of N fertilizer in EU-27 for the next decade. Total N fertilizer use in EU-27 increased till the 1980s. Thereafter, a few sudden drops occurred with stabilized use in between these sudden drops. The sudden drops coincided with changes in the Common Agricultural Policy and with the political changes in central European countries, and not so much with the implementation of environmental Directives. The fertilizer statistics experts from EFMA were somewhat surprised about the projected decrease in N fertilizer use in the ND full 2020 and Balfert 2020 scenario’s; they expect that the need for food and biofuel will outbalance the effects of further implementation of the environmental policies.

5. Impact Assessment of a Possible Modification of the IPPC Directive

5.1. Introduction

The Integrated Pollution Prevention and Control (IPPC) Directive adopted in 1996, aims at minimizing environmental pollution and nuisance from large operations/installations in the European Union. Under IPPC Directive, large pig and poultry farms with more than 2000 places for fattening pigs and/or more than 750 sows and/or more than 40,000 chickens have to operate according to permit conditions based on BAT. BAT includes measures to reduce NH_3 emissions. Newly built farms have to comply with IPPC since October 2007 and the final deadline for full implementation of the IPPC Directive to existing installations is 30 October 2007.

Measures considered at EU level as BAT for the whole sector are described in detail in the “Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs (July 2003)”, also referred to as the BREF-Document. These include for example BATs for covered storage of animal manure, improved housing systems, air purification, manure handling and treatment, low-emission manure application. These documents also include estimates of the NH_3 emission factor per animal category (kg per animal place and year), and assessments of the economic aspects (costs/benefits), animal welfare aspects. Though explicitly mentioned in the BREF (European Commission, 2003), spreading of animal manure to land is not legally included under the IPPC Directive, if this spreading is not carried out as part of an installation as defined in the Directive. According to the definition, the term "installation" means a "stationary technical unit where one or more activities listed in Annex I of the Directive *(in this case, intensive rearing of poultry or pigs)* are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution". This is interpreted by the European Commission that manure spreading would be legally covered only in cases where the spreading is carried out on the site of the installation and that a technical connection (e.g. a pipe) is used. Some Member States do include spreading more generally under the permit conditions of IPPC installations by applying a wider interpretation of the IPPC Directive. As follows also from the analyses presented in Chapter 2, 3 and 4, not ensuring the implementation of BAT for manure spreading on IPPC farms would in part nullify the effect of other abatement measures for NH_3 emissions applied on IPPC farms.

One of the proposed measures of the Thematic Strategy on Air Pollution (CEC, 2005a) is the assessment of the extension of the IPPC directive to intensive cattle rearing installations and a possible revision of the thresholds for intensive rearing installations of pigs and poultry. The extension of the IPPC directive to intensive cattle rearing and the possible modification of thresholds values may have to play an important role in achieving the objectives of the Thematic Strategy on Air Pollution.

This chapter summarizes the results of task 4 of the Ammonia Service Contract. The aim of task 4 has been defined as: *'To assess the impacts of the extension of the IPPC Directive to intensive cattle rearing installations and a possible revision of the thresholds for intensive rearing installations of pigs and poultry'*. Detailed results are presented in Annex 4[23]. This chapter summarizes the results of inventories and the assessments. We begin with a short overview of the methodology applied in this Task.

5.2. Methodology

The study comprised two phases:

1. Inventory of livestock farm structure data (farm size distribution data) and broad assessment of 3 potential lowered thresholds for pigs and poultry rearing, and 3 possible thresholds for cattle rearing
2. In depth assessment of 1 selected lowered threshold for pigs and poultry, and 1 possible new threshold for cattle rearing

In the assessment, notably of the phase 2, the following issues are addressed:

- impact on ammonia and greenhouse gas emissions (using RAINS)
- impact on nitrate and nitrous oxide emissions (using MITERRA-EUROPE)
- impact on other pollutants and nuisance (e.g. odour; using own assessment tools)
- impact on social and economic issues (using CAPRI)

The basis for the analyses performed under this Task is the information obtained from EUROSTAT on farm size distribution (2003 census data). Since basic EUROSTAT farm size categories do not specifically include the farm sizes that correspond with the IPPC thresholds, additional work was carried out by EUROSTAT to provide the proper (requested) data. The results are summarized below. Details, e.g. the farm size distribution for pig, poultry and cattle production, are presented in Annex 4.

Next, a broad inventory was made of the situation per Member State (EU-25) concerning the relevant environmental legislation, and the penetration (implementation) of Best Available Techniques (BATs), either as a consequence of the IPPC Directive and of national environmental legislation (for farms not covered by the IPPCD or setting permit conditions going beyond the requirements of the IPPC Directive), or both. These results are described in the Background Report in Annex 4. In the description of BAT, the RAINS abbreviations are used:

- SA = Stable Adaptation (implicitly including CS)
- CS = Covered Storage (low and high efficiency)
- LNA = Low Nitrogen (manure) Application (low and high efficiency)
- LNF = Low Nitrogen (animal) Feed

This inventory has resulted in tables per Member State, presenting the estimated % of animals that is kept on farms with one or more of the above mentioned NH_3 emission abatement (BAT) measures. The Background Report (Annex 4) was presented during the

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[23] Annex 4. Monteny, G.J., H.P Witzke and D.A. Oudendag 2007. Impact assessment of a possible modification of the IPPC Directive. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Alterra Report. Wageningen.

meeting of the national representatives in the IPPC Advisory Group (AG) for comments. Comments were received, processed, and included in the input files for the 3 models used (RAINS, MITERRA-EU, CAPRI).

When BATs were the result of national legislation, the % of animals kept on farms with the techniques were estimated from the information gathered from and provided by Member States. When BAT was a result of implementation of the IPPC Directive, the following was assumed (and submitted for consultation to the MS representatives):

- SA and CS for pig and poultry farms
- CS for cattle farms

Both SA and CS, both with high efficiency emission reducing systems, for pig and poultry farms were assumed to be fully implemented in IPPC farms in 2020. Although the IPPC-Directive and therefore BAT, is not compulsory for the cattle sector, CS with high efficiency was assumed to be implemented on cattle farms with animal numbers above the selected thresholds.

Low Nitrogen Feed (LNF) was assumed to be implemented in 2020 in most MS, especially for farms in MS who make no or limited use of low protein animal feed. Experts interpretation was used, mainly based upon national legislation and/or based upon guidelines issues under the CLTRAP and/or based upon the BREF-document).

During the study it became clear that LNA, although being part of the CLTRAP Ammonia Abatement guidelines and BREF, is not considered being an integrated (legal) part of permitting under the IPPC Directive in all Member States. Therefore, all IPPC related scenarios were run with and without LNA as part of IPPC permits. The results provide information about the level of importance of including LNA in the framework of IPPC, and about the need to enforce application of this measure either under the IPPC or in the framework of another Directive (e.g. Nitrates Directive).

During the process of providing a basis for assessing the lowering of the IPPC thresholds for intensive animal rearing (pigs and poultry) and suggested new thresholds for cattle husbandry, attempts were made to find a solid basis for comparison of IPPC thresholds for different species. The following options are used:

- Livestock Units
- N excretion

The analysis led to the conclusion that N excretion would offer the most representative basis for defining a new set of revised thresholds, referred to as IPPC1, IPPC2, and IPPC3.

All data gathered are reported in the Background Report (Annex 4[24]) and processed in such a way that they can be used as direct input to the models. The following scenarios have been assessed:

- Situation in 2020, with the full implementation of the Nitrates Directive (ND full

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[24] Annex 4. Monteny, G.J., H.P Witzke and D.A. Oudendag 2007. Impact assessment of a possible modification of the IPPC Directive. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Alterra Report. Wageningen

2020) and also implementation of BATs on all IPPC farms (2020_IPPC). This scenario takes into account the implementation of BAT as a result of national legislation. Developments in animal numbers are obtained from CAPRI. Development of the farm size distribution is not taken into account, since no data could be found to support any assumption on this

- Situation in 2020, assuming 3 levels of IPPC thresholds, using the options for inter-comparison of thresholds for various animal types, and taking into account the basic BAT penetration option (LNF/SA/CS); IPPC1, IPPC2 and IPPC3
- Similar as above, but than taking into account full implementation of LNA as a part of the IPPC permitting; IPPC1+LNA, IPPC2+LNA, IPPC3+LNA
- All IPPC scenarios for 2020 assume full implementation of the Nitrates Directive (ND full 2020)

The results of the analysis include development of the NH_3 emission per Member State, the development of the number of IPPC farms (and permits), and the permitting costs and permitting efficiency associated. Furthermore, the impact on the losses of other nitrogen compounds, nitrate and nitrous oxide, and methane is presented to assess the level of trade off of pollutants. Finally, the social and economical impacts of lowering of IPPC thresholds have been analysed, using the CAPRI model.

5.3. Current farm size distribution and number of IPPC farms

Figures 5.1 – 5.4 summarize the farm size distribution for EU-25 in 2003, for fattening pigs, sows, laying hens, and broilers. The numbers represent the total number of animals and the total number of farms for various thresholds. Data used for this analysis were provided by EUROSTAT.

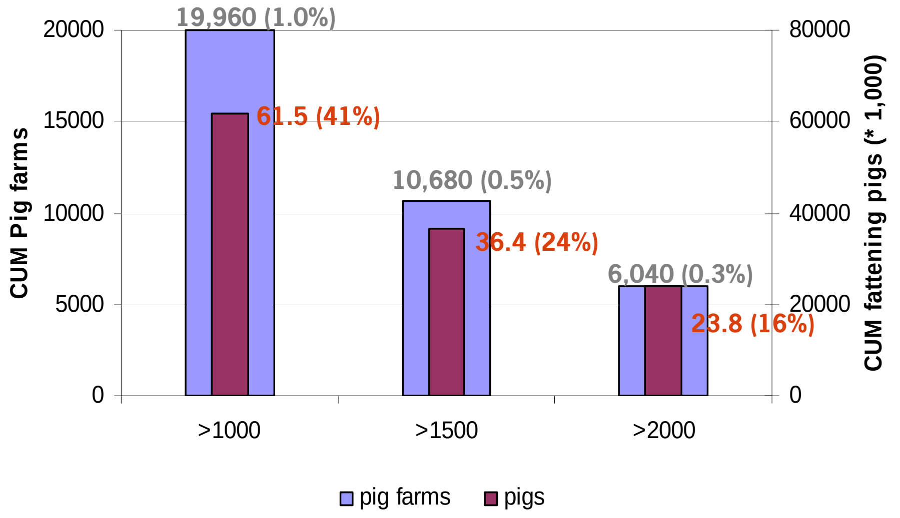

Figure 5.1. Number (and % of total) of pig farms and number of fattening pigs for three thresholds (> 1000, > 1500 and > 2000 fattening pigs per farm).

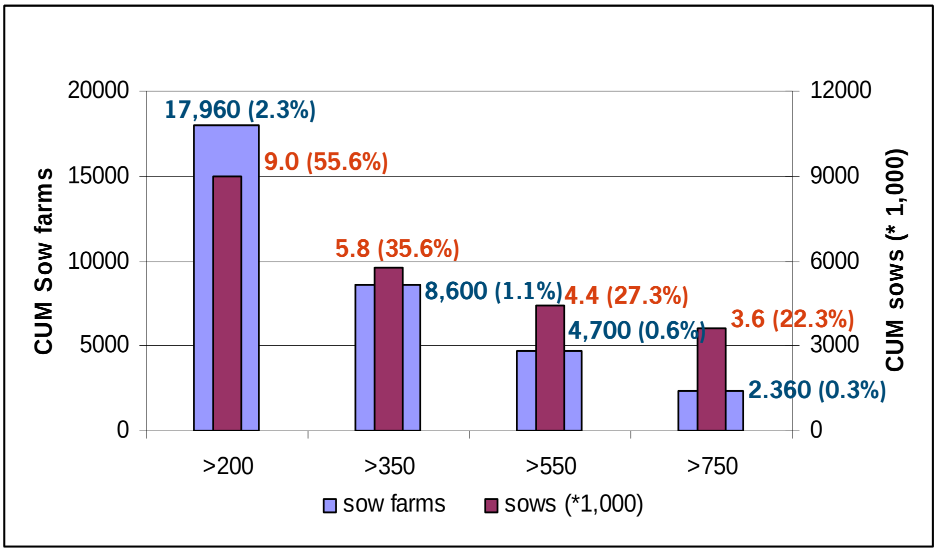

Figure 5.2. Number (and % of total) of sow farms and number of sows for four thresholds (> 200, > 350, >550 and > 750 sows per farms).

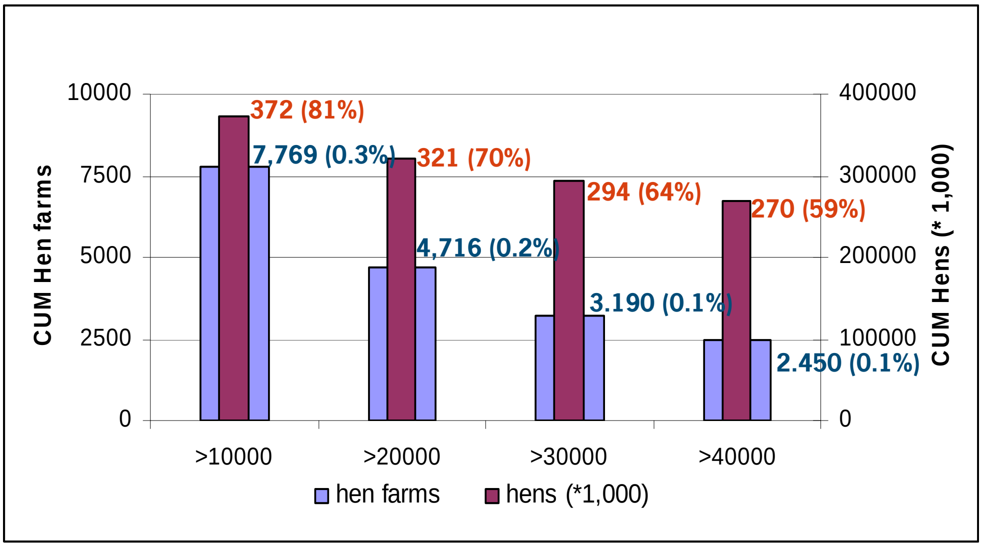

Figure 5.3. Number (and % of total) of laying hen farms and number of laying hens for four thresholds (>10000, >20000, >30000 and >40000 hens per farm).

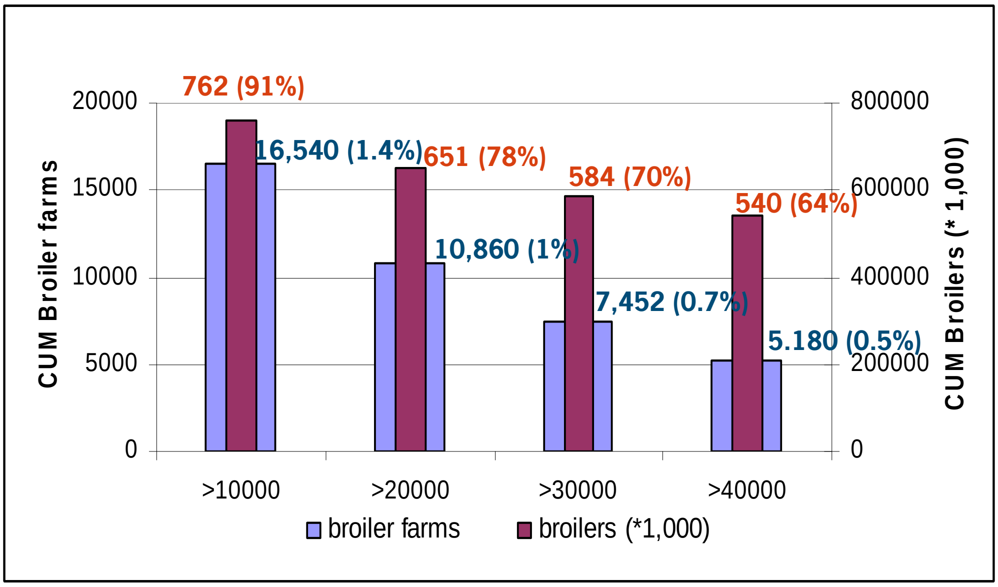

Figure 5.4. Number (and % of total) of broiler farms and number of broilers for four thresholds (thresholds (>10000, >20000, >30000 and >40000 broilers per farm).

Based on the 2003 farm size distribution data, the following numbers of farms and animals (total and for "IPPC farms") can be summarized (Table 5.1)

Table 5.1. Number of farms and number of animals on these farms, covered by the current IPPC thresholds, according to 2003 census data. Numbers between brackets indicate the number of "IPPC farms" and "IPPC animals" in percent of the total number of farms and total number of animals, respectively (source Eurostat, 2006).

	Farms		**Animals (in million head)**	
	Total	IPPC	Total	IPPC
Fattening pigs	1927260	6040 (0.3%)	150.0	23.8 (16%)
Sows	769070	2360 (0.3%)	16.1	3.6 (22%)
Laying hens	3017570	2450 (0.1%)	460.8	270 (59%)
Broilers	1147190	5180 (0.5%)	839.3	539 (64%)

These data show that the total number of "IPPC farms" (>2,000 fattening pigs; >750 sows; >40,000 poultry) in the EU-25 is around 16,000. This is less than 0.1% of the total number of farms in the EU-25. On these farms, 16% of the total number of fattening pigs, 22% of the total number of sows, and around 60% of the total number of poultry are kept.

5.4. Assessment of possible new IPPC thresholds

For the assessment of possible new IPPC thresholds, a common basis was sought to compare the environmental impact of each animal category. Two bases were selected:

- Live Stock Units (LSU)
- N excretion

In the discussion with the Commission representatives, N excretion was selected for use in the further analysis, since N excretion is found to reflect the impact of animal production on the environment (notably concerning N) better than Livestock Units.

Table 5.2 summarizes the mean N excretions for various farm animals (source RAINS), and converts the possible thresholds for fattening pigs to other animals, using the N excretion per animal as common basis.

Based on the N excretion, current IPPC thresholds for fattening pigs, sows and broilers could be explained; only for laying hens the current level of 40,000 is too high. If N excretion is used as basis for possible thresholds for intensive rearing of dairy cattle and other cattle, thresholds would be around 220 and 500 head per farm of dairy cattle and other cattle respectively. When the N excreted during grazing (approximately 50% of the total N excretion) is not taken into account, the thresholds would become 450 and 1,000 head per farm, respectively.

Table 5.2. Overview of mean N excretion per animal species, in kg N per animal per year, and possible "N excretion based thresholds" for various animal species, derived from the possible thresholds for fattening pigs.

Animal species	Mean N excretion	Possible thresholds for farms (number animals per farm), using the possible thresholds for fattening pigs as basis			
Fattening pigs	11	2000	1750	1500	1250
Dairy cows	100.0	220	193	165	138
Other cows	45.0	489	428	367	306
Sows	28.0	786	688	589	491
	11.0	2000	1750	1500	1250
Broilers	0.6	36667	32083	27500	22917
Laying hens	0.8	27500	24063	20625	17188
Sheep/goat	14.0	1571	1375	1179	982
Ducks	1.0	22000	19250	16500	13750
Horses	64.0	344	301	258	215
Rabbits	0.7	31429	27500	23571	19643
Turkeys	2.1	10476	9167	7857	6548

5.5. Analyses of the scenarios

In the selection of the various scenarios, N excretion was used as a basis for the determination of the thresholds (equivalent N excretions), as described above. The range of lowered IPPC thresholds (see Table 5.3) is based upon a discussion, taking into account the number of extra farms covered by the lowered thresholds and the expected effectiveness of reduced emissions per extra farm (and permit) covered. A revised threshold for fattening pigs is taken as a basis; thresholds for other animal species are expressed against these thresholds.

Scenario IPPC1 demonstrates the impact of lowering thresholds for the poultry sector (especially for laying hens), and introduced thresholds for cattle. In IPPC2 and IPPC3, a further reduction of the thresholds for cattle and poultry is taken, in combination with reduced thresholds for pigs.

Table 5.3. Selected thresholds values for animals in the four scenarios; current IPPC and IPPC1, IPPC2 and IPPC3.

Animal species	Scenarios 2020			
	Current IPPC	IPPC1	IPPC2	IPPC3
Fattening pigs	> 2000	> 2000	> 1750	> 1500
Sows	> 750	> 750	> 675	> 600
Hens	> 40000	> 27500	> 25000	> 20000
Broilers	> 40000	> 37000	> 32000	> 27000
Dairy cows	-	> 450	> 400	> 350
Other cattle	-	> 1000	> 850	> 700

Tables 5.4, 5.5, 5.6 and 5.7 present the % of animals covered by each of the IPPC scenarios. The exact percentage is taken up for thresholds that correspond with EUROSTAT farm size categories. In all other cases, the percentages are obtained from creating sub-categories and interpolation. In general, when larger sub-categories are used, the distribution of animal over the categories is non-linear (less animals are kept on smaller farms); when smaller sub-categories were needed, the number of animals is equally distributed over the sub-categories. A full account of the distribution of animals over sub-categories is given in the Background Report (Annex 4[25].

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[25] Annex 4. Monteny, G.J., H.P Witzke and D.A. Oudendag 2007. Impact assessment of a possible modification of the IPPC Directive. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Alterra Report. Wageningen.

Table 5.4. Total number (in thousands) and relative number (in percent of total number) of animals covered per Member State by the current IPPC thresholds.

	Fattening pigs on IPPC farms with pigs		Sows on IPPC sow farms		Laying hens on IPPC hen farms		Broilers on IPPC broiler farms	
Country	Pigs	% of total	Sows	% of total	Hens	% of total	Broilers	% of total
BE	451	6.9	22	3.4	6530	50.0	8290	45.6
CZ	1137	32.4	179	45.6	9320	88.8	15640	85.8
DK	2382	18.4	344	24.5	2130	43.5	10870	89.0
DE	2479	9.3	359	13.7	37050	66.5	41020	72.7
EE	111	31.0	0	0.0	860	69.9	0	0.0
GR	177	16.3	17	12.5	2420	21.3	11780	45.9
ES	5017	23.7	1311	40.5	42480	71.4	50010	47.9
FR	1045	6.9	94	6.9	43560	59.0	48770	35.2
IE	725	42.3	88	50.9	630	29.9	6470	69.9
IT	3724	43.4	290	39.4	26270	74.2	89930	83.6
CY	162	37.4	28	48.0	250	32.9	2650	73.4
LV	77	18.5	17	35.8	1670	65.5	0	0.0
LT	217	20.0	46	50.1	2170	54.0	1660	66.4
LU	0	0.0	0	0.0	0	0.0	0	0.0
HU	1504	32.7	156	42.7	4840	33.7	9540	72.0
MT	0	0.0	0	0.0	0	0.0	0	0.0
NL	1310	11.7	200	17.8	22750	61.6	33980	80.3
AT	0	0.0	0	0.0	740	12.2	1760	31.5
PL	811	4.4	102	5.3	21250	41.1	78670	63.8
PT	415	19.6	31	10.1	7940	68.9	8110	42.1
SI	89	14.6	23	34.7	0	0.0	0	0.0
SK	413	28.3	48	32.0	3730	80.9	7260	88.6
FI	23	1.7	17	9.7	540	12.6	4000	66.1
SE	238	12.5	53	26.1	2480	41.3	5520	93.4
UK	1295	25.7	177	30.8	30000	62.1	103420	91.2
EU25	23803	15.9	3602	22.3	269610	58.5	539350	64.3

Some 16% and 22% of respectively fatteners and sows fall under current IPPC thresholds, whereas this is around 60% for the poultry sector. Since current IPPC is not applicable for cattle, 0% of the cattle herd in EU-25 fall under IPPC compliance.

Table 5.5. Percentage of animals covered per Member State for revised IPPC thresholds according to scenario 'IPPC1'.

	Fatteners >2,000 %	Sows > 750 %	Hens >27,500 %	Broilers > 37,000 %	Dairy >450 %	Other cattle > 1,000 %
Belgium	6.9	3.4	67.0	48.6	1.2	0.7
Czech Rep.	32.4	45.6	90.6	86.6	77.8	6.5
Denmark	18.4	24.5	57.9	89.7	7.6	0.5
Germany	9.3	13.7	70.9	74.3	14.5	1.2
Estonia	31.0	0.0	72.4	0.0	49.8	4.3
Greece	16.3	12.5	24.0	47.7	0.6	0.3
Spain	23.7	40.5	78.1	50.7	5.2	1.2
France	6.9	6.9	68.0	37.7	0.9	0.2
Ireland	42.3	50.9	39.4	71.5	4.2	0.2
Italy	43.4	39.4	78.4	84.3	11.3	1.9
Cyprus	37.4	48.0	44.6	74.7	24.2	2.0
Latvia	18.5	35.8	65.5	0.0	9.4	1.0
Lithuania	20.0	50.1	54.7	70.4	6.7	1.0
Luxembourg	0.0	0.0	0.0	0.0	3.1	0.3
Hungary	32.7	42.7	36.3	73.3	63.1	5.5
Malta	0.0	0.0	5.2	3.4	0.0	0.0
Netherlands	11.7	17.8	71.0	81.5	1.7	2.2
Austria	0.0	0.0	20.8	34.9	0.0	0.0
Poland	4.4	5.3	46.3	65.4	3.5	0.5
Portugal	19.6	10.1	74.0	44.0	5.2	1.3
Slovenia	14.6	34.7	0.6	4.4	2.5	0.1
Slovakia	28.3	32.0	82.6	89.2	74.7	6.8
Finland	1.7	9.7	20.8	67.8	0.1	0.1
Sweden	12.5	26.1	56.0	93.8	5.6	0.3
United Kingdom	25.7	30.8	70.9	91.7	13.3	0.9
EU-25	15.9	22.3	65.4	65.9	9.7	0.9

Since no change in the IPPC thresholds for fatteners and sows was taken as a basis for scenario 1, the % of animals covered remains unchanged compared to table 2. For the poultry sector, the revised thresholds results in an increase in the % of animals that fall under the IPPC to around 66%. Furthermore, the suggested thresholds for cattle result in a coverage of 9.7% for dairy cows and 0.9% for other cattle.

Table 5.6. Percentage of animals covered per Member State for revised IPPC thresholds according to scenario 'IPPC2'

	Fatteners >1750 %	Sows >675 %	Hens > 25000 %	Broilers >32000 %	Dairy >400 %	Other cattle >850 %
Belgium	12.3	5.3	69.1	53.6	1.8	2.2
Czech Rep.	38.9	47.5	91.0	87.9	80.5	19.5
Denmark	25.3	27.9	60.4	90.7	10.5	1.5
Germany	12.5	15.2	72.1	76.9	15.8	3.6
Estonia	37.3	4.1	72.4	0.0	52.5	12.8
Greece	20.1	13.7	24.7	50.6	1.1	1.0
Spain	28.3	42.6	79.4	55.4	6.0	3.7
France	12.3	9.1	69.6	41.8	1.4	0.7
Ireland	49.9	53.1	41.3	74.2	5.6	0.6
Italy	48.0	41.4	79.7	85.5	14.0	5.6
Cyprus	46.2	50.6	47.1	76.8	31.7	5.9
Latvia	21.7	36.6	65.5	0.0	10.2	2.9
Lithuania	23.1	50.6	54.7	77.0	7.1	3.1
Luxembourg	6.2	1.6	0.0	0.0	4.0	0.9
Hungary	36.3	43.8	36.8	75.3	65.0	16.4
Malta	5.0	0.0	10.5	9.0	0.0	0.0
Netherlands	16.1	21.2	73.1	83.4	2.4	6.6
Austria	0.4	0.2	22.5	40.5	0.0	0.0
Poland	5.3	5.5	47.4	68.0	3.8	1.5
Portugal	24.3	12.1	74.8	47.1	5.8	3.8
Slovenia	17.8	34.7	1.2	11.6	2.5	0.4
Slovakia	34.5	34.0	83.1	90.2	78.2	20.3
Finland	3.8	10.6	23.7	70.5	0.1	0.2
Sweden	17.2	27.9	58.5	94.3	7.1	0.9
United Kingdom	31.7	33.4	72.6	92.5	17.9	2.7
UE-25	**20,1**	**24,2**	**66,8**	**68,5**	**11,1**	**2,8**

In scenario 2, all thresholds are lowered, resulting in an increased coverage of animals by IPPC. The increase is the largest for fattening pigs (+4%), and broilers (+3%).

Table 5.7. Percentage of animals covered per Member State for revised IPPC thresholds according to scenario 'IPPC3'.

	Fatteners >1500 %	Sows >600 %	Hens >20000 %	Broilers >27000 %	Dairy >350 %	Other cattle >700 %
Belgium	17.7	7.2	73.3	60.1	2.4	4.4
Czech Rep.	45.3	49.3	91.8	89.7	83.2	38.9
Denmark	32.2	31.3	65.5	92.1	13.4	3.0
Germany	15.7	16.8	74.5	80.3	17.1	7.3
Estonia	43.6	8.1	72.4	0.0	55.3	25.6
Greece	23.9	14.9	26.2	54.5	1.7	2.0
Spain	33.0	44.6	81.9	61.4	6.8	7.5
France	17.7	11.2	72.7	47.2	1.9	1.3
Ireland	57.5	55.2	45.2	77.8	7.1	1.2
Italy	52.6	43.4	82.3	87.1	16.6	11.3
Cyprus	55.1	53.2	52.2	79.5	39.1	11.7
Latvia	24.9	37.3	65.5	0.0	11.0	5.8
Lithuania	26.2	51.0	54.7	85.7	7.5	6.1
Luxembourg	12.4	3.1	0.0	0.0	4.9	1.9
Hungary	39.8	44.9	37.7	78.1	66.9	32.7
Malta	10.0	0.0	20.9	16.4	0.0	0.0
Netherlands	20.4	24.6	77.5	85.9	3.1	13.2
Austria	0.8	0.4	26.0	47.8	0.0	0.0
Poland	6.1	5.8	49.7	71.4	4.2	2.9
Portugal	29.0	14.1	76.2	51.0	6.5	7.7
Slovenia	20.9	34.7	2.4	21.1	2.5	0.9
Slovakia	40.7	36.0	83.9	91.5	81.7	40.5
Finland	5.8	11.5	29.5	74.0	0.2	0.5
Sweden	21.9	29.7	63.4	95.1	8.6	1.9
United Kingdom	37.8	36.1	76.0	93.6	22.5	5.3
EU-25	**24.3**	**26.1**	**69.6**	**72.0**	**12.5**	**5.7**

The most stringent IPPC thresholds in this study results in a coverage of around 25% for the pig sector, 70% for the poultry sector, 12,5% for dairy cows, and nearly 6% for other cattle.

In table 5.8, the number of farms for each animal sector covered by each scenario is presented.

Table 5.8. Number of farms covered by various IPPC scenarios.

Scenarios	Fatteners	Sows	Laying hens	Broilers	Dairy cows	Other cattle	Total
Current IPPC	6040	2380	2450	5180	0	0	16050
IPPC1	6040	2380	3572	5862	7283	383	25520
IPPC2	8360	3238	3953	6998	9357	1149	33054
IPPC3	10680	4115	4716	8474	11430	2298	41714

Some 16,000 farms in the EU-25 have to comply with IPPC under the current thresholds (Table 5.8). Each scenario adds roughly 8,000 farms to that number. Assuming equal costs for permitting in all sectors, the total costs would increase by 50% when the scenario 1 thresholds would be implemented. Based on UK data, that indicate annual costs of permitting of around 3,000 € per farm (UK data: around 3,000 - 4,000 € or 2,500 – 3,000 UK Pound per permit issued; Pellini and Morris, 2002), the total amount of money involved in permitting would be around 50 million Euro per year, with a 50% increase for each scenario. In scenario IPPC3, most of the permits would be issued for the fattening pig and dairy cow sector, meaning that these sectors would be facing the highest costs compared to other sectors.

Table 5.9. Summary of NH_3 emission in 2020 for various scenarios, compared to current IPPC thresholds (in 1,000,000 kg or kton NH_3).

	Current IPPC	IPPC1	IPPC2	IPPC3	IPPC1+ LNA	IPPC2+ LNA	IPPC3+ LNA
Total NH3 emissions agriculture	2,800	2,771	2,763	2,751	2,726	2,712	2,691
Difference with current IPPC (kton)	-	30	37	49	74	88	110
in % compared to current IPPC	-	98,9	98,7	98,2	97,4	96,9	96,1

Table 5.10. Efficiency and additional efficiency of permitting under the various sets of thresholds.

	Current IPPC	IPPC1	IPPC2	IPPC3	IPPC1 +LNA	IPPC2 +LNA	IPPC3 +LNA
Permits (IPPC farms)	16,050	25,520	33,054	41,714	25,520	33,054	41,714
Cumulative efficiency per permit (1,000 kg/permit)	-	3,1	2,2	1,9	7,8	5,2	4,3
Additional efficiency (d_Emission/d_permit)	-	3,1	1,0	1,4	7,8	1,9	2,2

The data in Table 5.9 show that a maximum reduction of 49 kton NH_3 is realized for scenario 3, where IPPC permits are issued for nearly 42,000 farms (sum of farms with > 1,500 fattening pigs, >600 sows, >20,000 laying hens, >27,000 broilers, >350 dairy cows, and >700 head of other cattle). The efficiency (Table 5.10) of the increased number of permits under scenario 3 when compared to the current IPPC situation is 1,900 kg NH_3 saved per permit (49 kton saved with the issuing of 24,000 permits). The permitting efficiency (and additional efficiency) decrease with progressing scenarios. The additional effect of lowering the thresholds from the values valid for scenario IPPC2 to values in scenario IPPC3 is 1,400 kg NH_3 extra saved per permit (12 kton extra saved by issuing an extra number of 8,000 permits). As indicated before, permits for the intensive rearing of pigs and poultry are assumed to include Stable Adaptations and Covered Storage (high efficiency).

When Low Nitrogen Application (high efficiency) is also included in the IPPC permits, the reduction in NH_3 emission drastically increases when compared to current IPPC, up to 110 kton for scenario 3. The additional effect of including LNA ranges from 44 kton for IPPC1 to 61 kton for IPPC3, and can be regarded as significant.
The greater impact of including LNA is also reflected in the increased efficiency per permit and the additional permitting efficiency. Despite this greater reduction, the NH_3 emissions from agriculture in 2020 due to lowering IPPC thresholds, inclusion of cattle, and tightened LNA use, is reduced with nearly 4% compared to the ‘current’ IPPC situation in 2020.

The development of NH_3-emissions in each EU-Member State (EU-25) is shown below in Figure 5.5. This figure shows that the NH_3 emission in all 2020 scenarios will be markedly lower for nearly all Member States when compared to the emission in 2000 (including the actual level of implementation of the Nitrates Directive in both years). This is caused by the lowered number of animals (from CAPRI calculations), the increased implementation of BAT following the IPPC Directive, and a reduced use of chemical fertilizers. Furthermore, the figure shows that lowering of the IPPC thresholds for intensive animal rearing, and the inclusion of IPPC thresholds for cattle husbandry has the greatest absolute impact on NH_3 emission in countries with the least national environmental legislation concerning BAT to reduce NH_3 emissions (See: Background report per Member State), like Poland, Italy, Czech Republic, Hungary, Portugal, UK and Spain. In a fair part of the other countries, national environmental legislation is assumed to be implemented to such a level that lowering thresholds has limited or no impact (e.g. for Germany, Belgium, Sweden, Denmark, Netherlands). The remainder Member States contribute little to the EU-27 NH_3 emission, and lowering of the thresholds has little to no impact on NH_3 emission.

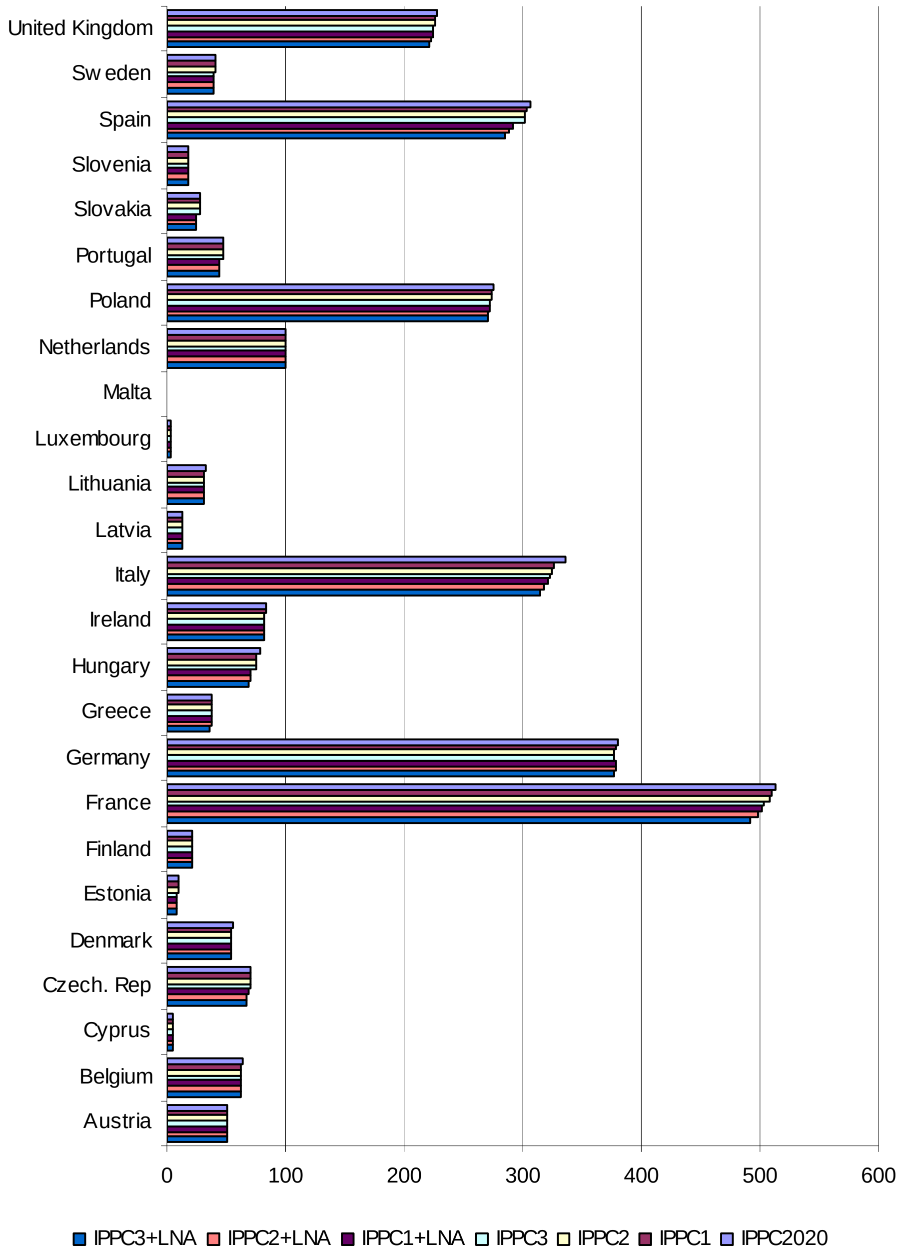

Figure 5.5. Ammonia emission in 2000 (scenario '2000+ND) and in 2020 (all other scenarios) from agriculture (in kton) per Member State for the various scenario's, compared to the ammonia emission in 2020 under 'current' IPPC (note: the order of scenarios in the legend is opposite to the order in the graph; 2000+ND scenario has the highest emission).

Without ‘proper implementation’ of NH_3 emissions abatement measures in housing systems, manure storage systems and following spreading of animal manure to land, increased emissions of nitrous oxide and in increased nitrate leaching may occur (See Chapters 2 and 3). However, in the scenarios we analysed, savings of NH_3 in animal manures following the implementation of NH_3 emissions abatement measures are taken into account via ‘integrated N management’ and ‘balanced fertilization’ to minimize pollution swapping.

As shown in Table 5.11, lowering of the thresholds slightly increases the emissions of nitrous oxide (N_2O) by 1.5 to 2.2% for the scenarios without LNA, and by 2.3 to 3.3% for the LNA scenarios. These increases are due to the fact that more animals fall under the IPPC directive and consequently more NH_3 is kept in the animal manure and applied to the land. The lowered thresholds, however, appear to have little effect on the leaching of nitrate (not shown). Obviously, the measures under the Nitrates Directive compensate for leaching rather than for nitrous oxide formation and emission. Lowering thresholds appear to have no significant impact on the emission of methane.

Table 5.11. Overview of absolute and relative levels of nitrous oxide (N_2O-N) and methane (CH_4) for the various scenarios.

	current IPPC	IPPC1	IPPC2	IPPC3	IPPC1 +LNA	IPPC2 +LNA	IPPC3 +LNA
N_2O-N (kton)	329	334	335	337	337	338	340
CH_4 (kton)	8,443	8,446	8,447	8,450	8,446	8,447	8,450
%N_2O		101.5	101.8	102.2	102.3	102.7	103.3
%CH_4		100.0	100.0	100.1	100.0	100.0	100.1

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5.6. Results of the IPPC scenario analyses by CAPRI

A selection of scenarios has been investigated in-depth with the CAPRI modelling system. The selection includes the following scenarios:

- Current IPPC (reference situation ND Full);
- IPPC1;
- IPPC2;
- IPPC3;
- IPPC2+LNA;
- IPPC3+LNA.

For this task, an increased IPPC coverage has been treated as being equivalent to an increased percentage of farms applying NH_3 emission abatement measures, similar as in the simulations with MITERRA-EUROPE. For the environmental impacts this is a gross simplification because large farms may have a far higher impact on local ecosystems than captured by their share in the regional aggregate. Furthermore the national IPPC shares have been applied to all NUTS2 regions in the Member States even though large farms may be concentrated in some areas only (as regional IPPC shares were unavailable).

In terms of economic impacts, the costs of NH_3 emission abatement measures have been applied according to the changed implementation of these measures. Investment cost and current cost of ammonia measures per unit were taken from the RAINS database. Additional administrative costs related to the permit procedure have been assumed to equal 2500 € per permit or 340 € per year[26]. The direct cost for ammonia measures per animal have been increased in line with this total amount per farm (see Annex 4).

The additional costs of animal production in IPPC farms tend to decrease the profitability and will slightly decrease the contribution of these farms to aggregate production. Given that IPPC farms cover a great share of total production in the poultry sector these supply reducing effects are most clear. In the first enforcement scenario 'IPPC1', i.e. with a moderately increased IPPC coverage, EU-27 production of poultry meat declines by 0.2% (Table 5.12). As a consequence there will be some increase in producer prices which is 0.5% at the EU level. These market effects also affect pork but are only about half as strong as on the poultry market. They help to limit the aggregate loss to agriculture to 240 m €. The aggregate loss hides reallocations within agriculture. Whereas the additional cost is born by IPPC farms only, the counteracting price increase benefits all farms.

The first level of IPPC extension would reduce aggregate NH_3 emissions by 47 ktons. This is a larger impact than according to Miterra-Europe simulations (28 ktons). The differences is related to the CAPRI assumption that LNF is a standard requirement for IPPC farms by 2020 which goes beyond the cautious penetration rates adopted in RAINS and Miterra-Europe. Table 5.12 also reveals small antagonistic effects on N_2O emissions which tend to increase slightly.

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[26] The administrative cost per farm for permits has been converted into an annual amount with an interest rate of 6% and an assumed life time for permits of 10 years due to changes in the legal framework.

Table 3.15: Simulation results of a moderate extension of IPPC coverage (IPPC1 2020) vs. IPPC0 in 2020

Absolute change IPPC1 vs. IPPC0 2020

	agric income [m €]	'net' dir cost [m €]	poultry meat prd [kton]	poultry price [€ / ton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-240	334	-19	6	-32	-23	-47	5	7	-3
Austria	2	2	0	5	0	0	0	0	0	0
Belgium	-9	13	-5	6	0	0	-1	0	0	0
Bulgaria	22	-21	0	1	0	1	0	1	0	0
Cyprus	-1	1	0	10	0	0	0	0	0	0
Czech. Rep	-16	18	-2	5	-2	-1	-1	1	0	0
Denmark	-3	9	-4	4	-1	-1	-2	0	1	0
Estonia	-2	2	0	9	0	0	0	0	0	0
Finland	0	2	0	6	0	0	0	0	0	0
France	-4	30	3	7	-3	0	-4	0	1	0
Germany	-34	68	-3	5	-4	-5	-6	1	1	-1
Greece	-3	3	-1	4	0	0	0	0	0	0
Hungary	-29	25	-3	9	0	-2	-1	0	0	0
Ireland	-24	17	-1	6	-2	0	-2	1	0	0
Italy	-144	95	-5	8	-7	-7	-15	-1	2	0
Latvia	0	1	0	49	0	0	0	0	0	0
Lithuania	-2	2	0	15	0	0	0	0	0	0
Malta	0	0	0	9	0	0	0	0	0	0
Netherlands	2	9	1	5	0	0	0	0	0	0
Poland	-8	15	-1	6	-1	-1	-2	0	0	0
Portugal	-3	6	-1	6	-1	0	-1	0	0	0
Romania	39	-28	1	2	-1	1	0	1	0	0
Slovakia	-4	4	0	7	0	-1	-1	0	0	0
Slovenia	-1	1	0	6	0	0	0	0	0	0
Spain	-14	33	-3	6	-4	-2	-6	0	1	0
Sweden	-2	5	0	5	0	0	0	0	0	0
United Kingdom	-1	21	2	6	-4	-3	-4	1	0	-1

Percentage change IPPC1 vs. IPPC0 2020

	agric income [%]	'net' dir cost [%]	poultry meat prd [%]	poultry price [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-0.1	1.6	-0.2	0.5	-0.3	-0.2	-1.6	0.1	0.9	-0.2
Austria	0.1	0.3	0.0	0.5	-0.2	0.0	-0.2	0.0	0.3	0.0
Belgium	-0.3	4.2	-1.4	0.5	-0.2	-0.1	-1.1	0.0	2.2	0.1
Bulgaria	0.9	-6.4	0.3	0.1	-0.2	0.5	0.3	0.5	0.1	0.0
Cyprus	-0.2	4.4	0.0	0.6	-0.5	-0.5	-2.6	0.0	1.1	-0.5
Czech. Rep	-0.9	4.8	-0.6	0.6	-0.5	-0.8	-1.7	1.0	-0.1	-1.4
Denmark	-0.1	1.7	-1.7	0.5	-0.9	-0.2	-3.9	0.0	2.4	-0.1
Estonia	-0.9	8.3	0.6	0.6	-0.1	-2.2	-2.6	-0.1	-1.3	-1.9
Finland	0.0	0.3	0.1	0.5	-0.1	0.0	-0.7	0.0	0.5	0.0
France	0.0	0.7	0.2	0.5	-0.1	0.0	-0.8	0.0	0.6	0.0
Germany	-0.2	1.7	-0.2	0.5	-0.2	-0.3	-1.4	0.0	0.7	-0.5
Greece	0.0	1.9	-0.6	0.5	-0.2	0.0	-1.4	0.0	0.7	0.1
Hungary	-0.7	3.7	-0.7	0.6	0.0	-0.9	-1.8	-0.2	1.8	-0.5
Ireland	-0.9	3.1	-0.5	0.5	-0.7	-0.1	-1.6	0.1	0.6	-0.3
Italy	-0.4	4.8	-0.5	0.5	-0.9	-0.8	-4.4	-0.1	3.1	-0.1
Latvia	-0.1	2.7	0.0	0.6	-0.3	-0.6	-0.6	0.0	-0.3	-1.0
Lithuania	-0.3	1.8	0.3	0.6	-0.1	-0.4	-0.8	-0.1	0.0	-0.4
Malta	0.1	2.1	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	0.0	0.4	0.2	0.5	-0.1	0.0	0.0	0.0	0.0	-0.1
Poland	-0.1	6.9	-0.1	0.6	-0.1	-0.2	-0.8	-0.1	0.6	-0.1
Portugal	-0.1	0.8	-0.4	0.5	-0.6	-0.2	-1.9	0.1	1.5	-0.2
Romania	0.7	-1.8	0.7	0.1	-0.2	0.5	0.3	0.4	0.1	0.0
Slovakia	-0.6	3.2	0.2	0.6	-0.3	-2.5	-4.5	-0.1	-0.2	-1.7
Slovenia	-0.2	2.0	0.6	0.6	-0.5	-0.1	-0.9	0.0	0.5	0.0
Spain	0.0	3.0	-0.2	0.5	-0.5	-0.1	-1.9	0.0	2.0	-0.1
Sweden	-0.1	0.5	0.0	0.5	0.0	-0.2	-0.9	0.0	0.5	0.0
United Kingdom	0.0	1.0	0.1	0.5	-0.5	-0.3	-1.9	0.1	0.3	-0.6

Fertilizer use is somewhat declining in the CAPRI simulations because farmers are assumed to maintain the desired ratio of crop available N supply to N demand. They would thus adjust to lower NH_3 losses with a decline of fertilizer application. However this adjustment does not completely eliminate the antagonistic effect on leaching, as a part of the increased N from manure will be considered unavailable to crops.

The variation between countries in the IPPC scenarios is driven by the assumed changes of penetration rates for NH_3 emission abatement measures which in turn mainly derive from the country level farm structure information and the expected implementation. The above average impact in Italy, for example, derives from a significant application of stable adaptation measures which are both costly and effective. The additional cost in turn reinforces the savings in emissions through their supply curbing impact. Excretion is usually declining as a consequence of LNF but this effect may be compensated to a large extent by an expansion of animal production, if the price increases on EU markets stimulate production more than the curbing effect of higher cost on IPPC farms.

Table 5.13. shows that the major contributions to aggregate income are hardly affected by scenario IPPC1.

Table 5.13. Contributions to agricultural income according to CAPRI simulations for a moderate extension of IPPC coverage (IPPC1 2020) vs. IPPC0 in 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	427108			0.0%		
Cereals	35589	105	339079	-0.1%	-0.1%	0.0%
Other non fodder	157328	252	624671	0.0%	0.0%	0.0%
Fodder	18922	9	2141668	0.0%	0.0%	-0.1%
Meat	74654	1629	45818	0.1%	0.2%	-0.1%
Other Animal products	59486	273	217671	0.1%	0.1%	0.0%
Other output	81129	164	493456	0.0%	0.0%	0.0%
Inputs	262230			0.1%		
Fertiliser	39252	819	47912	0.0%	0.0%	0.0%
Feedingstuff	71915	47	1543543	-0.3%	-0.3%	0.0%
Other input	151063	283	532917	0.4%	0.3%	0.1%
European Union 15						
Production value	371005			0.0%		
Cereals	26426	110	239820	-0.1%	-0.1%	0.0%
Other non fodder	140787	263	535176	0.0%	0.0%	0.0%
Fodder	15796	9	1764251	0.0%	0.0%	0.0%
Meat	64895	1695	38275	0.1%	0.2%	-0.1%
Other Animal products	51308	278	184390	0.1%	0.1%	0.0%
Other output	71794	174	413408	0.0%	0.0%	0.0%
Inputs	225505			0.1%		
Fertiliser	31791	850	37390	0.0%	0.0%	0.0%
Feedingstuff	62599	47	1324382	-0.3%	-0.2%	0.0%
Other input	131114	292	449002	0.4%	0.3%	0.1%
European Union 12						
Production value	56102			0.0%		
Cereals	9163	92	99259	-0.1%	-0.1%	0.0%
Other non fodder	16541	185	89496	0.0%	0.0%	0.0%
Fodder	3126	8	377418	-0.1%	0.0%	-0.1%
Meat	9759	1294	7543	0.2%	0.2%	0.0%
Other Animal products	8178	246	33281	0.1%	0.0%	0.0%
Other output	9335	117	80048	0.0%	-0.1%	0.1%
Inputs	36725			0.1%		
Fertiliser	7461	709	10523	0.0%	0.0%	0.0%
Feedingstuff	9316	43	219161	-0.4%	-0.5%	0.0%
Other input	19948	238	83915	0.3%	0.2%	0.1%

The change in agricultural income is one component of the total change in 'economic welfare' (Table 5.14).

Table 5.14. Contributions to the change in conventional economic welfare according to CAPRI simulations for a moderate extension of IPPC coverage (IPPC1 2020) vs. IPPC0 in 2020 [million €]

	EU27	EU15	EU12
Total	-532	-491	-41
Consumer money metric	-236	-206	-30
Agricultural income	-240	-239	-1
Premiums	0	0	0
Agricultural Output	89	68	21
Output crops	-37	-30	-7
Output animals	126	98	28
Output rest	0	0	0
Agricultural Input	329	307	22
Crop specific Input	-7	-6	-1
Animal specific Input	-227	-183	-44
Other Input	564	496	67
'Net' direct cost	334	313	21
Profit of dairies	1	1	0
Profit of other processing	-48	-42	-6
Tariff revenues	-4	-1	-3
FEOGA first pillar	4	3	0

The price increases reduce consumer welfare. A part of the additional 'net direct cost' for NH_3 emission abatement measures on IPPC farms (334 m €) is thus passed on to consumers (aggregate loss: 236 m €) such that agriculture is less affected (-240 m €). This 'net direct cost' is defined as in Annex 3: "It is the cost of additional quality of management and feed plus costs of permits and net of any savings on fertilizer cost or feed quantities due to LNF". Note that the total welfare loss is somewhat larger than the net direct cost but not very far away from this straightforward measure of economic cost. Impacts on the processing industry and on the budget are negligible. Whereas the change in our conventional welfare measure is clearly negative it has to be mentioned that the benefits of this and other scenarios in terms of reduced emissions have not been monetised. The estimated (partial) welfare loss may be interpreted as an estimate of the cost to society to achieve the environmental improvements in terms of reduced emissions of NH_3.

Moving to the strong extension of IPPC coverage (Tables 5.14-5.18) reinforces all effects discussed so far without modification in basic relationships.

Table 5.15. Simulation results of a strong extension of IPPC coverage (IPPC2 2020) vs. IPPC0 in 2020

Absolute change IPPC2 vs. IPPC0 2020

	agric income [m €]	'net' dir cost [m €]	poultry meat prd [kton]	poultry price [€ / ton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-392	622	-28	10	-43	-41	-63	5	8	-5
Austria	4	5	0	8	0	0	0	0	0	0
Belgium	-18	27	-6	9	0	-1	-1	0	0	0
Bulgaria	30	-26	0	2	-1	1	0	1	0	0
Cyprus	-2	2	0	15	0	0	0	0	0	0
Czech. Rep	-20	20	-2	7	-2	-1	-1	1	0	0
Denmark	-13	19	-4	7	-1	-2	-3	0	0	0
Estonia	-2	2	0	14	0	0	0	0	0	0
Finland	1	3	0	9	0	0	0	0	0	0
France	-34	78	2	11	-5	-2	-8	0	1	0
Germany	-66	120	-5	8	-5	-8	-9	0	1	-1
Greece	-4	5	-1	7	0	0	-1	0	0	0
Hungary	-39	36	-3	12	0	-2	-2	0	0	0
Ireland	-31	28	-1	9	-3	0	-2	1	0	0
Italy	-186	143	-4	12	-7	-11	-17	-2	2	0
Latvia	-1	1	0	72	0	0	0	0	0	0
Lithuania	-4	5	0	22	0	0	0	0	0	0
Malta	0	0	0	13	0	0	0	0	0	0
Netherlands	-1	22	-1	7	0	-1	0	0	0	0
Poland	-6	24	-1	9	-2	-1	-2	0	0	0
Portugal	-5	12	-2	9	-1	-1	-1	0	0	0
Romania	53	-35	1	3	-1	2	0	2	0	0
Slovakia	-5	6	0	10	0	-1	-1	0	0	0
Slovenia	-4	4	0	9	0	0	0	0	0	0
Spain	-35	75	-6	9	-5	-5	-8	0	2	0
Sweden	-5	10	0	8	0	-1	-1	0	0	0
United Kingdom	-1	39	4	9	-6	-5	-6	2	0	-1

Percentage change IPPC2 vs. IPPC0 2020

	agric income [%]	'net' dir cost [%]	poultry meat prd [%]	poultry price [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-0.2	2.8	-0.2	0.8	-0.4	-0.4	-2.2	0.1	1.1	-0.4
Austria	0.1	0.7	-0.3	0.8	-0.4	0.1	-0.3	0.1	0.6	-0.2
Belgium	-0.5	8.6	-1.8	0.8	-0.2	-0.3	-1.4	-0.1	2.4	-0.1
Bulgaria	1.1	-8.7	0.4	0.1	-0.4	0.7	0.3	0.7	0.2	0.0
Cyprus	-0.5	7.8	0.0	0.9	-0.4	-1.0	-4.2	-0.3	1.1	-0.9
Czech. Rep	-1.1	6.0	-0.6	0.9	-0.6	-1.1	-2.4	1.0	-0.1	-1.6
Denmark	-0.4	3.5	-1.8	0.8	-0.7	-0.6	-4.4	-0.1	2.2	-0.5
Estonia	-0.8	9.5	0.8	0.9	-0.2	-2.4	-3.0	-0.1	-1.3	-1.9
Finland	0.1	0.4	0.2	0.8	-0.2	0.1	-0.9	0.1	0.7	0.0
France	-0.1	1.8	0.1	0.8	-0.2	-0.1	-1.6	0.0	0.8	0.0
Germany	-0.4	3.1	-0.3	0.8	-0.3	-0.6	-2.0	0.0	0.8	-0.7
Greece	0.0	3.3	-0.8	0.8	-0.2	0.0	-1.9	0.0	0.9	0.1
Hungary	-1.0	5.3	-0.7	0.9	-0.1	-1.3	-2.7	-0.4	2.0	-0.7
Ireland	-1.2	4.3	-0.5	0.8	-1.1	-0.1	-1.9	0.2	0.6	-0.5
Italy	-0.5	6.7	-0.4	0.8	-1.0	-1.2	-5.1	-0.2	3.3	-0.5
Latvia	-0.2	4.0	0.4	0.9	-0.4	-0.7	-0.7	0.0	-0.3	-1.2
Lithuania	-0.7	3.5	0.4	0.9	-0.2	-0.5	-1.0	-0.1	0.0	-0.6
Malta	0.0	4.6	0.3	0.9	0.0	-0.4	0.0	0.0	0.0	-5.0
Netherlands	0.0	1.0	-0.1	0.8	-0.1	-0.3	-0.2	0.0	-0.2	-0.3
Poland	-0.1	10.3	-0.1	0.9	-0.2	-0.2	-1.0	0.0	0.8	-0.1
Portugal	-0.1	1.5	-0.5	0.8	-0.7	-0.4	-2.4	0.0	1.6	-0.4
Romania	1.0	-2.5	1.0	0.1	-0.3	0.8	0.5	0.6	0.1	0.0
Slovakia	-0.8	4.1	0.3	0.9	-0.4	-2.9	-5.6	-0.2	0.0	-1.9
Slovenia	-0.6	6.2	0.5	0.9	-0.7	-0.4	-2.1	-0.3	1.0	0.0
Spain	-0.1	6.6	-0.4	0.8	-0.7	-0.4	-2.5	0.0	2.2	-0.5
Sweden	-0.3	1.1	0.1	0.8	0.0	-0.4	-1.5	0.1	0.5	-0.3
United Kingdom	0.0	1.6	0.2	0.8	-0.8	-0.5	-2.6	0.2	0.3	-0.9

Even for the strong expansion the aggregate income effects are rather moderate on the sectoral level, in particular in percentage terms. Evidently this does not hold for the farms affected.

Table 5.16. Contributions to agricultural income according to CAPRI simulations for a strong extension of IPPC coverage (IPPC2 2020) vs. IPPC0 in 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	427108			0.1%		
Cereals	35589	105	339079	-0.2%	-0.2%	0.0%
Other non fodder	157328	252	624671	0.0%	0.0%	0.0%
Fodder	18922	9	2141668	-0.1%	0.0%	-0.1%
Meat	74654	1629	45818	0.3%	0.4%	-0.2%
Other Animal products	59486	273	217671	0.2%	0.2%	0.0%
Other output	81129	164	493456	0.0%	0.1%	-0.1%
Inputs	262230			0.2%		
Fertiliser	39252	819	47912	0.0%	0.0%	0.0%
Feedingstuff	71915	47	1543543	-0.5%	-0.4%	0.0%
Other input	151063	283	532917	0.7%	0.6%	0.1%
European Union 15						
Production value	371005			0.1%		
Cereals	26426	110	239820	-0.2%	-0.2%	0.0%
Other non fodder	140787	263	535176	0.0%	0.0%	0.0%
Fodder	15796	9	1764251	0.0%	0.1%	-0.1%
Meat	64895	1695	38275	0.3%	0.4%	-0.2%
Other Animal products	51308	278	184390	0.2%	0.2%	0.0%
Other output	71794	174	413408	0.0%	0.1%	-0.1%
Inputs	225505			0.3%		
Fertiliser	31791	850	37390	0.0%	0.0%	0.0%
Feedingstuff	62599	47	1324382	-0.5%	-0.4%	-0.1%
Other input	131114	292	449002	0.7%	0.6%	0.0%
European Union 12						
Production value	56102			0.1%		
Cereals	9163	92	99259	-0.2%	-0.2%	0.0%
Other non fodder	16541	185	89496	0.0%	0.0%	0.0%
Fodder	3126	8	377418	-0.1%	0.0%	-0.1%
Meat	9759	1294	7543	0.4%	0.4%	0.0%
Other Animal products	8178	246	33281	0.2%	0.1%	0.1%
Other output	9335	117	80048	0.0%	-0.1%	0.1%
Inputs	36725			0.1%		
Fertiliser	7461	709	10523	0.0%	0.0%	0.0%
Feedingstuff	9316	43	219161	-0.6%	-0.6%	0.0%
Other input	19948	238	83915	0.5%	0.3%	0.2%

Finally we add the welfare effects of a strong extension of IPPC coverage (Table 5.17). The price increases reduce consumer welfare and pass on a significant part of the direct cost for NH3 emission abatement measures on IPPC farms to consumers such that agriculture is less affected. Impacts on the processing industry and on the budget are negligible. As under scenario IPPC1 the change in our conventional welfare measure is clearly negative (-980 m €), indicating that reduced emissions of NH3 are not available for free.

Table 5.17. Contributions to the change in conventional economic welfare according to CAPRI simulations for a strong extension of IPPC coverage (IPPC2 2020) vs. IPPC0 in 2020 [million €]

	EU27	EU15	EU12
Total	-980	-907	-73
Consumer money metric	-471	-410	-61
Agricultural income	-392	-393	1
Premiums	0	0	0
Agricultural Output	251	207	43
Output crops	-84	-67	-17
Output animals	335	274	61
Output rest	0	0	0
Agricultural Input	642	600	43
Crop specific Input	-14	-12	-2
Animal specific Input	-336	-281	-55
Other Input	992	892	100
'Net' direct cost	622	584	39
Profit of dairies	2	2	0
Profit of other processing	-114	-102	-12
Tariff revenues	1	1	0
FEOGA first pillar	7	7	0

At this point it will be illuminating to look at the separate contributions from LNF to the impacts of the ‘strong’ extension of IPPC coverage under scenario IPPC2. For this purpose it has been investigated what would be the result if, contrary to the CAPRI default assumption, LNF would *not* be mandatory for IPPC2 farms. Comparing this scenario with the standard version of IPPC2 reveals the partial contribution of LNF according to our simulations (Table 5.18).

This partial LNF impact compares well with the results from Annex 3 where it has been investigated what would be the LNF impacts without further ammonia measures on IPPC2 farms. The presence or absence of standard ammonia measures modifies the estimated contribution of LNF measures, but does not fundamentally change the picture: On the EU27 level the agricultural income loss is 564 m € (397 m € according to Annex 3) and ammonia losses decline by 32 ktons (as in Annex 3), for example. This consistency is reassuring. More importantly it confirms that the contribution of LNF in the CAPRI simulations of IPPC scenarios is significant and partly explains the stronger impacts obtained compared to Miterra-Europe. Note that the agricultural income loss due to LNF on IPPC2 farms is larger than the additional loss when moving from the IPPC1 extension to IPPC2. Expressed differently the gain in income would have been higher if LNF were abolished on all IPPC2 farms rather than eliminating both ammonia measures and LNF on the additional farms coming under IPPC at this state of extension.

Table 5.18: Simulation results of scenario IPPC2 (strong extension of IPPC coverage) with LNF compared to IPPC2 without LNF in 2020

Absolute change IPPC2 without LNF vs. IPPC2 2020

	agric income [m €]	'net' dir cost [m €]	poultry meat prd [kton]	poultry price [€ / ton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-541	1175	-83	30	-23	-108	-32	14	-6	-15
Austria	13	9	1	27	-1	0	0	0	0	0
Belgium	-9	37	-4	29	0	-1	0	0	0	0
Bulgaria	9	-4	1	13	-1	0	0	0	0	0
Cyprus	-3	3	0	42	0	-1	0	0	0	0
Czech. Rep	-12	21	3	20	-2	0	0	1	0	-1
Denmark	-11	15	-1	22	1	-6	-1	0	0	-1
Estonia	-2	2	0	38	0	-1	0	0	0	0
Finland	-3	11	-1	31	0	0	0	0	0	0
France	23	129	17	36	-4	-2	-1	2	0	-1
Germany	-93	197	-16	25	-1	-17	-5	1	-1	-3
Greece	-3	14	-2	21	-1	0	0	0	0	0
Hungary	-39	53	-3	34	0	-4	-1	0	0	0
Ireland	-40	45	-2	28	-4	0	0	3	0	0
Italy	-133	175	-14	40	0	-19	-5	-1	-1	-2
Latvia	-1	1	0	199	0	0	0	0	0	0
Lithuania	-3	4	0	60	0	-1	0	0	0	0
Malta	0	0	0	37	0	0	0	0	0	0
Netherlands	-25	48	-24	23	0	-6	-1	0	0	-1
Poland	-12	48	3	24	-1	-6	-1	0	0	-1
Portugal	-17	29	-3	29	0	-2	-1	0	0	0
Romania	19	-6	3	16	-1	1	0	1	0	0
Slovakia	-2	5	0	28	0	-2	-1	0	0	0
Slovenia	3	2	2	26	0	0	0	0	0	0
Spain	-122	202	-6	29	-3	-22	-7	1	-1	-2
Sweden	-3	16	-2	25	1	-1	0	0	0	0
United Kingdom	-74	119	-34	30	-6	-17	-6	5	-1	-3

Percentage change IPPC2 without LNF vs. IPPC2 2020

	agric income [%]	'net' dir cost [%]	poultry meat prd [%]	poultry price [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-0,3	6,1	-0,6	2,5	-0,2	-1,1	-1,1	0,1	-0,8	-1,4
Austria	0,4	1,7	0,5	2,5	-0,8	0,2	0,1	0,2	-0,1	-0,4
Belgium	-0,3	15,3	-1,4	2,5	-0,2	-0,4	-0,4	-0,1	-0,4	-0,6
Bulgaria	0,3	0,8	0,9	0,8	-0,4	0,2	0,1	0,1	-0,1	-0,2
Cyprus	-0,8	20,3	-1,0	2,4	1,2	-3,0	-4,7	-0,5	-3,3	-2,3
Czech. Rep	-0,7	5,2	1,2	2,4	-0,7	-0,4	-0,5	1,4	-0,6	-1,7
Denmark	-0,4	5,6	-0,4	2,5	0,4	-1,8	-1,8	-0,2	-1,4	-2,5
Estonia	-1,1	13,7	1,1	2,4	0,0	-3,0	-2,6	-0,2	-1,3	-2,6
Finland	-0,2	1,6	-0,6	2,5	-0,2	-0,1	-0,1	0,1	-0,2	-0,5
France	0,1	3,4	0,8	2,5	-0,2	-0,1	-0,2	0,1	-0,2	-0,3
Germany	-0,5	6,4	-0,9	2,5	-0,1	-1,2	-1,0	0,1	-0,9	-2,0
Greece	0,0	8,7	-1,4	2,5	-0,3	-0,1	-0,3	0,1	-0,2	-0,2
Hungary	-1,0	8,2	-0,6	2,4	0,0	-2,3	-1,8	-0,1	-0,8	-1,6
Ireland	-1,5	4,7	-1,4	2,5	-1,5	0,0	-0,3	0,6	-0,4	-1,2
Italy	-0,4	7,5	-1,6	2,5	0,0	-2,2	-1,7	-0,1	-1,6	-2,6
Latvia	-0,3	5,8	0,4	2,4	-0,6	-1,0	-1,0	0,1	-0,5	-1,7
Lithuania	-0,5	5,0	0,9	2,4	-0,2	-1,0	-0,9	0,0	-0,2	-1,2
Malta	0,2	13,6	1,9	2,4	0,0	-0,4	0,0	-0,5	0,0	0,0
Netherlands	-0,2	3,6	-4,0	2,5	0,2	-1,3	-1,4	0,0	-1,6	-1,3
Poland	-0,1	26,8	0,2	2,4	-0,1	-1,0	-0,6	-0,1	-0,5	-1,0
Portugal	-0,4	3,9	-1,0	2,5	-0,3	-1,1	-1,4	0,2	-1,1	-1,4
Romania	0,3	0,1	1,8	0,8	-0,2	0,3	0,2	0,2	0,0	-0,1
Slovakia	-0,3	4,8	0,3	2,4	0,0	-4,4	-3,3	0,2	-1,6	-3,8
Slovenia	0,5	5,4	3,1	2,4	-0,3	0,0	0,2	-0,1	-0,5	-0,5
Spain	-0,3	25,4	-0,4	2,5	-0,4	-1,6	-2,2	0,1	-1,5	-2,0
Sweden	-0,2	2,2	-1,3	2,5	0,5	-1,0	-0,9	0,2	-0,6	-0,3
United Kingdom	-0,7	5,8	-1,9	2,5	-0,7	-1,6	-2,8	0,4	-1,5	-2,2

The contribution of LNF to the overall effects is particularly interesting for the income and welfare impacts (Table 5.19). It may be seen that the ‘net direct cost’ are an incomplete indicator of total welfare cost.

Table 5.19: Contributions to the change in conventional economic welfare according to CAPRI simulations for scenario IPPC2 (strong extension of IPPC coverage) with LNF compared to IPPC2 without LNF in 2020 [million €]

	EU27	EU15	EU12
Total	-2284	-2025	-259
Consumer money metric	-1324	-1158	-166
Agricultural income	-564	-512	-53
Premiums	1	0	1
Agricultural Output	575	485	90
Output crops	-234	-171	-62
Output animals	808	656	152
Output rest	0	0	0
Agricultural Input	1140	997	143
Crop specific Input	-41	-35	-6
Animal specific Input	-973	-856	-116
Other Input	2153	1888	265
'Net' direct cost	1190	1054	136
Profit of dairies	9	7	1
Profit of other processing	-381	-340	-42
Tariff revenues	17	16	1
FEOGA first pillar	41	40	1

For the strong expansion of IPPC coverage we have also investigated the additional effect of mandatory additional low nitrogen application of manure (Table 5.20).

Table 5.20: Simulation results of scenario IPPC2 (strong extension of IPPC coverage) with additional LNA compared to IPPC2 without additional LNA in 2020

Absolute change IPPC2 + more LNA vs. IPPC2 2020

	agric income [m €]	'net' dir cost [m €]	poultry meat prd [kton]	poultry price [€ / ton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-90	177	-15	4	-34	-1	-43	0	4	1
Austria	2	1	0	3	0	0	0	0	0	0
Belgium	4	2	1	4	0	0	0	0	0	0
Bulgaria	1	0	0	2	0	0	0	0	0	0
Cyprus	-2	1	0	8	0	0	0	0	0	0
Czech. Rep	-12	9	-4	4	-1	0	-1	0	0	0
Denmark	2	2	-1	3	-1	0	-1	0	0	0
Estonia	-1	1	0	7	0	0	0	0	0	0
Finland	1	1	0	4	0	0	0	0	0	0
France	-14	23	-5	5	-7	0	-10	0	1	0
Germany	28	3	6	3	1	1	2	0	0	0
Greece	-2	2	-1	3	0	0	-1	0	0	0
Hungary	-14	13	-4	7	-2	0	-3	0	0	0
Ireland	-4	4	-1	4	-1	0	-1	0	0	0
Italy	-6	14	-3	5	-3	0	-5	0	1	0
Latvia	-1	1	0	38	0	0	0	0	0	0
Lithuania	-2	2	0	11	0	0	0	0	0	0
Malta	0	0	0	7	0	0	0	0	0	0
Netherlands	6	4	2	3	0	0	0	0	0	0
Poland	6	7	1	5	-2	0	-2	0	0	0
Portugal	-9	7	-1	4	-2	0	-2	0	0	0
Romania	2	0	0	2	0	0	0	0	0	0
Slovakia	-7	5	-1	5	-1	0	-2	0	0	0
Slovenia	0	0	0	5	0	0	0	0	0	0
Spain	-65	52	-8	4	-10	-1	-14	0	1	0
Sweden	-2	2	-1	3	0	0	-1	0	0	0
United Kingdom	0	20	5	4	-2	0	-2	0	0	0

Percentage change IPPC2 + more LNA vs. IPPC2 2020

	agric income [%]	'net' dir cost [%]	poultry meat prd [%]	poultry price [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	0.0	0.6	-0.1	0.3	-0.3	0.0	-1.5	0.0	0.6	0.1
Austria	0.1	0.1	0.0	0.3	-0.4	0.0	-0.5	0.0	0.3	0.0
Belgium	0.1	0.0	0.2	0.3	0.0	0.1	0.1	0.0	0.1	0.0
Bulgaria	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Cyprus	-0.4	3.4	-0.6	0.4	-2.4	-0.4	-8.8	-0.2	3.4	0.5
Czech. Rep	-0.7	2.2	-1.7	0.4	-0.3	-0.2	-3.3	0.0	0.9	0.2
Denmark	0.1	0.3	-0.6	0.3	-0.3	0.0	-1.1	0.0	0.2	0.1
Estonia	-0.7	4.1	0.3	0.4	-0.7	-0.3	-4.2	-0.2	1.4	0.0
Finland	0.0	0.1	0.2	0.3	-0.1	0.0	-0.3	0.0	0.2	0.0
France	0.0	0.5	-0.2	0.3	-0.3	0.0	-2.0	0.0	0.7	0.2
Germany	0.2	-0.1	0.3	0.3	0.1	0.1	0.5	0.0	-0.1	-0.1
Greece	0.0	1.3	-0.6	0.3	-0.2	-0.1	-2.3	0.0	0.5	0.2
Hungary	-0.4	1.6	-0.7	0.4	-0.5	-0.1	-4.1	0.0	1.2	0.3
Ireland	-0.2	0.9	-0.5	0.3	-0.2	0.0	-0.7	0.0	0.5	0.0
Italy	0.0	0.6	-0.3	0.3	-0.5	0.0	-1.5	0.0	0.9	0.2
Latvia	-0.2	0.7	-0.4	0.4	-0.2	0.0	-1.2	0.0	0.3	0.0
Lithuania	-0.3	1.4	0.1	0.4	-0.3	-0.2	-2.0	-0.1	0.5	0.1
Malta	0.2	0.0	0.7	0.4	0.0	0.4	0.0	0.0	0.0	0.0
Netherlands	0.1	0.0	0.3	0.3	-0.1	0.1	0.1	0.0	0.1	0.0
Poland	0.1	1.6	0.1	0.4	-0.2	0.1	-0.8	0.0	0.4	0.1
Portugal	-0.2	0.9	-0.5	0.3	-1.5	-0.1	-4.4	0.0	1.8	0.3
Romania	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Slovakia	-1.0	2.4	-0.7	0.4	-1.1	-0.6	-10.6	-0.4	3.0	0.8
Slovenia	0.1	0.6	0.6	0.4	-0.5	0.0	-0.7	0.0	0.5	0.5
Spain	-0.2	3.8	-0.4	0.3	-1.3	-0.1	-4.6	0.0	1.8	0.3
Sweden	-0.1	0.4	-0.9	0.3	-0.3	-0.1	-1.6	0.0	0.9	0.0
United Kingdom	0.0	0.4	0.3	0.3	-0.3	0.0	-1.1	0.0	0.3	0.1

Associated welfare and income effects are given in Table 5.21

Table 5.21: Contributions to the change in conventional economic welfare according to CAPRI simulations for scenario IPPC2 (strong extension of IPPC coverage) with additional LNA compared to IPPC2 without additional LNA in 2020 [million €]

	EU27	EU15	EU12
Total	-259	-205	-54
Consumer money metric	-169	-144	-25
Agricultural income	-90	-61	-30
Premiums	0	0	0
Agricultural Output	124	113	11
Output crops	4	3	0
Output animals	121	110	11
Output rest	0	0	0
Agricultural Input	215	173	41
Crop specific Input	-1	0	0
Animal specific Input	-5	4	-9
Other Input	221	170	51
'Net' direct cost	177	138	40
Profit of dairies	0	0	0
Profit of other processing	-2	-2	-1
Tariff revenues	1	0	1
FEOGA first pillar	-1	-1	0

Finally we will look at the ‘very strong’ extension of IPPC coverage in scenario IPPC3 (Tables 5.22; 5.23).

Table 5.22: Simulation results of a very strong extension of IPPC coverage (IPPC3 2020) vs. IPPC0 in 2020

Absolute change IPPC3 vs. IPPC0 2020

	agric income [m €]	'net' dir cost [m €]	poultry meat prd [kton]	poultry price [€ / ton]	mineral fertiliser [kton N]	excretion [kton N]	total NH3 loss [kton N]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
EU27	-558	892	-37	13	-56	-63	-85	4	9	-7
Austria	7	7	-1	11	-1	0	0	0	0	0
Belgium	-19	37	-7	12	0	-1	-1	0	0	0
Bulgaria	27	-23	0	4	-1	1	0	1	0	0
Cyprus	-3	2	0	20	0	0	0	0	0	0
Czech. Rep	-25	22	-2	10	-2	-2	-1	1	0	-1
Denmark	-11	21	-4	9	-1	-3	-3	0	0	0
Estonia	-3	3	0	18	0	-1	0	0	0	0
Finland	1	4	0	13	0	0	0	0	0	0
France	-86	138	-1	15	-8	-6	-14	-3	1	0
Germany	-70	150	-7	10	-7	-10	-12	0	1	-1
Greece	-6	8	-2	9	-1	0	-1	0	0	0
Hungary	-45	44	-4	16	-1	-3	-2	0	0	0
Ireland	-38	38	-1	11	-4	0	-2	2	0	0
Italy	-253	198	-2	16	-9	-16	-22	-2	2	-1
Latvia	-1	1	0	94	0	0	0	0	0	0
Lithuania	-5	5	0	28	0	0	0	0	0	0
Malta	0	0	0	17	0	0	0	0	0	0
Netherlands	1	32	-1	10	0	-2	0	0	0	0
Poland	-5	32	-2	11	-2	-1	-3	0	1	0
Portugal	-7	18	-2	12	-1	-2	-2	0	0	0
Romania	43	-28	2	5	-1	2	0	2	0	0
Slovakia	-6	7	0	13	-1	-2	-1	0	0	0
Slovenia	-3	4	0	12	0	0	-1	0	0	0
Spain	-46	106	-11	12	-7	-9	-10	1	2	-1
Sweden	-5	13	0	10	0	-1	-1	0	0	0
United Kingdom	2	53	6	12	-9	-6	-7	4	0	-2

Percentage change IPPC3 vs. IPPC0 2020

	agric income [%]	'net' dir cost [%]	poultry meat prd [%]	poultry price [%]	mineral fertiliser [%]	excretion [%]	total NH3 loss [%]	total CH4 emisions [%]	total N2O emisions [%]	leaching [%]
EU27	-0.3	4.0	-0.3	1.1	-0.5	-0.6	-2.9	0.0	1.3	-0.6
Austria	0.2	1.0	-0.6	1.0	-0.7	0.1	-0.5	0.1	0.9	-0.2
Belgium	-0.5	11.6	-2.2	1.0	-0.3	-0.4	-1.6	0.0	2.6	-0.3
Bulgaria	1.0	-6.6	0.4	0.3	-0.4	0.6	0.3	0.6	0.1	-0.1
Cyprus	-0.8	11.4	0.0	1.1	-0.4	-1.7	-6.3	-0.5	1.1	-0.9
Czech. Rep	-1.4	7.3	-0.6	1.1	-0.7	-1.4	-3.4	1.1	0.0	-1.7
Denmark	-0.4	4.2	-1.7	1.0	-0.6	-1.0	-4.9	-0.2	2.1	-1.0
Estonia	-1.3	13.3	1.1	1.1	-0.2	-3.0	-4.1	-0.4	-1.3	-2.3
Finland	0.1	0.7	0.1	1.0	-0.3	0.1	-1.3	0.1	0.9	0.0
France	-0.3	3.4	0.0	1.0	-0.4	-0.4	-2.9	-0.1	1.2	0.0
Germany	-0.4	4.1	-0.4	1.0	-0.4	-0.7	-2.5	0.0	1.1	-0.9
Greece	-0.1	4.9	-1.2	1.0	-0.3	-0.1	-2.5	0.1	1.1	0.1
Hungary	-1.2	6.6	-0.7	1.1	-0.1	-1.6	-3.4	-0.5	2.2	-0.9
Ireland	-1.5	5.3	-0.6	1.0	-1.5	-0.1	-2.2	0.4	0.7	-0.7
Italy	-0.7	9.3	-0.3	1.0	-1.2	-1.8	-6.5	-0.3	3.6	-0.9
Latvia	-0.3	4.7	0.4	1.1	-0.5	-0.7	-0.7	0.2	-0.3	-1.3
Lithuania	-0.7	4.1	0.4	1.1	-0.2	-0.7	-1.5	-0.2	0.1	-0.8
Malta	-0.2	6.8	0.3	1.1	0.0	-0.9	-1.3	0.0	0.0	-5.0
Netherlands	0.0	1.5	-0.1	1.0	-0.1	-0.4	-0.4	0.0	-0.4	-0.6
Poland	-0.1	13.6	-0.1	1.1	-0.2	-0.2	-1.2	0.0	1.0	-0.2
Portugal	-0.2	2.2	-0.8	1.0	-0.9	-0.7	-3.1	0.0	1.6	-0.7
Romania	0.8	-1.7	1.0	0.3	-0.3	0.7	0.4	0.5	0.1	0.0
Slovakia	-0.9	4.9	0.4	1.1	-0.5	-3.5	-6.9	-0.3	0.0	-2.3
Slovenia	-0.5	6.5	0.5	1.1	-1.4	-0.4	-3.1	-0.1	1.9	0.0
Spain	-0.1	9.7	-0.6	1.0	-0.9	-0.7	-3.3	0.0	2.6	-0.9
Sweden	-0.4	1.4	0.2	1.0	0.0	-0.5	-2.0	0.1	0.6	-0.3
United Kingdom	0.0	2.2	0.3	1.0	-1.1	-0.6	-3.5	0.3	0.3	-1.3

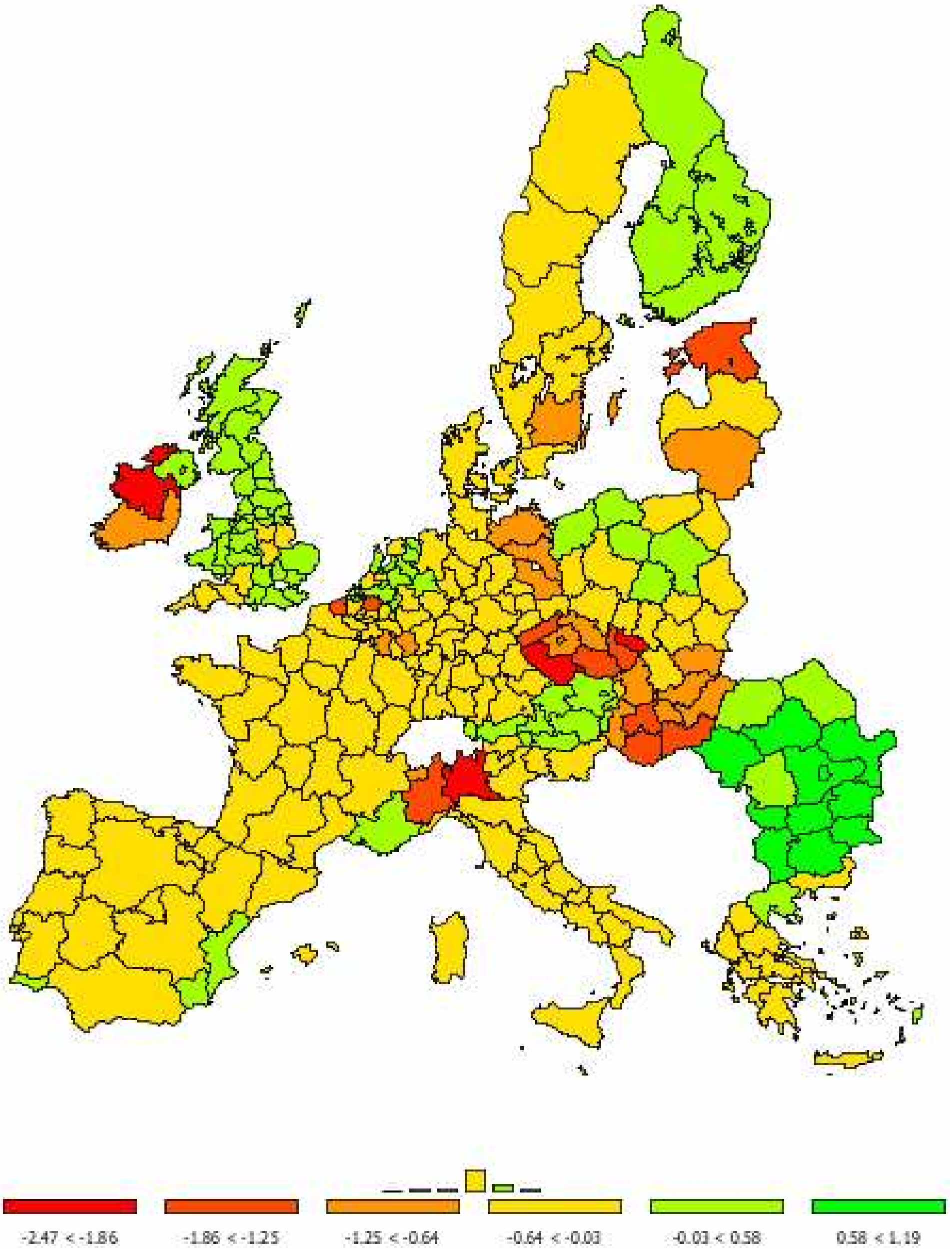

Figure 5.6. Regional variation of percentage income effects for scenario IPPC3 2020 relative to IPPC0 in 2020.

In the case of the IPPC3 2020 scenario we might also find non-negligible differences between regions (Figure 5.6). In general we see that even with a very strong extension of IPPC coverage the aggregate income effects are usually very small and sometimes even positive. This does not hold where the positive impact from small increases in meat prices is insufficient to compensate for the increase in costs and loss in meat output and where the animal sector contributes significantly to overall agricultural output. Gains are possible if the increase in farms covered under IPPC is small (FI, UK, evidently in BG + RO, where IPPC coverage is unknown).

Table 5.23: Contributions to agricultural income according to CAPRI simulations for a very strong extension of IPPC coverage (IPPC3 2020) vs. IPPC0 in 2020

	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]	EAA value [million €]	Unit value EAA [€ / t]	Quantity [1000 t]
European Union 27						
Production value	427108			0.1%		
Cereals	35589	105	339079	-0.4%	-0.4%	0.0%
Other non fodder	157328	252	624671	0.0%	0.0%	0.0%
Fodder	18922	9	2141668	-0.1%	0.0%	-0.1%
Meat	74654	1629	45818	0.4%	0.7%	-0.2%
Other Animal products	59486	273	217671	0.2%	0.2%	0.0%
Other output	81129	164	493456	0.1%	0.2%	-0.1%
Inputs	262230			0.4%		
Fertiliser	39252	819	47912	-0.1%	0.0%	-0.1%
Feedingstuff	71915	47	1543543	-0.7%	-0.6%	-0.1%
Other input	151063	283	532917	1.0%	0.9%	0.1%
European Union 15						
Production value	371005			0.1%		
Cereals	26426	110	239820	-0.4%	-0.3%	0.0%
Other non fodder	140787	263	535176	0.0%	0.0%	0.0%
Fodder	15796	9	1764251	-0.1%	0.1%	-0.1%
Meat	64895	1695	38275	0.4%	0.7%	-0.3%
Other Animal products	51308	278	184390	0.2%	0.2%	0.0%
Other output	71794	174	413408	0.1%	0.2%	-0.2%
Inputs	225505			0.4%		
Fertiliser	31791	850	37390	-0.1%	0.0%	-0.1%
Feedingstuff	62599	47	1324382	-0.7%	-0.6%	-0.1%
Other input	131114	292	449002	1.0%	0.9%	0.1%
European Union 12						
Production value	56102			0.1%		
Cereals	9163	92	99259	-0.4%	-0.4%	0.0%
Other non fodder	16541	185	89496	0.0%	0.0%	0.0%
Fodder	3126	8	377418	-0.1%	0.0%	-0.2%
Meat	9759	1294	7543	0.6%	0.7%	-0.1%
Other Animal products	8178	246	33281	0.2%	0.2%	0.1%
Other output	9335	117	80048	0.1%	0.0%	0.0%
Inputs	36725			0.2%		
Fertiliser	7461	709	10523	0.0%	0.0%	-0.1%
Feedingstuff	9316	43	219161	-0.9%	-0.9%	0.0%
Other input	19948	238	83915	0.8%	0.6%	0.2%

Finally we add the welfare effects of the very strong extension of IPPC coverage (Tables 5.24. The price increases reduce consumer welfare and pass on a significant part of the net direct cost for NH_3 emission abatement measures on IPPC farms to consumers such that agriculture is less affected. Impacts on the processing industry and on the budget are negligible. The change in our conventional welfare measure is negative (- 1425 m €), indicating that reduced emissions of NH3 are costly.

Table 5.24: Contributions to the change in conventional economic welfare according to CAPRI simulations for a very strong extension of IPPC coverage (IPPC3 2020) vs. ND Full 2020 [million €]

	EU27	EU15	EU12
Total	-1425	-1293	-132
Consumer money metric	-686	-599	-87
Agricultural income	-558	-532	-27
Premiums	-2	-2	1
Agricultural Output	374	327	47
Output crops	-136	-102	-34
Output animals	509	429	80
Output rest	0	0	0
Agricultural Input	930	856	74
Crop specific Input	-21	-18	-3
Animal specific Input	-485	-406	-80
Other Input	1437	1280	157
'Net' direct cost	892	822	70
Profit of dairies	4	3	0
Profit of other processing	-178	-161	-17
Tariff revenues	4	4	0
FEOGA first pillar	9	9	1

The key results from the CAPRI simulations are collected again in Table 5.25 including also a sensitivity analysis on additional LNA measured starting from scenario IPPC3

Table 5.25: Simulation results of increase coverage of farms by IPPC

	agric income [m €]	consumer welfare [m €]	total econ welfare [m €]	total NH3 loss [kton]	total CH4 emisions [kton N]	total N2O emisions [kton N]	leaching [kton N]
IPPC1	-240	-236	-532	-47	5	7	-1036
IPPC2	-392	-471	-980	-63	5	8	-5
IPPC2 + more LNA	-482	-640	-1239	-107	5	12	-3
IPPC3	-558	-686	-1425	-85	4	9	-7
IPPC3 + more LNA	-655	-877	-1712	-138	4	304	-5
				abatement relative to welfare cost estimate			
				NH3 [g / €]	CH4 [g / €]	N2O [g / €]	leaching [g / €]
IPPC1				88	-10	-13	1947
IPPC2				65	-6	-8	5
IPPC2 + more LNA				86	-4	-10	3
IPPC3				60	-3	-6	5
IPPC3 + more LNA				81	-2	-177	3

5.7. Discussion

Task 4 consisted of a wide variety of activities, with a focus on the collection of data needed for the assessment of lowering the IPPC threshold for intensive animal rearing, and the inclusion of thresholds for cattle husbandry.

Data collection and analyses

Statistical data were obtained from EUROSTAT and used throughout the study to assure a uniform basis for the calculations. However, during the study the MS were invited to submit MS specific information. This showed that there are differences between EUROSTAT and MS data on farm size distribution, the number of IPPC farms and the number of permits issued. For future work, a more solid and consolidated basis for statistical information must be found to make the outcome of these type of studies recognizable for MS representatives. Statistical agencies within the MS should, therefore, have to work more closely together with more general agencies like EUROSTAT. As regards the number of IPPC farms and permits, information derived directly from Member States representatives is supposed to be more reliable than data from other, more general sources.

Information on the environmental legislation per MS was gathered to the extent possible. Especially in the perspective of penetration of Best Available Techniques there appeared to be a gap between the advisors' perception and the perception of the MS representatives. Their information was used to improve the table with inputs on % of penetration of BAT. Nevertheless, a more detailed inventory of the BAT penetration in the coming years, based upon current and developing legislation, is advised to improve the validity of projections.

Effects of threshold modifications on emissions

Revised IPPC thresholds for intensive animal rearing and new thresholds for cattle were chosen on the basis of criteria concerning maximum permitting efficiency and restricted increase in number of permits. The scenarios chosen appeared to have a relatively small effect on the total NH_3 emissions, whereas also the adverse effects on other emissions (pollution swapping effects) were limited. Limited pollution swapping was mainly a results of the formulation of the scenarios; these included measures to reduce all N losses to the environment, such as balanced fertilization, full implementation of the Nitrates Directive and low nitrogen feeding. Key issue appeared the inclusion of 'low emission application of animal manure'. This measure is now not legally regarded as an element of the IPPC permit in many MS, although it is a part of the BAT-Reference Document under the IPPC Directive. A maximum reduction of the NH_3 emissions with 106 kton can be achieved in 2020, when lowering the thresholds for intensive animal rearing and thresholds for cattle husbandry include provisions on "low emission application of animal manure'. Therefore, it is recommended to consider strengthening of the EU legislation concerning 'low emissions application of animal manure', either in the framework of the IPPC Directive, or under any other Directive (e.g. Nitrates Directive). Next to 'low nitrogen animal feeding', low emission manure application is the most cost-effective way to abate NH_3 emissions.

Reduction of the total NH_3 emissions by 106 kton in 2020, due to a more stringent IPPC Directive, can not be considered as ‘a substantial reduction’. Quite some efforts and costs are needed in terms of numbers of permits and administrative costs for this extra permitting to achieve the reduction. When the outcome of the calculations for 2000 and 2020 are compared, much more effect is seen from a more strict application of the current IPPC Directive (including low emission application of animal manure and low nitrogen feeding) than from lowering thresholds. Especially when considering the difference between European and MS related interpretation of the IPPC Directive, more effort is needed to improve compliance on MS level with the IPPC Directive as it is.

Autonomous developments and full implementation of the Nitrates Directive will decrease the total NH_3 emissions by 616 kton in 2020 relative to the reference year 2000. This decrease is much larger than the additional impact of lowered IPPC thresholds (28-106 kton). Including Low Nitrogen Application as a Best Available Technique in the IPPC permits significantly contributes to decreasing total NH_3 emissions.

The efficiency of permits is strongly reduced when IPPC thresholds are lowered. Cumulative efficiency, expressed in kg NH_3 saved per permit, is reduced from 3,000 to 1,800 for IPPC1 and IPPC3, respectively. This is markedly higher for the LNA scenarios (7,600 and 4,200 kg, respectively). The additional efficiency (extra NH_3 saved per extra permit issued) is around 1,200 kg and 2,400 kg for without and with LNA, respectively.

The trade off of losses following from lowered IPPC thresholds for nitrate leaching and methane emissions are small, especially when compared to the 2000+ND scenario. The scenarios where LNA is considered, slightly increase N_2O emissions (3.7% maximum).

Impact Assessment

As to the Impact Assessment for the Commission, the following options have been considered:
1. Inclusion of BAT for manure spreading
2. Inclusion of different threshold for poultry species
3. Extending the scope of the IPPC Directive

A brief analysis of options 1 and 2 are presented below.

As can be concluded from Table 3.10 in the Annex report to Task 4[27], the impact of including BAT for ‘low-emission manure spreading’ (Low Nitrogen Application, LNA) ranges from 44 - 61 kton, depending on the scenario. These figures are obtained by deducting the emission reductions for each scenario with and without LNA. The largest impact of LNA is observed for the IPPC3 scenario, because of the large number of farms under IPPC in this scenario. The range indicated is in good accordance with the figures presented by IIASA in their final report (around 50 kton for Scenario IPPC1).

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[27] Annex 4. Monteny, G.J., H.P Witzke and D.A. Oudendag 2007. Impact assessment of a possible modification of the IPPC Directive. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Alterra Report. Wageningen

Following option 2, a revised threshold for poultry (for various poultry species) can be made using the information of Table 4.4 in the Annex report to Task 4. Based upon uniform N-excretion factors per animal species, the following poultry thresholds would hold:

- broilers: 40,000 (no change)
- laying hens: 30,000
- ducks: 24,000
- turkeys: 11,429

For laying hens, the threshold would be in between the threshold for the basic scenario and Scenario IPPC1 (see table 4.4 in the Annex report to Task 4). No information could be gathered for the number of duck and turkey farms. We estimate that around 900 extra poultry farms would fall under the IPPC, bringing the total to 17,000 IPPC farms for all animal species. Since the emission reduction for Scenario IPPC1 is 30 kton (Table 3.10 in the Annex report), as a result from lowered thresholds for poultry and cattle, the lowering of poultry thresholds only will result in an emission reduction of less than 10 kton. The costs (compliance costs and investment costs) will also be limited compared to the costs for Scenario IPPC1 (see e.g. Table 3.17 in the Annex report).

Economic assessments

It is evident that additional IPPC coverage will achieve improvements on NH_3 emissions at moderate cost whereas progress on leaching would be minimal. Including LNA as BAT on the IPPC farms clearly increase the effectiveness of NH_3 emissions abatement in terms of total emission avoided and also in terms of efficiency (higher yield in abatement per € of welfare loss). Again it has to be noted that a great part of the economic loss is born by consumers. Price increases of 1% for meat under IPPC3 may appear negligible but they sum up to significant economic cost. It has to be acknowledged that these price increases are part of the uncertainties. Among other influences they hinge on the unknown degree of consumer preferences for EU produced meat which determine the amount of pass through of additional cost in the livestock sector. With greater substitutability the economic losses would fall more on agriculture than on consumers.

Deciding on the optimal level involves some comparisons of inputs and outputs. A welfare theoretic perspective suggests to compare the ratio of avoided NH_3 emissions to the cost of NH_3 emission abatement measures in terms of conventional welfare loss. Under this criterion it is clearly recommendable to promote the application of LNA measures. The stronger extensions of IPPC coverage without LNA measures appears to be less favourable, but the differences are quite small. Considering that there are many uncertainties in a model based analysis like this one is it fair to state that all levels of IPPC extension have similar yields in terms of ammonia abatement. The decision needs to be made on other grounds therefore, for example on the required total abatement while minimizing interference with the private sector.

Uncertainties in economic modeling

There are a number of uncertainties surrounding economic modeling analyses. These uncertainties can be categorized in 4 categories, as follows:

1. Simplifications:

- Profit maximising farmers seem to contradict observed inefficiency
- Ignorance of heterogeneity of farmers, consumers, locations (within NUTS2)
- Limited choice space for farmers: no endogenous technology choice,
- Lack of detail in policy representation: IPPC treated as a certain percentage of NUTS2 without local relevance

2. Data and parameters

- Initial CAPRI nitrogen surplus in crop sector and in feeding depends on statistical data with gaps and errors
- Different conceivable data sources (e.g. animal stocks vs. animal production)
- Uncertain parameters: elasticities, emission factors, expert coefficients (grass yields and losses, average nutrient availability from manure, leaching fractions, crop residues)

3. Future developments

- Future of milk quotas (maintained in simulations), future WTO agreement
- Boom in energy crops
- Farm structure and penetration rates ammonia measures
- Catching up in New MS, accession of more countries (Western Balkan, Turkey?)
- Future macro development (GDP, inflation, exchange rates)

4. Implementation

- Will the measures be sufficiently monitored if they are not in the farmers interest?
- Will farmers counteract in unforeseen ways?
- Will Member State implement the measures as planned on EU level?

6. Stakeholder consultations, presentations and workshops

6.1. Introduction

In the call for tender of the Ammonia Service Contract, the European Commission emphasized the need for appropriate stakeholder consultation, and for presenting the results in relevant working groups, notably under the IPPC Directive, Nitrates Directive, and NEC Directive. Further, a number of presentations in specialised working groups were foreseen as well as regular meetings with representatives of the Commission. These activities were indicated in Task 5. The aim of this task has been defined as:
"To consult stakeholders about relevant issues of the contract and to present and discuss results".
This chapter provides a summary of the activities carried out under this task.

6.2. Meetings with the European Commission

The kick-off meeting of Ammonia Service Contract (ASC) was held in Brussels on 26th January 2006. During this meeting the draft Inception Report of the ASC was discussed. On the basis of this discussion, a revised Inception Report was submitted by the 21th of February 2006.

The first progress meeting of the ASC was held on 31 May 2007. During this meeting the progress in each task was discussed. The tasks and especially the scenario's that needed to be analysed were specified further.

The Interim Report was submitted on 21 September 2006. The second progress meeting of the ASC was held on 11 October 2006. During this meeting the draft Interim Report of the ASC was discussed. Based on the discussions during the second progress meeting, a revised Interim Report was submitted by 27 November 2006.

The draft Final Report was submitted on 21 January 2007.The third progress meeting of the ASC was held on 14 February 2007. During this meeting the draft Final Report of the ASC was discussed. Based on the discussions during the third progress meeting, a Final Report was submitted by 21 March 2007. This Final Report was discussed during a fourth meeting on 17 April 2007. A revised Final Report was submitted by 31 May 2007.

Detailed minutes have been made of all meetings (both draft and after review, revised minutes). In addition to these formal meetings, numerous bilateral meetings have been held to discuss specific organisational aspects and specific activities related to tasks, notably in relation to the activities in task 4 (on the possible modification of the IPPC Directive), but also in relation to tasks 1, 2 and 3.

In addition, various bilateral meetings have been held with representatives of the Commission.

6.3. Presentations in working groups and workshops

Presentations about the content and progress of the ASC have been given for:
- the advisory Group of IPPC in Brussels (more than once),
- the UNECE Expert Group on Ammonia Abatement in Prague,
- the NEC working group in Brussels,
- the Nitrate Committee in Brussels
- Working Group on National Emission Ceilings & Policy Instruments (NEC-PI)
- DEFRA in UK (Ammonia Research Co-ordination Meeting)

In addition, intermediate results of the results of the ASC have been presented and discussed at

- COST 729 meeting
- 12th Ramiran International Conference "Technology for Recycling of Manure and Organic Residues in a Whole-Farm Perspective" in Aarhus, 6-7 September 2006
- ECN-meeting about integrated N management in Amsterdam, 8 December 2006
- Seminar at Soil Science Institute Sophia, Bulgaria, 25 September 2006.
- ESF-Conference about N in Environment and Ecology in Obergurgle, Austria, October 15-16, 2006
- Seminar University of Gottingen, Germany, 16 October 2006
- Nitro-Europe Meeting in Wageningen on September 21-22, 2006.
- First International Ammonia Conference, Ede, Netherlands, March 2007
- FEFAC meeting
- EFMA meeting
- COPA meeting

Further, numerous bilateral discussions and consultations have been held with specialists and representatives of the Member States of the EU-25, Eurostat, and national statistical offices, so as to collect the necessary information on the possible modification of the IPPC Directive in task 4. Also, European Animal Feeding Producers Association (FEFAC) and various scientists of the Animal Sciences Group of Wageningen University were consulted on the prospects of low-protein animal feeding.

6.4. Project meetings

Various project meetings were held to discuss, arrange and fine-tune the various activities in the tasks of the ASC. Project team meetings were held:

- in Wageningen on 18 January, 2006
- in Wageningen, on 28 March, 2006, jointly with the IIASA team
- in Bonn, on 6 April, 2006, jointly with the IIASA-team
- in Wageningen, on 30 August, 2006
- In Bonn, on 8 December 2006
- In Wageningen, on 24-25 January 2007

Detailed minutes have been made of all meetings (both draft and after review, revised minutes). In addition, numerous bilateral meetings, and discussion over the telephone and via email were held.

7. Discussion and Conclusions

The work presented in this report provides a first step towards an integrated approach for assessing the effects of EU environmental policies and measures at EU-27 level, Member State level and regional level (NUTS-2 and Nitrate Vulnerable Zones). This report also provides suggestions to improve the effectiveness and efficiencies of the environmental policies and to arrive at more integrated policies.

The call for tender of the Ammonia Service Contract (ASC) mentioned that an integrated approach was only partly taken into account during the preparation of the Thematic Strategy on Air Pollution, partly because the RAINS/GAINS model, that was used to assess control scenarios that meet the environmental objectives of the Thematic Strategy on Air Pollution, does not yet include estimates of the effect of NH_3 emission abatement measures on nitrate losses to the aquatic environment. Also, the impact of measures taken to reduce nitrate leaching to groundwater and surface waters on the emissions of NH_3, N_2O and CH_4 to the atmosphere have not been assessed. The call for tender of the ASC mentioned further the need for integrated approaches from the perspectives of the obligations set out by the Water Framework Directive (2000/60/EEC) to achieve a good chemical and ecological status for all waters by 2015. These obligations may have as implication the need to decrease nitrogen (N) and phosphorus (P) inputs via fertilisers and animal manure beyond the levels currently required, suggesting the need for assessing the effects of policies and measures on N and P emissions to the environment in an integrated way.

The MITERRA-EUROPE model, developed in the course of the ASC, is a simple modelling tool that can be used to assess the impact of measures to decrease NH_3 emissions from agriculture on nitrate leaching to groundwater and surface waters, and on the emissions of NH_3, N_2O, NO_x and CH_4 from agriculture to the atmosphere. The NH_3 emissions abatement measures are similar to those in the RAINS/GAINS model. Also the emission factors and the level of implementation of the NH_3 emissions abatement measures in the various countries are similar to those in the RAINS/GAINS model for the reference year 2000 and for the various NEC scenarios. Further, MITERRA-EUROPE allows assessing the effects of measures aimed at decreasing nitrate leaching and/or decreasing the emissions of N_2O, NO_x and CH_4 from agriculture to the atmosphere, on the emissions of NH_3 from agriculture to the atmosphere. Finally, MITERRA-EUROPE includes P cycling and P balances, and allows the assessment of the effects of policies and measures on N and P emissions to the environment in an integrated way. Despite these achievements, there is a clear need for further testing and improvement of MITERRA-EUROPE, as indicated also in Chapter 2. The results of the various assessments and scenario analyses have been made available through the website www.scammonia.wur.nl

The results of the qualitative assessments summarized in chapter 3 as well as the results of the quantitative assessments made with MITERRA-EUROPE, as summarized in

Chapter 2, indicate that implementation of single NH_3 emissions abatement technologies of the UNECE Working Group on Ammonia Abatement (RAINS measures) are effective in decreasing NH_3 emissions, but when not combined with integrated N management have the risk of antagonistic effects on N leaching and N_2O and CH_4 emissions. Hence, greater emphasis should be paid to the non-technological measure "Nitrogen management at whole-farm level" of the UNECE Working Group, so as to nullify such antagonistic effects. Clearly, there is need to consider the NH_3 emissions abatement measures as packages; each package of measures must include at least the non-technological measure "Nitrogen management at whole-farm level", and must be combined with one or more technological NH_3 emissions abatement measures.

Some nitrate leaching abatement measures of the Nitrates Directive have the potential of synergistic effects; they decrease N leaching losses and tend to decrease also the emissions of NH_3, N_2O and NO_x, in part because of the emphasis on balanced N fertilization and the application limit of 170 kg N per ha from animal manure. The latter limit forces livestock farms with a high livestock density to lower the N excretion of the livestock through for example low-protein animal feeding and increasing the animal performance of the herd. However, there are also measures taken within the framework of the Nitrates Directive that may have antagonistic effects; those measures increase the emissions of NH_3, N_2O and CH_4. Examples include the prohibition of application animal manure in winter and bufferstrips (less leaching, but higher N_2O emission). The Nitrates Directive indirectly also contributes to the tendency of increased zero-grazing of dairy cattle; this tendency leads to increased emissions of NH_3, N_2O and CH_4, unless strict NH_3 emissions abatement technologies are implemented too.

Clearly, this study indicates that there is a need for further integration of measures. There is a need for joint implementation of the NH_3 emissions abatement measures as well-integrated packages. There is also a need for joint implementation of the measures of the NH_3 emissions abatement technologies of the UNECE Working Group on Ammonia Abatement (RAINS measures) with those of the N leaching abatement measures of the Nitrates Directive. There is also scope for exploring the potential for further integration of the NH_3 emissions abatement concerns into CAP, and particularly through Rural Development policy. When integrating agricultural and environmental policies, it is important to emphasize again that the emission abatement measures are implemented jointly, as a well-integrated package so as to circumvent pollution swapping.

The dominant current instrument in EU environmental policy is regulation, while a mixture of regulations, economic incentives and persuasive and communicative instruments seem more effective and efficient (Chapter 3). Further, the current addressee of the environmental policies in EU agriculture is solely the farmer, while it seems attractive to involve suppliers, processing industry, retailers, consumers and the community at large too. Next, current governance in EU environmental policy is solely central governance, while there seems room for a greater participation of local communities through interactive governance and self governance (e.g., environmental co-operatives, food chain), so as to increase the moral support of the policies. This is visualized schematically in Figure 7.1.

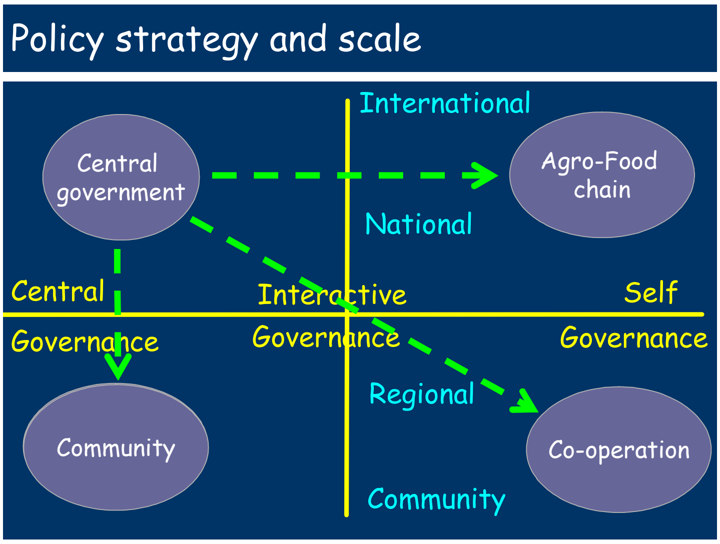

Figure 7.1 Envisaged partial changes in the governance of environmental policies and measures in agriculture, so as to increase the moral support and facilitate the implementation and robustness of the environmental policies in practice (after Joep van den Broek, in prep.)

The results of the analysis of the National Projection 2020 scenario (RAINS 2020) indicate that the emissions of NH$_3$ will have decreased by about 10% in 2020 relative to the reference year 2000 (about 340 kton NH$_3$) to a level of 3130 kton. This decrease will be brought about mainly by decreases in animal number and in N fertilizer use. Full and strict implementation of the Nitrate Directive will decrease the emissions of NH$_3$ by another 150 – 200 kton. Lowering the threshold values for the number of pigs and poultry on farms that fall under the regime of the IPPC Directive and including large dairy farms and large farms with other cattle under the IPPC may add another 30-110 kton NH$_3$ per year, but at relatively high administrative costs. Implementation of the most promising measures ‘low-protein animal feeding’ and ‘balanced N fertilization’ may contribute another 150-300 kton NH$_3$ per year. Implementing an optimal combination of NH$_3$ emission abatement measures and balanced N fertilization will lower the NH$_3$ emissions in 2020 to a level of 2375 kton per year, which is below the target of the Thematic Strategy on Air Pollution. The objective of the Thematic Strategy on Air Pollution for NH$_3$ emission is to decrease the NH$_3$ emission from agriculture in EU-25 to a level of ~2450 kton by 2020 (or ~2650 kton per year in EU-27. Hence, the most promising measures identified and assessed in this study can greatly contribute to achieving the objective of the Thematic Strategy on Air Pollution.

These projected decreases in NH$_3$ emissions following the implementation of various measures are not realized without costs. The costs of the technological NH$_3$ emissions abatement measures are in the range of 1-10 euro per kg NH$_3$ (in the optimal combination scenario about 3 euro per kg NH$_3$; see also Amann, et al., 2006b). The cost of the nitrate leaching abatement measures of the Nitrates Directive are in the range of €1 to more than

€20 per kg of N saved from dissipation to the environment in Member States of the EU-15, but the information about the economic costs of measures is rather scattered (Zwart et al., 2006. The direct costs of low-protein animal feeding and balanced N fertilization for farmers are low (Chapter 4), close to €1 per kg of N saved from dissipation to the environment. However, the indirect costs may be significant. Firstly, there is a continuous need for training and convincing farmers about emission control measures and about improving N use efficiency (partly also through demonstration). Farmers also need to receive the information and the tools for implementing the measures properly. Secondly, there is need for control and verification in practice of the implementation of measures and for monitoring the effectiveness and efficiency of the measures. Cost for control may be high when the level of detail in the prescription of measures is high, as for example in the case of the Nitrates Directive. Thirdly, there is a need for long-term investments in research and extension services, to further explore and test options for improving N use efficiency, and to provide scientific underpinning for promising measures (see also Mosier et al., 2004).

There are a few possible and/or likely trends in society that may have a significant influence on the projected decreases in NH_3 emissions between 2000 and 2020. A few of these trends are listed below. Note that none of these trends have been included specifically in the assessments.

- The need for bio fuels increases rapidly and may contribute to intensification of agricultural production (and hence increased N emissions?) as well as to a lower animal feed quality and hence increased N excretion by livestock.
- Farms rapidly increase in scale, because of the economic advantages. Specialized (livestock) farms also tend to conglomerate further, because of economic advantages for suppliers, processing industry and retailers. This trend challenges the robustness of the limit of 170 kg animal manure N per ha. How will this affects the prospects for manure processing and, subsequently, how will it affect NH_3 emissions?
- The possible abolishment of the milk quota system in the EU by 2015 will probably contribute to increases in the number of dairy cattle regionally, and thereby increase the environmental pressure regionally.
- The recent FAO study ‘Livestock’s Long Shadow’ (Steinfeld et al., 2006) reports that enlarged centres of livestock production emerge near animal feed production sites (Latin America, Midwest of US, Southeast Asia), and thereby increasingly compete with ‘old production centres’ in for example EU. This trend may challenge the trends in livestock number of the NEC scenarios, and hence in NH_3 emissions. Increased incidence of animal diseases may also have a great affect on animal number.
- It is as yet largely unclear how the management plans of the Natura 2000 areas will contribute to changes in the (evolution) of livestock numbers, and hence to changes in the regional distributions of NH_3 emissions.

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Annexes

Annex 1. Velthof, G.L., D.A. Oudendag and O. Oenema 2007. Development and application of the Integrated Nitrogen Model MITERRA-EUROPE. Ammonia Service Contract 70501/2005/422822/MAR/C1, Task 1. Alterra Report. Wageningen.

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Annex 4. Monteny, G.J. 2007. On the potential impact of Revised IPPC thresholds for Pigs and Poultry, and on Possible Thresholds for Cattle livestock operations in the EU-25. Ammonia Service Contract 070501/2005/422822/MAR/C1, Task 4. Animal Science Group, Wageningen.

Annex 5. Call for tender

Service contract: Integrated measures in agriculture to reduce ammonia emissions. Reference no ENV.C.1/SER/2005/0035.

I. Background information

The European Commission is planning to adopt by mid 2005 a Thematic Strategy on air pollution. The objective of this Strategy is to meet the objectives of the Environmental action plan, which have the aim of achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment. The Clean Air for Europe program has produced the scientific basis for the Strategy (http://www.europa.eu.int/comm/environment/air/cafe/index.htm). Various health and environmental ambition levels for 2020 have been evaluated and a global ambition level will be proposed in the Strategy.

On the basis of the national reports and during the preparation of the Strategy, it has been demonstrated that ammonia emissions participate to the eutrophication and acidification and to the formation of secondary particulate matter in the atmosphere. The main source of ammonia emission is agriculture (cattle farming for about 40%, pig and poultry about 40%, and the use of N-fertilisers about 20%). These ammonia emissions and impacts have been quantified using the RAINS/GAINS model developed by IIASA (http://www.iiasa.ac.at/web-apps/tap/RAINS/GAINSWeb/). The model allows identifying the most cost effective packages of measures to meet various environmental and health objectives, such as the objectives of the Strategy. Different abatement technologies and associated costs are included in the model. For each country, assumptions on projections of the main drivers for the agricultural sector (such as animal numbers, fertiliser use) and on the penetration rate of the various agricultural practices and technologies were made on the basis of bilateral consultations with the countries and as a results of a questionnaire sent to all Member States (http://www.iiasa.ac.at/RAINS/GAINS/reports/ir-04-048.pdf). The data on abatement technologies used in the RAINS/GAINS model are based amongst others on the guidelines for ammonia abatement developed and updated by Working Group on Ammonia Abatement of the UNECE Convention on Long Range Transboundary Air Pollution (CLRTAP) (http://www.unece.org/env/aa/welcome.htm).

In a first approach, the following measures to reduce ammonia were identified in the Thematic Strategy: (i) In the framework of the revision of the emission ceilings under the National Emission Ceiling directive (NEC) (2000/1258/EC) — integration of new objectives for eutrophication, acidification and for particulate matter. As a consequence, new emission ceilings for ammonia will be developed before end 2006 as well as new guidelines for the national programs required under the directive. (ii) In the context of the general review of the Integrated Prevention and Pollution Control (IPPC) directive, a possible extension of the directive to include installations for intensive cattle rearing and a possible revision of the current thresholds for installations for the intensive rearing of pigs and poultry.(iii) In the context of the current rural development regulation and the Commission proposals for rural development for 2007-13, the Commission encourages the Member States to make full use of the measures related to farm modernisation, meeting standards and agro-environment to tackle ammonia emissions from agricultural sources

In the evaluation of the measures aimed at reducing ammonia emissions, the necessity and the interest of an integrated approach to the nitrogen cycle (N cycle) as a whole was highlighted, in order to address ammonia, but also nitrous oxide (N_2O) and nitrate emission. The importance and relevance to consider the nitrogen cycle as a whole for policy development was recently highlighted notably through the Nanjing declaration on nitrogen management (http://www.initrogen.org/nanjing_declaration.0.html). Such an integrated approach shall also cover methane emissions, which are intensively linked to the nitrogen cycle. Measures aiming at reducing the emissions of one of those pollutants could imply either a reduction, an increase or have no effects on other pollutants.

During the preparation of the Strategy, the integrated approach was only partly taken into account notably because the current version of the RAINS/GAINS model does not include estimates of the effect of the different measures taken to reduce ammonia emission on nitrate losses to the aquatic environment. On the other hand, the impact of measures taken to reduce nitrate emissions to water on ammonia, N_2O and methane emissions is not yet assessed. The integrated approach to N-cycle should be considered, taking also into account the obligations set out by the Water Framework Directive (2000/60/EEC) to achieve a good status for all water by 2015, which may have as implication, the need to reduce nutrient inputs via fertilisers beyond the levels currently required, notably in order to tackle phosphate water pollution and eutrophication.

Finally, in the framework of the revision of NEC directive, a new baseline scenario will be developed by IIASA and submitted to bilateral consultations with the stakeholder. This new baseline will include new energy and agriculture projections integrating the measures taken by the Member States in order to meet the objectives of the Kyoto protocol. The impact of the CAP reform as assessed by a recent study of EEA will also be integrated. The new baseline should be finalised for end 2005.

II Objectives

The objective of the contract is to have defined the most appropriate integrated and consistent actions to reduce various environmental impacts (notably water, air, climate change) from agriculture.

Specifically, the objective is to have developed and applied a m allowing to assess and quantify the costs and the cost and the effects of various policies and measures aiming at reducing the impact of agriculture on water air pollution and climate Both ancillary benefits and trade offs of measures need to be identified. The impacts and feasibility of the most promising measures needs to be analysed in depth.

III Description of tasks

The tenderer shall provide in his offer a proposal for a work plan and methodology for each identified task and sub-task to achieve the objectives of the assignment. This work plan will be discussed with the Commission within one month of the signing of the contract at a kick-off meeting. At that meeting the details of the work plan will be decided to be included in the inception report with the final work plan. It is essential in the offer to clearly state the sources of information for each task and hence to avoid double work as compared to existing contracts/reports/studies. The place of performance will be outside Commission premises (extra muros).

The EU 25 Member States are to be covered in this assignment and as far as possible Romania, Bulgaria, Turkey and Croatia. For these 4 countries, the tenderer should describe in its offer the limitations he expects to encounter and their implications for the output of each task. If necessary, for specific sub-tasks to be specified in the offer, a methodology could be proposed based on the detailed analysis of case studies in certain representative Member States or geographical/agricultural zones to enable a general assessment for all the countries. The tenderer should justify in its offer the relevance and representativeness of the possible case studies he intends to propose.

As the Commission has used the RAINS/GAINS model as a basis for the Strategy and will use the same model in order to prepare the review of the NEC ceilings, it is important to explain in the offer how the contractor will use and build bridges with the information, results and approaches of the RAINS/GAINS model and the associated CAFE cost and benefit analysis In addition, all the calculations will be achieved for the same years as those used in the RAINS/GAINS model. The contractor will have to reserve some resources to ensure a good understanding and compatibility with the RAINS/GAINS model, including if necessary direct contacts with the IIASA team.

Task 1: Develop an integrated approach

It is expected from the contractor to develop a simple method to assess the impact on nitrate measures/technologies aiming at reducing ammonia emissions as integrated in the RAINS/GAINS model. Similarly, the impact on ammonia, N_2O and methane emissions of at least 3 level of implementation of the nitrate directive will be assessed This will require development of an integrated model parameters and data for the assessment.

The following sub-tasks are suggested:

a). For each of the abatement technologies identified in the RAINS/GAINS and in the UNECE WG guidelines for ammonia abatement estimation of its implication in terms of nitrate emission;

b.) Development of a method allowing to make bridges between on one hand the grid/country approach as developed in RAINS/GAINS and the linked models (such as the atmospheric pollutant dispersion model EMEP) and on the other hand the different zones as defined in the nitrate directive;

c). Assuming 3 of implementation of the nitrate directive (partial, full compliance, reinforced actions, to address phosphate pollution and to meet the good water status of the WFD by 2O1 for each Member State, identification of the measures aiming at reducing nitrate emissions in the waters and assessment of their implications in terms of air emissions. The measures to be considered should be those to be included in the action programme according to the nitrate directive and in particular the measures of annexes II and III. It is expected from the contractor to define as far as possible the possible other specific measures and reinforced actions to be included by the Member States in their programs for nitrate vulnerable zones according to article 5 paragraph 5 of the nitrate directive;

d). Analysis of the consequences on nitrate emissions and as far as possible on the compliance with the directive of at least 3 scenarios with the RAINS/GAINS model and chosen after consultation with the Commission.

The final output of this task will be report covering the task and sub tasks as described above accompanied with a documented calculation sheet allowing the Commission to make additional simulations on the basis of both RAINS/GAINS new scenario and other measures which could be taken under the nitrate directive

Task 2: Analysis of International and European instruments

The contractor will analyse the existing European and international (under the CLRTAP and climate change Conventions) instruments aiming at reducing emissions of nitrous oxide and methane, ammonia and nitrate in the waters. This concerns at least the code of good practises (notably those developed under the Nitrate Directive and under the CLRTAP Convention), provisions under the two pillars of the CAP, action plans in the vulnerable zones under the nitrate directive. In its offer, the tenderer should clearly identify the relevant instruments he intends to analyse.

It is expected from the contractor to identify the possible synergies (and/or possible antagonisms — if any) in existing International and European policies accompanied with recommendations to ensure an optimal coherence.

The final output of this task will be a technical report covering the task and sub-tasks as described above.

Task 3: In depth assessment of the most promising measures

Based on the results of task 1 and 2, and on other relevant sources of information and expertise to be detailed in the offer a list of the most promising (package of) measures will be identified and proposed to the Commission for in depth analysis. For each measure a broad assessment of its cost and impact will be achieved. In order to be considered as promising, the (package of) measure should correspond to the following criteria i) co-beneficial effects for water, air, climate change and soil protection; ii) feasible notably from an administrative and enforceability point of view; iii) potentially acceptable by the farmers notably for what concerns costs and additional efforts at• farm level; iv) compatibility with the need for improved animal welfare’.

This list will include at least adapted feeding strategies aiming at ensuring the same level of production with a reduced nitrogen contents in food and/or an adaptation of the feeding to the level of growth of the animals.

Three (3) set of (package of) measures will be selected after a dialogue with the Commission and assessed in depth by the contractor. On the basis of the results of the RAINS/GAINS model, the output of task 1, and of the CAFE cost and benefit analysis, the contractor will analyse for each country the potential impact of the promising measures notably in terms of emission reduction, costs and benefits, social impact, and additional administrative burden. These assessments will be achieved respecting the guidelines on impact assessment as established by the Commission.

The contractor will furthermore identify the most effective European and/or national instruments in order to implement this could concern new legislation, adaptation of code of good practises (notably those developed under the nitrate directive and under the CLRTAP Convention), provisions under the two pillars of the Common Agricultural policy, etc. On the basis of a dialogue with the Commission, he will then summarise the main elements to be integrated in possible future European instruments.

The final output of this task will be a technical report covering the task and sub tasks accompanied with an impact assessment for the 3 identified set of measures and/or policies respecting the guidelines on impact assessment as established by the Commission.

Task 4: Impact Assessment of a possible modification of the IPPC directive:

One of the proposed measures of the Strategy is the assessment of the extension of the IPPC directive to intensive cattle rearing installations and a possible revision of the thresholds for intensive rearing installations of pigs and poultry’ In the offer, a clear distinction should be introduced for cattle pig and poultry in way of including the impact of the CAP reform as well as the possible evolution of the farming structure in the new Member States should be detailed in the offer. The following sub-tasks are suggested:

1. Data gathering on the current situation: For each Member State, the following information should be gathered:

a) Pig and poultry installations: (1) the number of installations linked with the number of animals with a clear distinction between those already covered by IPPC and the others (2) a quantitative estimation of the environmental impacts for each size-category of installation (3) level of variation of environmental performance across the EU (4) estimation of the impacts of implementing the IPPC Directive (reduction of the environmental impacts/estimation of the economic and social impacts);

b) Cattle installations: (1) the number of installations linked with the number of animals with a clear distinction between those already covered by national permitting legislation (which can be based on the concept of BAT or can fix minimum standards for the operation of such installations) (2) a quantitative estimation of the environmental impacts for each size-category of installation (3) a description of the current regulation of this sector across the EU (4) level of variation of environmental performance across the EU.

2. Definition and broad assessment of various options: On the basis of existing legislation in the Member States (and notably any thresholds set by Member States for the purposes of the ETA Directive Annex II which refers to intensive livestock installations), and on the basis of its own expertise, the contractor will propose various realistic options (at least 3 different options) to the Commission for lowering the current thresholds (and introducing a new threshold for cattle installations).

After approval of the proposed options by the Commission, the implications of various possible thresholds for each of these activities will be assessed for each country and for the EU as a whole. This includes at least an assessment of: (1) the number of installations which could be concerned (additionally to those already covered by IPPC and/or national legislation) (2) on the basis of possible BAT (Best available techniques), emission reductions at least of ammonia, methane and N emissions as well as, on the basis of the results of task 1, the implications on nitrate emissions (3) costs and benefits. Costs evaluation will include in particular the up take of BAT and the administrative burden (e.g. permits application, costs for authorities for issuing permits and controlling the installations). All the scenarios should be compared to a do nothing scenario, including in particular the application of the current Community framework (in particular the nitrate directive, the water framework directive and common agricultural policy,.). On this basis, the potential added value of a possible extension of the IPPC directive will be discussed.

In order to calculate the potential impact of these options, the contractor is supposed to define broadly the possible BAT to be applied. This should be done on the basis of the existing BREF on intensive livestock, definition of BAT and comparison with the technologies integrated in RAINS/GAINS. For cattle installations, for which the BAT are not yet defined at EU level, the contractor is expected to define the main elements which could be integrated in possible BAT and their associated costs, notably on the basis of existing national legislation and permitting rules which will be summarised in the report. Particular focus should be set on feeding strategies, housing techniques, storage of manure and spreading of manure.

Assessment of the impacts of lowering the current thresholds: On the basis of the results o t e sub-task 2, and after approval of the Commission, one level of threshold will be chosen for each activity and in depth assessed in respect of the guidelines on impact assessment as established by the Commission. In. its offer, the tenderer is expected to include a first proposal of table of contents of the impact assessment.

In addition to the impacts already analysed in task 2, local disturbance (odour, noise) and diffuse spreading of heavy metals and as well as social impact will notably be assessed. The social impact will need to take account of the economic state of the sector and the extent to which applying]IPPC would affect the ability of farmers to keep operating, employment, etc. In order to reduce the possible social impact, it is expected from the contractor to identify possible European accompanying measures.

The final output of this task will be a technical re ort covering the task and sub tasks as defined above accompanied with a complete proposal o impact assessment for the selected scenario for each sector strictly respecting the guidelines on the impact assessment as established by the Commission.

Task 5: Stakeholder consultation, presentations, workshop

In its offer, the tenderer will describe its methodology to ensure an appropriate stakeholder (including NGO’s, farmer organisation, Members States experts, etc) consultation. It is expected from the contractor to present the results in various relevant working groups notably under the IPPC, nitrate and national emission ceiling directives. At least six presentations/meetings in Brussels should be foreseen in these specialised working groups. In addition, at least 3 follow-up meetings should be foreseen with the Commission representatives. Depending on the proposals of the contractor, ad-hoc workshops and/or expert meetings could be organised in Commission buildings.

Annex 6. Overview of the scenarios analyzed in Tasks 1, 3 and 4 of the Ammonia Service Contract.

Task	Scenarios	Description
1	RAINS A 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000 (Amann M. et al., 2006)
1	RAINS A 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010 (Amann M. et al., 2006)
1	RAINS A 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020 (Amann M. et al., 2006)
1	RAINS optimized 2020	National Projections baseline scenario for the revision of the NEC Directive, optimized to achieve the targets of the Thematic Strategy in 2020 (Amann M. et al., 2006)
1	ND partial 2000	National Projections baseline scenario for the revision of the NEC Directive, 2000, including partial implementation of the measures in Nitrate Vulnerable Zones (Annex 1)
1	ND partial 2010	National Projections baseline scenario for the revision of the NEC Directive, 2010, including partial implementation of the measures in Nitrate Vulnerable Zones (Annex 1)
1	ND full 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures in extended areas of Nitrate Vulnerable Zones (Annex 1).
1	WFD 2020	National Projections baseline scenario for the revision of the NEC Directive, 2020, including full (strict) implementation of the measures in extended areas of Nitrate Vulnerable Zones plus (strict) equilibrium P fertilization on all agricultural land (Annex 1).
3	ND full 2020 (Reference scenario)	National Projections baseline scenario for the revision of the NEC Directive, 2020, plus full implementation of the N leaching abatement measures in extended areas of Nitrate Vulnerable Zones
3	LNF 10%, all farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to all farms.
3	LNF 10%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 10% decrease in N excretion, applied to IPPC farms only
3	LNF 20%, all farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to all farms
3	LNF 20%, IPPC farms, 2020	ND full 2020 (see above) plus low-protein animal feeding that leads to a 20% decrease in N excretion, applied to IPPC farms only
3	Balfert 2020	ND full 2020 (see above) plus strict implementation of balanced N fertilization on all farms, irrespective of NVZs
3	Optimal Combination, 2020	Rains optimized 2020 (see Table 2.6) plus Balfert 2020

Thresholds values for animals in the four scenarios; current IPPC and SCE1, SCE2 and SCE3 analyzed in Task 4.

Animal species	Scenarios 2020			
	Current IPPC	SCE1	SCE2	SCE3
Fattening pigs	> 2000	> 2000	> 1750	> 1500
Sows	> 750	> 750	> 675	> 600
Hens	> 40000	> 27500	> 25000	> 20000
Broilers	> 40000	> 37000	> 32000	> 27000
Dairy cows	-	> 450	> 400	> 350
Other cattle	-	> 1000	> 850	> 700