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Regionalisation of Nitrogen Balances with the CAPRI Model (RegNiBal)

Pilot project in support of the Eurostat Working Group on Agri-Environmental Indicators

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Abstract

The report presents the results of the pilot project "Regionalisation of Gross Nitrogen Balances with the CAPRI model" (RegNiBal), which was carried out by Joint Research Centre in cooperation with Eurostat and delegates from the volunteering countries (France, Germany, Hungary and Italy). The objective of the pilot project was to evaluate the differences between national Eurostat/OECD Gross Nitrogen Balances (GNB) and the GNB calculated using the CAPRI model, with the overall goal of using the CAPRI model to (operationally) provide regional GNB data to complement the national GNBs.

EXECUTIVE SUMMARY

The recent developments in the Common Agricultural Policy (CAP) call for the monitoring of the environmental impacts of agricultural activities at regional level (EC 2006). Environmental assessments at regional level are also needed according to the EC Rural Development Policy (2007-2013), and to the EU Nitrate and Water Framework Directives. In Europe, the Gross Nutrient Balance (GNB) is considered to be a priority agri-environmental indicator (EC 2006) of relevance for both water- and air-quality policies. Regional GNB estimations produce more accurate results than the national estimations, especially for countries that experience different climates or have regionally differing agricultural production systems (Özbek 2014, Özbek and Leip 2015).

The Eurostat Working Group on agri-environmental indicators (AEI) therefore explored the possibility of refining the spatial resolution of reported GNBs[1], going from national to (at least) NUTS2 level, and possibly also beyond[2]. The development of such methods, however, is challenging and requires approaches to 'disaggregate' national data which are unavailable at higher resolution to smaller spatial units.

The "Common Agricultural Policy Regional Impact" (CAPRI) model could potentially provide such data. CAPRI is already used to calculate the GNB at the NUTS2 level, as well as on a high resolution map for scientific projects and concept development (Leip *et al* 2011b, 2011d, 2008, Britz and Leip 2009, Leip *et al* 2011a).

The "Regionalisation of Gross Nitrogen Balances with the CAPRI model" (RegNiBal) pilot project was carried out by the JRC in cooperation with Eurostat and delegates from four volunteering countries: Italy, France, Germany and Hungary. The objective of the pilot project was to evaluate differences between national Eurostat/OECD GNB figures and the GNB figures calculated using CAPRI, and to assess the feasibility of using the CAPRI model to (operationally) provide regional GNB data to complement the national GNBs.

The RegNiBal project aimed to:

- Perform a detailed analysis of GNB methodology in Eurostat/OECD GNB common guidelines (Eurostat, 2013) and in the CAPRI model
- Assess methodological differences between the methods used by the countries in the project, CAPRI, and the Eurostat/OECD GNB common guidelines (Eurostat 2013)
- Assess the numeric differences between the datasets of the countries in the project, CAPRI and the Eurostat databases
- Identify the causes of the differences between datasets, and suggest solutions for selected issues to the countries taking part in the project, CAPRI and Eurostat

This report describes modifications that were implemented in the national and CAPRI methodologies since the start of RegNiBal (partly based on results of the project), and makes recommendations for actions to be taken in order to improve the comparability and quality of the data.

1 The national GNBs of 12 EU Member States presented in the Eurostat GNB database were calculated by the countries. The GNBs for other countries were not available, and have been estimated by Eurostat.

2 Working Group on agri-environmental indicators meeting in February 2012

Summary of the results, conclusions and further research

How many issues could/could not/could partly be solved?

We identified 33 "issues" that were related to major discrepancies between the methods and warranted further assessment: 28 of these concerned both CAPRI and the national (DE, FR, HU, IT) methodologies in the project, three related to general aspects of the CAPRI model, and two related to EUROSTAT data. At the end of the project, 12 of the identified issues were solved, three were partially solved and 18 could not be solved. However, but some progress and concrete recommendations were made for almost all of the issues identified.

For the unsolved issues: can we say that national data are generally better/worse than CAPRI?

At the beginning of the project, the differences between the surplus calculated with CAPRI data and the national methodologies were high. Some national data were updated/corrected (partly on the basis of RegNiBal observations and recommendations), which led to a reduction in the differences with CAPRI. At the end of the project, the absolute differences between the CAPRI and national data were 31% for France, 26% for Hungary, 13% for Italy and 3% for Germany.

At the start of the RegNiBal project, we found that CAPRI was generally more reliable than the national methodologies, but this situation changed with the improvements made, as described above. Further analysis is currently needed to evaluate whether CAPRI or national data (NAT) are 'better' with regard to the remaining unsolved issues.

Overall, which unsolved topics are most important?

Nitrogen (N) excretion by swine and N removal by grass are considered to be the most important unsolved issues because of their considerable impact on N-input and N-output levels.

Estimating the N excretion by swine was found to be problematic for all countries participating in the project. CAPRI estimates for feed intake by swine were higher than the NAT figures of DE and FR. Further animal budget analysis for IT and HU is needed to understand the reason for differences in N-excretion coefficients. Countries are not always sufficiently accurate in estimating and/or using the average number of animals and N-excretion coefficients in N-manure-excretion estimations.

Estimating the N removal by grass was found to be problematic for three of four project countries. For estimates of the dry matter yields of grassland, the differentiation of permanent grassland according to the proposal of the GRASSDATE project (Velthof *et al* 2014) would likely help: (i) grassland out of production but maintained, (ii) unimproved grassland (including both sole use or private land and common land), (iii) improved grassland (by N-input levels <50, 50-100, >100 kg N/ha/yr, sole use and common land).

In which major areas is CAPRI is relatively weak?

The major areas of difficulties for CAPRI are the following:

- Grassland yield and grass N content.
- Feed intake, partly linked to inaccurate statistical data (Leip *et al* 2014). Detailed animal budgets from all countries are not available for comparison.
- Seed and planting materials should be explicit in the CAPRI GNB.
- N from organic fertilisers (other than manure) and manure withdrawal, stocks, and import estimations are not considered in the CAPRI model.

Can the CAPRI model be used to provide national GNB (at NUTS2 level), and if not, what needs to be done?

- The CAPRI model is very strong in making GNB calculations, and the RegNiBal project enabled us to identify several possible improvements in national data and methods.
- The use of the animal budget to estimate N excretion is a major asset in the CAPRI methodology, but runs the risk of including outliers if the use of feed is overestimated in the statistical sources.
- There is a large level of uncertainty in the yields of grass and other (non marketable) fodder, as well as their N content. This also affects the accuracy of national data.
- Generally, RegNiBal showed that the CAPRI model could provide adequate national (and later on regional and spatially explicit) GNBs. However, for the four countries assessed, further work is needed to in order to understand the residual disparities in the data.
- The CAPRI model can calculate Land N Budgets (corresponding to GNBs) and Farm N Budgets (FNB). A comparison of the N-surplus calculated using both method helps to constrain the calculations. In the FNB method, feed and fodder produced in the country (or region) and manure applied within the country (or region) are considered as 'internal flows' and thus do not need to be estimated to quantify the N surplus; on the other hand, data on 'imported' feed and 'exported' animal products are needed (for details on the comparison of the two approaches, see Leip *et al* 2011b). In the CAPRI model, data on animal products and imported feedstuffs are available from statistical sources, and are more reliable than the data on fodder N intake and manure excretion.
- Regional-level data were available only for FR and IT. While the focus of the project was on comparisons at the national scale, RegNiBal showed that some improvements were also beneficial for the regional comparisons.

How can the process be simplified/improved?

One observation of RegNiBal was that some ‘mistakes’ are made due to different interpretations of the Eurostat/OECD Handbook on Nutrient Budgets (Eurostat 2013) or by inaccurate use of data. Differences in the statistical data used for the national GNBs and data reported to Eurostat in other statistical tables also led to inconsistencies.

The process can be simplified by making use of data tables already available from Eurostat for GNB calculation at national and (in principle) NUTS2 levels. This could help to considerably reduce the reporting burden on countries.

What should the next steps be?

There are three different options:

1. Regional GNBs that are fully consistent with the national GNBs submitted cannot currently be generated. However, national estimates are not necessarily better than CAPRI estimates, so regional and spatially explicit data generated by the CAPRI model can be regarded as suitable for providing advice to policy. Such data will be useful proxy data, that is independent of the national official GNBs.
2. CAPRI GNBs can be converged with official national GNBs. This would help improve both CAPRI and national estimates, but requires further investment. Such investment would, however, also have added value for other areas, such as improved CAPRI scenarios for climate change mitigation assessments, the use of CAPRI as an independent estimate of GHG emissions, harmonisation of national methodologies, and improved consistency between various datasets.
3. Another route could be the abovementioned ‘simplified process’ which makes use of existing information as much as possible and generates national (and regional) GNBs that are fully consistent with the Eurostat/OECD common guidelines (which is also suitable for producing regional GNBs). Such a system would probably be most cost-efficient in the short term and would efficiently provide good estimates.

Any combination of the three abovementioned options is possible, as are ‘hybrid’ solutions. For example, a Eurostat algorithm using existing data tables could be informed by data from both countries and the CAPRI model.

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LIST OF ABBREVIATIONS AND SYMBOLS

AEI	Agri-environmental indicators
ARVALIS	French Agricultural Applied Research Organisation
ATMOSD	Atmospheric deposition
BIOFIX	Biological fixation
BNF	Biological nitrogen fixation
CAPRI	Common Agricultural Policy Regionalised Impact
CITEPA	Interprofessional Technical Centre for Studies on Air Pollution
CORPEN	French Steering Committee for Environmentally Friendly Agricultural Practices
DEnat	National data sent by Germany
CRESID	Crop residues (input)
DM	Dry matter
DüV	German Fertilization Ordinance
EFMA	European Fertilizer Manufacturers Association
EMEP	European Monitoring and Evaluation Programme (EMEP) under the Convention on Long-range Transboundary Air Pollution (CLRTAP) for international co-operation to solve transboundary air pollution problems.
EXCRET	Nitrogen in excretion of animals
EXPPRD	Nitrogen export with harvested material and crop residues or animal products
FLEG	The share of leguminous crops in OFAR
FRnat	National data sent by France
GNB	Gross Nitrogen Balance
GRAE	Extensively managed permanent grassland
GRAI	Intensively managed permanent grassland
GRAS	Total permanent grassland
ELBA	A sectorial model for economic and environmental analysis
HUnat	National data sent by Hungary
IDELE	French Livestock Institute
IMAGE	Integrated Model to Assess the Global Environment
INEA	Italian National Institute of Agricultural Economics
IPCC	Intergovernmental Panel on Climate Change
ISTAT	Italian Statistical Office

ITnat	National data sent by Italy
JKI	Federal Research Centre for Cultivated Plants of Germany
KSH	Hungarian Statistical Office
LEVL	Activity level of crop (1000 ha) or animal (1000 heads) production activities
MAAF	French Ministry of Agriculture, Food and Forestry
MINFER	Mineral fertiliser applied, including some parts lost in runoff or emissions
MITERRA	A tool for integrated assessment of N emissions from agriculture
NAT	National data
NITF	Nitrogen requirement in above-ground biomass (harvested and crop residues)
NUTS	Nomenclature of territorial units for statistics
OCER	Other cereals aggregate in the CAPRI model
OECD	Organisation for Economic Co-operation and Development
OFAR	Other fodder from arable land in the CAPRI model
RegNiBal	Regionalisation of Nitrogen Balances with the CAPRI model
SURTOT	Total surplus nutrient input net of exports in products
f_{BNF}	The share of fixed N in NITF
UAA	Utilised Agricultural Area
UNFCCC	United Nations Framework Convention on Climate Change
Δ_{act}	Actual difference between CAPRI and NAT
Δ_{abs}	Absolute difference between CAPRI and NAT
Δ_{perc}	Percentage difference between CAPRI and NAT
$\Delta_{absperc}$	Absolute percentage difference between CAPRI and NAT

GLOSSARY[3]

Atmospheric nitrogen deposition - the process by which N airborne particles and gases are deposited to soils, vegetation, water bodies, and other surfaces

Biological N fixation (BNF) - the action carried out by a range of bacteria that are either living in loose associations with plants, in symbiotic associations with plants (Rhizobium and Actinomycetes), or free-living in soils or water

BNF by free living organisms – the nitrogen fixation by free-living organisms

BNF by grass-legume mixtures – the nitrogen fixation through the area under temporary and permanent grassland mixed with leguminous forage crops

BNF by leguminous crops – the nitrogen fixation through the action of bacteria which live symbiotically in root nodules of leguminous crops

Free-living organisms - cyanobacteria (most prominent in rice fields), heterophic diazotrophic bacteria and autotrophic bacteria in agricultural systems

Change in manure stock - the manure stock at beginning of the year minus the manure stock at the end of the year

Consumption of fertiliser - the sum of the consumption of mineral fertilisers and other organic fertilisers (excluding manure)

Crop product - all crop products harvested or grazed on the reference area

Crop residues - the residues of (i) plants which remain after harvesting of the (fodder) crop (e.g. stalks and stubble); (ii) harvested as a by-product of the fodder (crop) (e.g. straw) and can be used as feed for animals, bedding material or other purposes; (iii) plants which are burned on the field

Crop residues removed from the field - the residues which are removed completely from agriculture, which may include straw, head leaves and stems and other crop residuals removed from the field

Crop yield - mean harvested production per unit of harvested area for crop products

Dry atmospheric nitrogen deposition – the atmospheric nitrogen deposition as a result of complex atmospheric processes such as settling, impaction, and adsorption

Excretion coefficient – factor representing the average amount of nutrients excreted per animal head per year (animal place or average annual animal number for animals with multiple production cycles)

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3 Prepared using the following sources:

(i) Eurostat, 2013. Nutrient Budgets, EU-27, NO, CH. Methodology and Handbook. Version 1.02. Eurostat and OECD, Luxembourg

(ii) RAMON - Eurostat's Concepts and Definitions Database

http://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC

(iii) Gross Nutrient Balance (aei_pr_gnb) - Reference Metadata

http://ec.europa.eu/eurostat/en/web/products-catalogues/-/KS-FM-13-004

(iv) Regulation (EC) No 543/2009 of the European Parliament and of the Council of 18 June 2009 concerning crop statistics and repealing Council Regulations (EEC) No 837/90 and (EEC) No 959/93

Fodder from arable land - lucerne, green maize and cereals for silage or green fodder, grass in rotation and other green fodder; not included the grass from permanent grassland, fodder beets and other roots for fodder

Harvested area - the part of the crop area that is harvested

Leguminous crops - leguminous plants, beans, soya bean, and pulses

Manure input - the sum of manure production by livestock minus manure withdrawals plus change in stocks plus manure imports

Manure withdrawal - the withdrawal of manure from agriculture, for instance exports of manure to other regions, non-agricultural use, processing of manure by industry, etc.

Mineral fertilisers - the fertilisers prepared using inorganic materials manufactured through an industrial process

N content – the coefficient which represents the N content of harvested or grazed crop products (kg N per tonne of biomass)

Nitrogen inputs – the nitrogen in mineral fertilisers and organic manure applied to agricultural land, seed and planting materials, biological fixation by leguminous crops and clover, and wet and dry deposition from the atmosphere

Nitrogen outputs - the nitrogen in biomass harvested from arable and permanent crops and crops used for fodder

Nitrogen surplus - the potential surplus of nitrogen on agricultural land, calculated as the difference between nitrogen inputs to an agricultural system and nitrogen removed (outputs) from the system per hectare of agricultural land

Organic fertilisers (excluding manure) - sewage sludge, urban compost, industrial waste products and other organic products which are used as fertilisers on agricultural soils

Permanent grassland - the land used permanently (for five years or more) to grow herbaceous forage crops, through cultivation (sown) or naturally (self-seeded), and that is not included in the crop rotation on the holding

Reference area - the Utilised Agricultural Area (UAA)

Temporary grassland – the land used for grazing, hay or silage included as a part of a normal crop rotation, lasting at least one crop year and less than five years, sown with grass or grass mixtures

Utilised agricultural area - the total area taken up by arable land, permanent pasture and meadow, land used for permanent crops and kitchen gardens included in the crop rotation on the holding

Wet atmospheric nitrogen deposition – the atmospheric nitrogen deposited through precipitation (rain, snow, clouds, and fog)

1 INTRODUCTION

Nitrogen (N) is an essential element for plant, animal and human nutrition. On the other hand, N losses can negatively impact environmental quality and human welfare (Sutton et al., 2011a,b, 2013). These impacts include negative effects on biodiversity, eutrophication, nitrate accumulation in waters, acidification, nitrous oxide emissions (with effects on global warming and the depletion of the stratospheric ozone layer), and risks to human health due to exposure to ozone and particulate matter (Sutton *et al* 2011a, Smil 2011).

Agricultural production is an important source of the N that ends up in ground- and surface waters and the atmosphere (Sutton et al., 2011a,b; Erisman et al., 2013; Fowler et al., 2013). N deficiency, N surplus (NS) and N-use efficiency (NUE) in agricultural production are estimated on the basis of agricultural N budgets (OECD 2001, Oenema *et al* 2003, Leip *et al* 2011b, Eurostat 2013, Britz and Witzke 2012).

The Gross Nutrient Balance is considered to be one of the key agri-environmental indicators (EC 2006, 2004, DG AGRI 2006, EC 2014, EU 2013), as it provides a measure of potential water pollution through the loss of nutrients from agricultural sources, as well as of potential air pollution, mainly through the emission of ammonia (NH_3). Recent developments in the Common Agricultural Policy (CAP) require the monitoring of environmental impacts of agricultural activities at regional level (EC 2006). Furthermore, N surplus and NUE are important to identifying the options for achieving a resource-efficient agri-food chain (e.g. European Commission 2011, 2014). Based on recent methodological development of the Gross Nitrogen Budget (GNB) or 'Land Nitrogen Budget'[4] (Leip et al., 2011c; Özbek and Leip, 2015), the Eurostat/OECD handbook for estimating national GNB was updated in 2013.

Regional estimations of nutrient budgets produce more accurate results than the national estimations, especially for the countries where different climates are observed or with regionally differing agricultural production systems (Özbek 2014, Özbek and Leip 2015). They are also more suitable as a basis for policy advice, as most environmental problems occur at the level of smaller regional (and non-administrative) units (De Vries et al., 2011a; Leip et al., 2011a; Grizzetti et al., 2012).

The Eurostat Working Group on agri-environmental indicators (AEI) therefore explored the possibility of refining the spatial resolution of reported GNBs, going from national to NUTS2 level, and possibly also beyond (Eurostat, 2012). The development of such methods, however, is challenging and requires approaches to 'disaggregate' national data which are unavailable at higher resolution to smaller spatial units.

The "Common Agricultural Policy Regionalised Impact" model (CAPRI) could potentially provide such data. CAPRI is already calculating GNB at the NUTS2 level and on spatial units at high resolution (Homogeneous Spatial Mapping Units, HSMU) for scientific projects and concept development (Leip *et al* 2011b, 2011d, 2008, Britz and Leip 2009).

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4 The term 'Land Nitrogen Budget' had been used to differentiate N surplus calculations that quantify the balance at the soil surface (Soil N Budgets) from those which also include losses from livestock housing and manure storage and management systems (Land Nitrogen Budgets). While the latter give similar results to the Farm N Budgets, they differ in data requirements (Leip *et al* 2011b).

Therefore, the "Regionalisation of Gross Nitrogen Balances with the CAPRI model" (RegNiBal) pilot project was launched, to be carried out by the JRC in cooperation with Eurostat and delegates from volunteering countries. The objective of the pilot project was to evaluate differences between national GNB and the GNB calculated using the CAPRI model, with the overall goal of using the CAPRI model to (operationally) provide regional GNB data to complement the national Eurostat/OECD GNBs. Italy, France, Germany and Hungary volunteered to participate in this pilot project.

This report presents the results of the RegNiBal pilot project and makes recommendations for actions which would facilitate the use of the CAPRI model for complementing national GNB estimates with data at the regional scale.

2 METHOD

2.1 OVERVIEW

We compared the estimates of national GNBs with CAPRI data for four countries: France, Germany, Hungary and Italy. For each country, differences between the 'national methodology' (as they are submitted to Eurostat) and the CAPRI methodology (see below) were identified and discussed. Based on this analysis, the causes of major differences were highlighted and solutions or improvements were suggested to one or both of the methodologies. In some cases, these 'solutions' were already implemented during the course of the project, leading to a decrease in the number of observed differences.

In the following we will refer to the datasets as given in Table 2.1:

Table 2.1 References of the data sets used in the report

Country	CAPRI	National methodology (NAT)
Germany	DEcapri	DEnat
France	FRcapri	FRnat
Hungary	HUcapri	HUnat
Italy	ITcapri	ITnat

2.2 CAPRI

The "Common Agricultural Policy Regionalised Impact" (CAPRI[5]) model (CAPRI, 2012) is a multi-purpose system for modelling the EU's agriculture, which helps analyse the socio-economic and environmental effects of agricultural policies and trade agreements (international/EU/member state/NUTS2), environmental policies, and changes in exogenous drivers (population/GDP, etc.). It is an economic model for agriculture, which integrates an environmental accounting model (Weiss and Leip 2012, Leip *et al* 2014, 2011b). It reports Nitrogen Balances at the spatial resolution of NUTS2[6]. CAPRI further

5 http://www.capri-model.org

6 NUTS : Nomenclature of Territorial Units for Statistics

comprises a disaggregation module which estimates land use shares, farm input and environmental indicators at the pixel level (1 km by 1 km) (Leip *et al* 2008, 2011c, Leip 2011).

A detailed description of the CAPRI model is given in CAPRI (2012), and a description of the accounting for GHG emissions is given in Leip et al. (2010) and Weiss and Leip (2012). The calculation of nitrogen flows and budget is explained in Leip et al. (2011c, 2014b).

Nitrogen surplus is defined in the CAPRI model as the difference between N input and output ($N_{surplus} = N_{inputs} - N_{outputs}$). Differences between the calculation made using CAPRI and the Eurostat (2013) 'ideal approach' include missing data in CAPRI on organic fertilisers other than manure, seed & planting material not considered in the input term, no estimation of biological N fixation by free-living organisms, and no data on manure imports and exports.

In this section, the CAPRI methodology for the quantification of the major terms in the GNB (atmospheric deposition, biological fixation, N removal in permanent grasslands (GRAS), in other fodder on arable land (OFAR) and in other crop production, N excretion for swine and other cattle, mineral fertiliser) is presented. For some of the terms, the method has been slightly changed or updated during the course of the project, as a follow-up from the interim recommendations. In this case, both the original method and the method of the latest CAPRI version are given.

CAPRI results were extracted at the beginning and end of the project. The final data are based on CAPRI rev. 130 from 24 July 2014.

2.2.1 ATMOSPHERIC N DEPOSITION

Original method

Atmospheric N deposition is derived from the European Monitoring and Evaluation Programme (EMEP) database, in which the data is obtained from EMEP measurement stations. CAPRI contains wet deposition measurement data for NH_4^+ and NO_3^- as compiled by Mulligan (2006): *"EMEP data have been obtained by multiplying the weighted mean concentration by the total amount of precipitation in the period. The concentrations for days with missing precipitation data have consequently been assumed equal to the weighted average of the period".*

Updated method

Atmospheric (wet and dry) deposition for different ecosystem types has been obtained from the EMEP MSC-W chemical transport model (version rv4.5, Simpson *et al* 2012, 2014). Atmospheric deposition is calculated in the model on a sub-grid for different land cover categories, taking into account vegetation cover, phenology and surface characteristics. These runs use emission data and meteorological data for the years 2003-2005. These data will be input into the CAPRI modelling framework at the pixel level.

2.2.2 BIOLOGICAL N FIXATION

Original method

Biological N fixation is estimated by assuming that a fixed share (f_{BNF}) of the N need in above ground biomass is covered by biological N fixation (Leip *et al* 2011b). These shares are 75% for soybeans and pulses, and 5% for GRAS. A weighted average of the share of legumes and other fodders are used for OFAR. The formula used for the calculation is given below:

$$Nbiofix = NITF * LEVL * f_{BNF} \qquad (1)$$

N_{biofix}	Biologically fixed N (kg N/yr)
NITF	Nitrogen requirement in aboveground biomass (harvested and crop residues) (kg N/ha/yr)
LEVL	Cropped area (ha)
f_{BNF}	The share of fixed N in NITF (%)

Updated method

CAPRI rev.130 uses new f_{BNF} values for N fixation for GRAS by using country-specific shares for fixed N on the basis of the LegumeFutures project (Helming *et al* 2014). GRAS f_{BNF} values for DE, FR, HU, and IT are 14%, 7%, 17%, and 16%, respectively.

2.2.3 N REMOVAL BY OFAR AND OTHER CROP PRODUCTS

Other fodder on arable land (OFAR) consists of annual green fodder including clover and mixtures, lucerne, other perennial green fodder (usually legumes) and temporary grassland. The removal of N by crop products is estimated by multiplying the N contents of the crops (kg N per kg of product)[7] by crop area and by crop yield. Crop yields in the CAPRI database are derived from crop production statistics in Eurostat. The N contents of crop outputs are based on the data used in the MITERRA model. The N contents in this study have been adjusted using a factor which is dependent on the fraction of N available to the plant (Velthof *et al* 2007).

2.2.4 N REMOVAL BY GRAS

N removal by GRAS production is estimated by multiplying the N content of GRAS (from the MITERRA model) by the GRAS area and yield. CAPRI uses expert data for 2002 as the key information for GRAS yields. In order to convert these data into time series, the data are linked to the aggregated cereal yields, assuming that long run yield growth and yearly fluctuations for grass can be approximated by cereal yields. The yields for pasture, meadows and other fodder on arable land are adjusted accordingly (Britz and Witzke 2012).

In CAPRI, the yield of intensively managed grassland (GRAI) and the yield of

7 See Annex 1 for N contents of all crops in CAPRI

extensively managed grassland (GRAE) were artificially created from the yield of GRAS. The area of GRAE and GRAI was arbitrarily set at 50% of the area of GRAS for all countries. The N contents of GRAS were 17.5, 17.2, 17.6 and 15.2 kg N/tonne for DE, FR, IT and HU, respectively.

2.2.5 N EXCRETION BY SWINE AND 'OTHER CATTLE'

N excretion coefficients are calculated in CAPRI on the basis of an animal budget: N exported in animal products (retention) is subtracted from the N intake through feed (Eq. 2.) to obtain N excretion. The N intake is derived from crude protein intake, which depends, among others, on the average live body weight, the daily weight gains and the length of the fattening period and, depending on the animal type, on the number of piglets born, eggs produced, milk yield. Crude protein intake is converted to N intake by applying a N:protein ratio of 1:6.

N retention is the sum of N in livestock products like eggs and milk and N in animal biomass (including meat), applying corresponding N contents.

$$N\ excretion = N\ intake - N\ retention \qquad (2)$$

Swine

The total swine population in the CAPRI model includes fattening pigs and sows. The CAPRI model uses the herd size of pigs, obtained by Eurostat through a maximum of four annual surveys (April, May or June, August, and December). The herd size of the sows is the average number emerging from these surveys (April, August, and December). The herd of fattening pigs is calculated by multiplying the number of slaughtered fattening pigs (= slaughtered pigs - slaughtered sows) by the average fattening period (Annex 2). The number of sows is directly used since they live for more than one year. Piglets up to a weight of 20 kg are included in the sows activity. The input for sows is one piglet of 20 kg and feed for the sow and piglets up to a weight of 20 kg; the output of the sows are piglets of 20 kg each, meat from the old slaughtered sow, and the manure from the sow and the young output piglets until they weigh 20 kg.

Since excretion of N by piglets is included in the CAPRI model for sows but not in the national data, we recalculated the N excretion coefficients for sows (with piglets) for NAT to make them comparable with those of the CAPRI model. In order to achieve this, we divided total N excretion of sows and piglets in NAT by the number of sows in NAT. In order to compare the number of swine in the CAPRI model and NAT, the CAPRI piglet number was calculated by multiplying the number of sows in the CAPRI model by the ratio [(number of piglets)/(number of sows)], obtained from the Eurostat livestock database[8].

8 http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database

Cattle

The activity level of heifers and bulls for fattening equals the number of slaughtered heads plus net exports of fattened live animals. If the numbers of slaughtered heifers and bulls are unavailable, 45% of total cattle slaughtering (excluding cows and calves if available) are used as a default value (Britz and Witzke 2012).

2.2.6 N FROM MINERAL FERTILISER

The total amount of N applied with mineral fertilisers is based on Member State data of the European Fertilizer Manufacturers Association (EFMA), as published by FAOSTAT, and from data gathered by IFA/FAO through an expert questionnaire, reporting average mineral fertiliser application rates per crop and Member State.

2.2.7 REGIONAL DATA AVAILABILITY

The CAPRI model calculates all GNB components at the NUTS2 level. Activity data (acreage, animal numbers) are obtained from regional databases or disaggregated to the NUTS2 level in the CoCo module, providing a Consistent and Complete database at this level. Mineral fertiliser application rates by crop and NUTS2 region are estimated in the fertiliser module taking into account the variation of yield and the available N input from manure, biological N fixation, crop residues and atmospheric deposition. N-excretion values are also region-specific. Atmospheric deposition is taken from gridded EMEP data and varies at the NUTS2 level. All other coefficients are constant at national (or even EU) level (Annex 3).

2.3 NATIONAL METHODS

GNB calculations of the countries are based on Eurostat/OECD common methodology. In the practical implementation of this methodology, Nsurplus is calculated by subtracting Noutput (harvested crops, forage, crop residues in the field) from Ninput (fertilisers, gross input of manure, atmospheric deposition, biological fixation, seed and planting materials), and the result is divided by the reference area A_{ref} (Eurostat 2013). A_{ref} is the total UAA, comprising arable land, permanent crop land, and utilised permanent grassland.

Some small differences were observed at the beginning of the RegNiBal project between the methodologies used by the four countries:

- FRnat does not include organic fertilisers and seed & planting materials.
- ITnat estimates withdrawals of manure and manure imports, but does not estimate crop residues exported[9].
- HUnat estimates manure withdrawals[10].
- DEnat, FRnat, and HUnat do not estimate manure import as the data is not available or negligible.

9 Same as above footnote.

10 The country estimated manure withdrawals at the beginning of the RegNiBal project, but this component is not included in the recalculated GNBs of HU-NAT.

With regard to data sources for the coefficients:

- ITnat uses country-specific N contents of all crops & forage, except for fodder root crops (OECD estimate), and country-specific N-excretion coefficients for all livestock except for male cattle, buffaloes, donkeys and mules (OECD estimate).
- FRnat uses country-specific N contents of all crops & forage, and uses country-specific N-excretion coefficients from their national GHG inventory (which is submitted to the United Nations Framework Convention on Climate Change - UNFCCC).
- DEnat uses country-specific data for all coefficients used in GNB calculations.
- HUnat uses expert estimations and values from the Hungarian nitrate regulation for N content of crops & forage and for N-excretion coefficients.

With regard to regional data, only FR and IT provided the regional balances at NUTS2 level. FR provided the regional balances for 2003, 2004 and 2005. IT provided them for 2006. Both countries used the same coefficients for all NUTS2 regions for all GNB components (except for regional average deposition rate of FR), and the same N animal excretion coefficients (except for pigs and heifers of IT (Annex 3).

3 RESULTS

The main GNB data components of the CAPRI model and countries, and the comparisons between them, are presented in Tables 3.1 and 3.2. The two tables show the GNBs estimated by the countries and by the CAPRI model at the beginning and end of the project, respectively. The following metrics were used in the analysis:

- Actual Difference $\boldsymbol{\Delta act = CAPRI - NAT}$
- Absolute Difference $\boldsymbol{\Delta abs = |\,CAPRI - NAT\,|}$
- Percentage Difference $\boldsymbol{\Delta perc = \frac{CAPRI-NAT}{NAT} \cdot 100}$
- Absolute Percentage Difference $\boldsymbol{\Delta absperc = \left|\frac{CAPRI-NAT}{NAT}\right| \cdot 100}$

According to Tables 3.1 and 3.2 (see also Annex 12), the differences in N surplus (SURTOT) between NAT and the CAPRI model were significantly lower at the end of the project for the changes implemented by the CAPRI model and NAT since the start of the RegNiBal project).

Table 3.1 The main GNB data components of the CAPRI model and countries at the beginning of the RegNiBal project

	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δact** (Gg N/yr)	Δperc ** (%)
EXCRET	814	680	134	20
MINFER	704	866	-162	-19
Organic Fertilisers	NE	9	NA	NA
BIOFIX	125	233	-108	-46
ATMOSD	185	180	5	3
Seed & Planting	NE	9	NA	NA
EXPPRD-CRESID	859	1 370	-511	-37
SURTOT	969	606	363	60

	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	195	124	71	57
MINFER	339	281	58	21
Organic Fertilisers	NE	1	NA	NA
BIOFIX	23	36	-13	-36
ATMOSD	55	66	-10	-16
Seed & Plant. mat.	NE	11	NA	NA
EXPPRD-CRESID	354	518	-164	-32
SURTOT	258	0	258	1 412 410

	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	1 357	1 263	93	7
MINFER	1 772	1 798	-26	-1
Organic Fertilisers	NE	60	NA	NA
BIOFIX	103	222	-119	-53
ATMOSD	189	399	-209	-53
Seed & Plant. mat.	NE	25	NA	NA
EXPPRD-CRESID	1 891	2 087	-196	-9
SURTOT	1 531	1 681	-150	-9

FR - Components*	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	1 610	1 820	-210	-12
MINFER	2 280	2 286	-7	0
Organic Fertilisers	NE	NE	NA	NA
BIOFIX	322	130	193	149
ATMOSD	502	622	-120	-19
Seed & Plant. mat.	NE	NE	NA	NA
EXPPRD-CRESID	2 579	3 589	-1 010	-28
SURTOT	2 135	1 268	867	68

NE: Not estimated; NA: Not applicable. Note: CAPRI data was extracted in May 2013.
* See Annex 4 for GNB components` legends. ** See Section 3. for the definitions.

Table 3.2 The main GNB data components of the CAPRI model and countries at the end of the RegNiBal project

IT***- Components*	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	773	832	-58	-7
MINFER	704	742	-38	-5
Organic Fertilisers	NE	8	NA	NA
BIOFIX	139	297	-158	-53
ATMOSD	185	216	-31	-14
Seed & Plant. mat.	NE	9	NA	NA
EXPPRD-CRESID	806	1 220	-414	-34
SURTOT	995	883	112	13

HU***- Components*	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	164	151	13	9
MINFER	339	281	58	21
Organic Fertilisers	NE	1	NA	NA
BIOFIX	28	20	8	42
ATMOSD	58	67	-9	-13
Seed & Plant. mat.	NE	9	NA	NA
EXPPRD-CRESID	342	331	11	3
SURTOT	247	197	50	26

DE***- Components*	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	1 305	1 263	42	3
MINFER	1 772	1 798	-26	-1
Organic Fertilisers	NE	60	NA	NA
BIOFIX	124	154	-30	-19
ATMOSD	184	349	-165	-47
Seed & Plant. mat.	NE	25	NA	NA
EXPPRD-CRESID	1 784	2 087	-303	-15
SURTOT	1 602	1 562	40	3

FR***- Components*	CAPRI (Gg N/yr)	NAT (Gg N/yr)	Δ_{act}** (Gg N/yr)	Δ_{perc} ** (%)
EXCRET	1 634	1 809	-175	-10
MINFER	2 280	2 326	-46	-2
Organic Fertilisers	NE	21	NA	NA
BIOFIX	416	320	96	30
ATMOSD	513	320	193	60
Seed & Plant. mat.	NE	34	NA	NA
EXPPRD-CRESID	2 486	3 037	-551	-18
SURTOT	2 357	1 793	564	31

NE: Not estimated; NA: Not applicable. Note: CAPRI data was extracted on July 2014. * See Annex 4 for GNB components` legends. ** See Section 3. for the definitions. *** IT national GNB is Eurostat estimation. (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_gnb&lang=en). Extracted on 17.11.2014.

3.1 IDENTIFICATION OF MAJOR DIFFERENCES

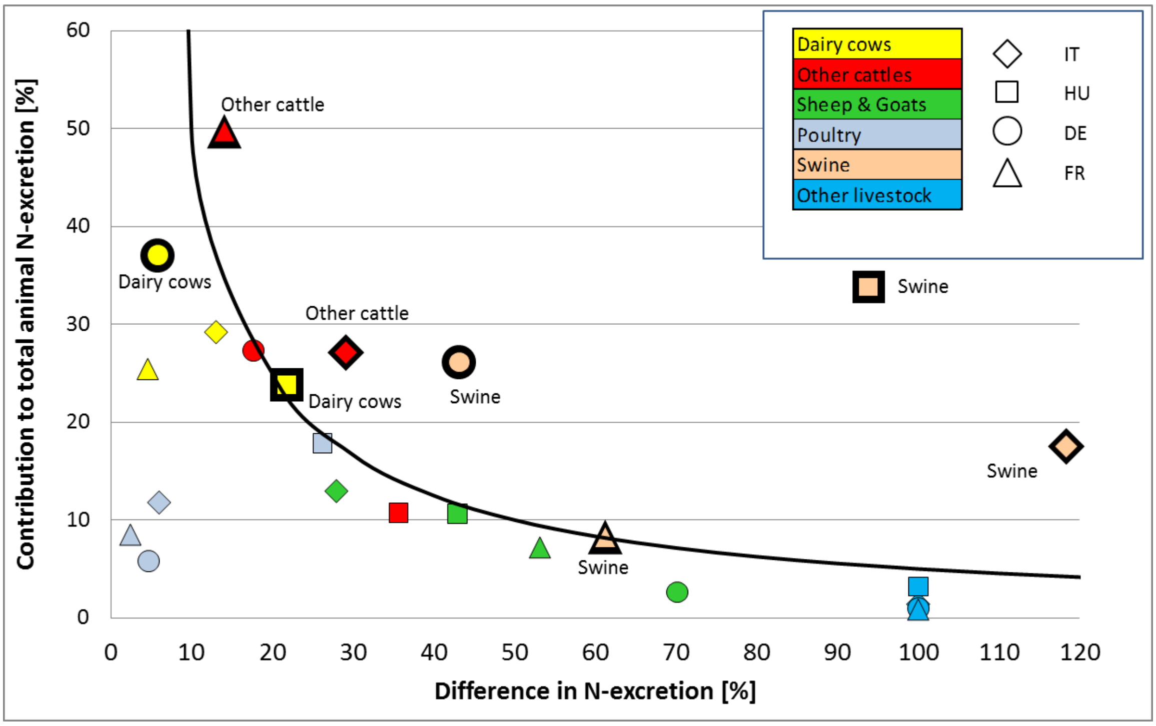
Major differences between NAT and CAPRI data were identified for livestock (based on the N animal excretion) and for crops (based on N in exported crop products and crop output excluding crop residues) as shown in Figure 1 and Figure 2, respectively. In each case, two criteria were combined (x and y axes in the Figures):

- (x) the absolute percentage difference between estimates (of animal excretion or N crop output) and
- (y) relative contribution of the individual animal/crop categories to total animal N excretion or N removal with crops in the country.

As the importance of a flow term to the total flow (N excretion or crop N output) depends on the methodology, the average of the CAPRI model and NAT shares was used.

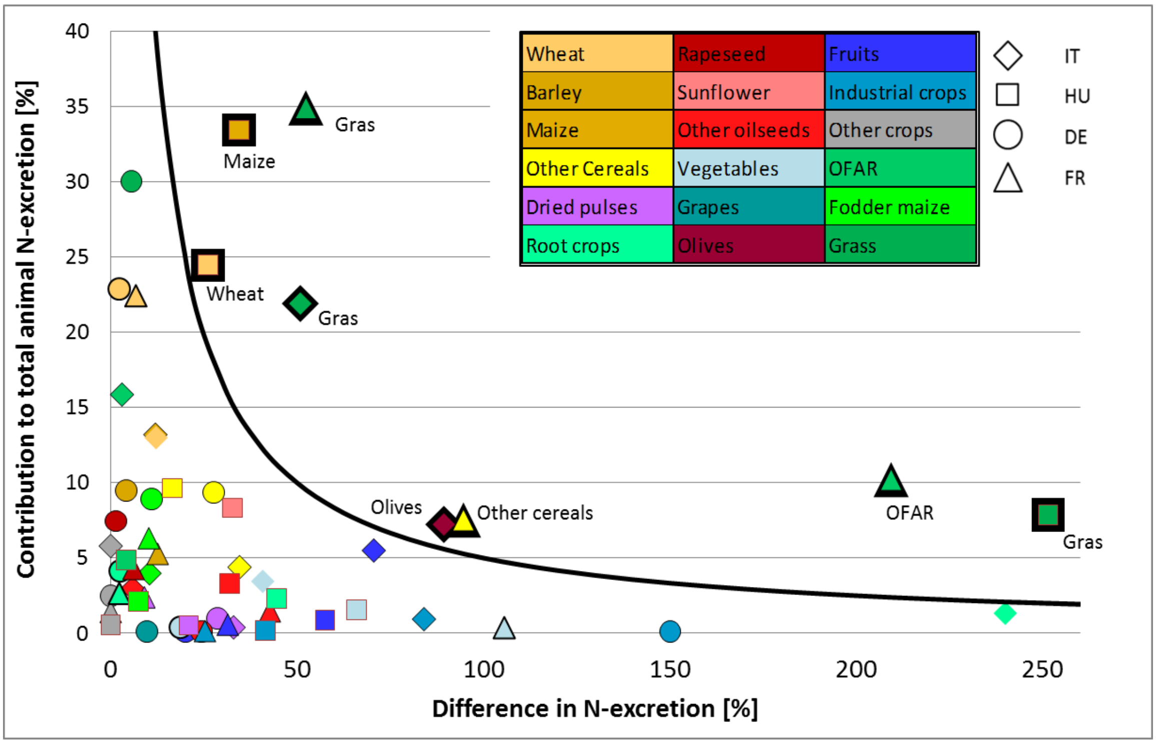
We applied a threshold of ($x * y > 0.05$, see lines in Figure 1 and Figure 2) to select those flows where both differences between the methodologies and significance for the GNB were high and which thus deserved further attention (see bold markers in Figure 1 and Figure 2). This method provided an initial list of selected flows for each country. For these initially selected flows, other terms of the GNB (biological N fixation, atmospheric deposition, and mineral fertiliser application) were analysed in a similar way, and were added to the list of non-matching flows if a large difference was observed. The following flows where identified:

- **Germany**: atmospheric deposition, N removal by other fodder on arable land (OFAR), permanent grassland (GRAS) and other cereals (OCER), biological fixation, N excretion by swine.
- **France**: N removal by OFAR, GRAS and OCER, N excretion by swine, sheep and goats, biological fixation, and atmospheric deposition.
- **Hungary**: N removal by GRAS, maize and wheat, N excretion by swine, and mineral fertiliser.
- **Italy**: N removal by GRAS, olives and fruits, N excretion by swine and other cattle, mineral fertiliser, and biological fixation.



Note: The average of CAPRI and country contributions is used in the y axis. The figure shows animal categories selected for in-depth analysis by countries. The larger symbols indicated the selected animal categories.

Figure 1 Animal categories selected for in-depth analysis



Note: The average of CAPRI and country contributions is used in the y axis. The figure shows crop categories selected for in-depth analysis by countries. The larger symbols indicated the selected crop categories. *OFAR='Other fodder from arable land'; **Other crops=NURS,FLOW,OCRO

Figure 2 Crop categories selected for in-depth analysis

3.2 INITIAL RECOMMENDATIONS TO IMPROVE THE QUALITY AND CONSISTENCY OF THE ESTIMATES

A first screening of the differences gave rise to some initial 'recommendations' that could help to improve the quality and consistency of the GNB estimates. These recommendations are listed below.

CAPRI

- Assess the possibility to include N input from organic fertilisers other than manure (sewage sludge, compost, etc.), seed & planting materials, and manure imports or exports.
- Update deposition flows, including both wet and dry deposition.
- Assess the possibility to update or use country-specific N contents of the crop aggregate 'other cereals' (OCER).
- Check and possibly update the N content of GRAS for FR (e.g. on the basis of GRASSDATE results)
- Revise the methodology to estimate biological nitrogen fixation (BNF), which was found to be lower compared to national and some literature data.

Germany

- Exclude BNF from free-living organisms unless new and better evidence for crops under national conditions are available.
- Check the model used to estimate atmospheric deposition and/or justify the absence of net atmospheric transport (export) of nitrogen.
- There are large differences between the DEnat and DEcapri N-excretion coefficients for fattening pigs. A comparison of detailed animal budgets is needed.

France

- Assess the possibility to include the N input from organic fertilisers, seeds and planting.
- Check yield and N content of OFAR.
- Assess the possibility to use the results of the GRASSDATE project for estimating N removal by GRAS.
- There are large differences between the FRnat and FRcapri N-excretion coefficients for swine, sheep and goats. A comparison of detailed animal budgets should be made.
- Check N-deposition values.

Hungary

- Check yield of GRAS. More information is required to make a conclusion as to the cause of discrepancy in grassland areas. Hungary should check why the GNB of grassland areas differs from the value reported to the EUROSTAT Crops products - annual data (apro_cpp_crop) database.

- Report the N content of crops and crop residues separately.
- One possible reason for the difference in the animal numbers between the CAPRI model and NAT could be that animals are slaughtered without entering the official statistics, which we recommend be checked.
- Additional and more detailed comparisons of the statistical data should also be made with respect to the differences observed in the N-excretion coefficients. A comparison of the animal budget for fattening pigs and sows in the CAPRI and NAT data would possibly be required.
- A more detailed comparison of fertiliser data of the HUcapri and HUnat is required.

Italy

- Include N crop residues removed from GNB estimations.
- Both ITnat and ITcapri should check the yields of GRAS; it may be that more information is required.
- Justify or revise the high N-content values used for olives and fruits. We also recommend that the ITcapri checks its data regarding olives.
- There are large differences between the ITnat and ITcapri N-excretion coefficients for swine and other cattle. A comparison of detailed animal budgets is needed.
- Include BNF by grass–legume mixtures in GNB estimations.
- Exclude BNF by free-living organisms unless new and better evidence for crops under national conditions are available.

Some of these recommendations were subsequently implemented, and issues were partly resolved. However, some were still unresolved at the end of the project. Section 4 discusses each of the identified flows.

4 DISCUSSION

4.1 N-INPUT BY ATMOSPHERIC N DEPOSITION (DE AND FR)

Atmospheric deposition was identified as an issue for two countries, with the following observations:

Germany

- Δ_{abs}: 209 Gg N/yr (Table 3.1)
- Δ_{absperc}: 53%

National method: Initially, DEnat used a methodology developed at UBA (Gauger *et al* 2008) for atmospheric deposition, which does not differentiate between arable land and permanent grassland. This was updated with data from a new study which differentiated between arable land and grassland (Gauger 2010, see Table 3.1). Data from Gauger (2010) is based on detailed gridded emission data from wet deposition measurements, high-resolution land-use maps for the years 2004-2007, and chemical transport modelling. Total deposition loads of N are calculated for a 1x1 km² grid by combining information of dry, wet and cloud /occult deposition fluxes (Gauger 2010).

Assessment: Even though estimates of atmospheric deposition decreased during this update from a total of 399 Gg N/yr to 349 Gg N/yr, the estimate was still considerably higher than that of DEcapri, at 189 Gg N/yr (2003-2005). The difference could be partly explained by the fact that DEcapri takes only wet deposition into consideration. Indeed, dry deposition, which was estimated by the updated DEcapri method (see Section 2.2.1) to be 72 Gg N/yr, would explain most of the difference (see Table 4.1).

Table 4.1 Wet, dry, and total deposition fluxes on the agricultural area in the German models and CAPRI model results for 2004

2004 data comparison	Atmospheric deposition on the agricultural area	NO_y-N	NH_x-N	N
Deposition DEnat Model (2010)	Wet deposition [Gg/yr]	71	99	170
	Dry deposition [Gg/yr]	61	132	193
	Total deposition [Gg/yr]	132	231	363
CAPRI Model* (updated method), Germany	Wet deposition [Gg/yr]	90	104	194
	Dry deposition [Gg/yr]	26	46	72
	Total deposition [Gg/yr]	116	150	266
CAPRI-updated / DEnat model (2010)	Δ_{abs} in total deposition [Gg/yr]	16	81	97
CAPRI-updated / DEnat model (2010)	$\Delta_{absperc}$ in total deposition [%]	12	35	27

* See Section 2.2.1 for the methodology

Recommendation and Conclusion: The CAPRI model needs to incorporate the new atmospheric deposition data, including both wet and dry deposition. DEnat was updated. Δ_{abs} of total atmospheric deposition between the updated CAPRI and DEnat data is now 93 Gg N/yr, compared to the original Δ_{abs} of 209 Gg N/yr (2003-2005). Moreover, the approach for the model estimation of dry deposition was revised within a recent national project (Wichink Kruit *et al* 2014). Implementing the results of the project will further decrease the N loads of atmospheric N deposition. Therefore, the issue is considered as resolved.

France

- Δ_{abs}: 120 Gg N/yr (Table 3.1)
- $\Delta_{absperc}$: 19%

National method: FRnat calculated atmospheric N deposition by multiplying N-deposition flux rates from EMEP by total area covered.

Assessment: A mistake in the value of the area used in the estimations of FRnat atmospheric deposition was identified (total area instead of utilized agricultural area) and corrected. This reduced the calculated value of atmospheric deposition from 622 Gg N/yr to 320 Gg N/yr, which was significantly lower than the FRcapri estimate of 502 Gg N/yr. The new EMEP data that will be incorporated in the CAPRI model (see section 2.2.1) will reduce Δ_{abs} of total atmospheric deposition between the updated CAPRI and FRnat data to 23 Gg N/yr (2003-2005).

Recommendation & Conclusion: After updating the atmospheric N-deposition data of both FRcapri and FRnat, $\Delta_{absperc}$ will decrease to an acceptable value of 7%. The issue is considered as resolved. However, FRnat could consider using the updated CAPRI method (see section 2.1.1), to differentiate between land uses.

4.2 N-INPUT BY BIOLOGICAL N FIXATION (DE, FR, IT)

Biological N fixation (BNF) was identified as an issue for three countries:

Germany

- Δ_{abs}: 119 Gg N/yr (Table 3.1)
- $\Delta_{absperc}$: 53%

The share of BNF in total N input was low for both the CAPRI model (3%) and DEnat (6%).

National method: BNF added up to a total of 222 Gg N/yr, and it contains: N-fixation of plant populations that can fix N, such as peas, beans, clover and mixtures, lucerne (64 Gg N/yr); N-fixation by legumes in permanent pasture (90 Gg N/yr) and N-fixation by free-living organisms (68 Gg N/yr). DEnat used default values from literature for the estimation of the BNF of legumes and free-living organisms. BNF by legumes in permanent pastures came from expert estimations.

Assessment of N-fixation in grasslands: Most of the difference in total N fixation between DEcapri and DEnat was explained by the difference in the BNF by free-living organisms (68 Gg N/yr), and GRAS (58 Gg N/yr). Now, the CAPRI model has implemented a new method for N fixation by GRAS, using country-specific shares for fixed N on the basis of the LegumeFutures project (Helming *et al* 2014). Following this methodology, the Δ_{abs} in symbiotic N fixation by GRAS between the CAPRI and the country datasets had decreased from 58 to 38 Gg N/yr.

Table 4.2 shows that the N-fixation coefficient for GRAS was lower in CAPRI than in DEnat data, and that the clover share in the GRAS of the country is closer to the average shares in the literature studies compared to the CAPRI model. We therefore recommended that the methodology of the CAPRI model should be revised.

Conclusion: The difference in symbiotic N fixation by GRAS between the CAPRI and the country datasets decreased after the implementation of a new method for N fixation by GRAS in the CAPRI model, using country-specific f_{BNF}. However, in order to close the issue, the legume share in GRAS must be defined for the country.

Table 4.2 N fixation by clover and GRAS in CAPRI and national data

	CAPRI	**National Data**
N fixation coefficient for clover (kg N/ton)	19.1 (=N fixation for clover / average yield)	18.6 (=N fixation for clover / average yield)
N fixation for clover (kg N/ha)	157*	153
Other data (kg N/ha)	47-235 in Denmark (Carter 2005) 74-280 in UK (Cowling 1982) 83-283 in Switzerland (Boiler and Nosberger 1987) 83-286 in Ireland (Masterton and Murphy 1976)	
N fixation coefficient for GRAS (kg N/ton)	0.9 (CAPRI old method) 1.4 (CAPRI new method) (=Symbiotic N fixation from GRAS / GRAS area / average yield)	3.1 (=N fixation (kg N/ha) / average yield)
The clover share in the GRAS (%)(=N fixation coefficient for GRAS / N fixation coefficient for clover*100)	5 (CAPRI old method) 7(CAPRI new method)***	17
Other data (%)	5-40 (Bachinger)** 1-75 in Finland Arja (2005)	

* Calculated by multiplying N need for OFAR by f_{BNF} (CAPRI data)
**http://www.zalf.de/de/forschung/institute/lse/downloads/Documents/oekolandbau/schaetztrainer/program/en_explain.pdf
*** See Section 2.2.2 on the new and old CAPRI methods.

Assessment of N-fixation by free-living organisms: According to Wagner (2012) the contribution of free-living organisms to global nitrogen-fixation rates is generally considered to be minor because of the scarcity of suitable carbon and energy sources. Heterotrophic free-living N_2 fixers that use plant residues such as straw and leaf litter appear to contribute only small amounts of N to dry land agriculture, mostly <5 kg N/ha per year (Unkovich *et al* 2008). However, some studies measured BNF by free-living organisms as being higher than 5 kg N/ha per year, giving an excess of 20 kg N/ha during the growing season in cereal fields in humid environments (Neyra and Dobereiner 1977). A study in Australia of an intensive wheat rotation farming system demonstrated that free-living microorganisms contributed 20 kg N/ha per year to the long-term nitrogen needs of this crop system (30-50% of the total needs, Vadakattu and Peterson

2006). Also, free-living N-fixation in flooded rice production systems has been shown to be up to 30 kg N/ha (Firth *et al* 1973), and in tropical crops such as sugarcane in the order of 10–65 kg N/ha per year (e.g. Boddey *et al* 1995), and in the order of 160 kg N/ha (Bohlool *et al* 1992).

Thus, the amount of N fixed by free-living soil bacteria is generally small, i.e. < 5 kg N per ha per year (Paul and Clark 1996, Unkovich *et al* 2008, Beriner and Hirsch 1984, Vitousek *et al* 2002), with the exception of high values found mainly in humid tropical regions. We recommend that BNF from free-living organisms should not be included in the GNB unless new and better evidence for crops under national conditions are available.

Conclusion: Germany will exclude BNF by free living organisms as soon as the methodology for the sustainability indicator 'N-surplus (Nachhaltigkeitsindikator N-Überschuss)' is revised (resolved).

France

- Δ_{abs}: 193 Gg N/yr (Table 3.1)
- $\Delta_{absperc}$: 149%

National method: The biological fixation methodology was updated in the last French National Working Group. Fixed coefficients in kg per ha were replaced with data on N removal with legumes (kg N/tonne/yr), the share of fixed N (%), and legume shares in grassland (%) on the basis of expert knowledge.

Assessment: Biological fixation for FR increased from 130 Gg N/yr to 294 Gg N/yr, and the Δ_{perc} in biological fixation between the CAPRI and FR data was minimised (from 149% to 10%).

Conclusion: The issue has been solved.

Italy

- Δ_{abs}: 108 Gg N/yr (Table 3.1)
- $\Delta_{\mathrm{absperc}}$: 46%

National method: ITnat used OECD coefficients of biological fixation, which are multiplied by the area of legume crops.

IT included N fixation by free-living organisms.

IT did not estimate N fixation by leguminous crops in grasslands.

Assessment: The biggest Δ_{abs} in biological fixation between CAPRI and the country results were from OFAR (47%), followed by N fixation from free living organisms (36%), soybean (11%) and N-fixation in permanent grassland (6%). ITnat estimated that fixed nitrogen was 13 Gg N/yr for clover and 142 Gg N/yr for alfalfa. The N fixation of these crops was 78 Gg N/yr higher than that of the OFAR group in the CAPRI model. Biological N fixation by free-living organisms came closely behind the OFAR group.

Table 4.3 The biological N-fixation data for OFAR

	CAPRI	IT	Other Data
N content (kg N/tonne)	13.1 for all OFAR crops (=NITF / Eurostat yield)	26.5 for alfalfa	22.0 (Macolino *et al* 2013) 29.3 http://www.feedipedia.org/node/275
% of N fixed in the amount of N exported[a]	75% for all OFAR crops	86% for alfalfa[b]	100% for leguminous crops (MITERRA) 200% for pulses, soybeans and legumes (IPCC, IMAGE[c])
The amount of biological N fixation of alfalfa (kg N/ha/yr)	76.6[d]	180	174 (Kelner *et al* 1997) 200 (Smil 1999)

Note: CAPRI data was extracted in May 2013.
[a] The source of other data is de Vries et al. (2011)
[b] Calculated by using alfalfa yields of IT in the Eurostat crop products database and the data reported by the country
[c] The Integrated Model to Assess the Global Environment
[d] Calculated by multiplying the N need of OFAR by f_{BNF} (CAPRI data)

Table 4.3 shows that the method for calculating BNF used in the CAPRI model yields relatively low N-fixation values compared to national and literature data. We therefore recommended that the methodology of the CAPRI model be revised. Now, the CAPRI model has implemented a new method for calculating N fixation by OFAR, using country-specific shares for fixed N on the basis of the LegumeFutures project (Helming *et al* 2014). But the Δ_{abs} in symbiotic N fixation by OFAR between the new CAPRI method and the country dataset is still high (decreased from 79 to 69 Gg N/yr). The main reason for this is that the NITF in the CAPRI data is lower than in NAT and in the literature (Table 4.3).

Recommendation & Conclusion:

- Differences in symbiotic N fixation by OFAR between the new CAPRI method and the country are still high. We recommend that CAPRI check the NITF value for OFAR.
- We recommend that BNF by free-living organisms should not be included in the GNB unless new and better evidence for crops under national conditions is available (see above).
- Italy should include the biological N fixation from grass–legume mixtures.

4.3 N-INPUT BY MINERAL FERTILISERS (HU AND IT)

Mineral fertilisers were identified as an issue for two countries, with the following observations:

Hungary

- Δ_{abs}: 58 Gg N/yr (Table 3.1)
- $\Delta_{absperc}$: 21%

This component has a high importance in HUcapri and HUnat. The share of this component in total N input was 55% and 54% for HUcapri and HUnat.

National method: HU mineral fertiliser data were based on fertiliser sales' data.

Assessment: The country data reported to both Eurostat and the FAO (281 kt/yr) was lower than the CAPRI data (339 kt/yr). The country expert recommended using the official mineral fertiliser for HU value in the CAPRI. However, HUcapri data also come from official sources.

Recommendation & Conclusion: The issue is 'open'. There is the need to check the HUnat and HUcapri data against the information from EFMA.

Italy

- Δ_{abs}: 162 Gg N/yr (Table 3.1)
- $\Delta_{\mathrm{absperc}}$: 19%

This component has a high importance in ITcapri and ITnat. The share of this component in total N input was 38% and 44% for ITcapri and ITnat.

National method: ITnat used mineral fertiliser sales data of the Italian Statistical Office (ISTAT).

Assessment: The ITcapri mineral fertiliser data were lower than the ITnat and FAO data. However, data in Eurostat databases were of the same magnitude as that used by the CAPRI model. There are two different sets of data for the country in two different Eurostat databases (Table 4.4).

Table 4.4 Consumption of mineral fertilisers in Italy (kt)

	CAPRI*	Data reported by the country**	FAO Fertilisers database***	Eurostat Consumption of Mineral Fertilisers Database****	Eurostat GNB Database****
Consumption of mineral fertilisers (kt)	704	866	838	686	742

* Extracted in May 2013
** Two-year average (2003, 2004); the other data are three-year averages (2003, 2004, 2005)
*** http://faostat3.fao.org/download/R/RF/E (Extracted on 20.11.2014)
**** http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/data/database (Extracted on 17.11.2014)

Recommendation & Conclusion: We recommend that Italy clarifies the values to be used and the reason for different data in different databases. The CAPRI model should be checked to determine the cause of the large difference with the FAO database. The issue is not resolved.

4.4 N EXCRETION BY SWINE (DE, FR, HU, IT)

N excretion by swine was identified as an issue for four countries:

Germany

- The highest Δ_{abs} in N excretion of animal categories between national and CAPRI data
- Δ_{act}: 122 Gg N/yr
- A significant share (130%) of the Δ_{act} of total N excretion by animals (94 Gg N/yr)

National method: N excretion coefficients for DE are derived from the German Fertilization Ordinance (DüV 2007) and calculated on the basis of an animal budget: exported N in animal products (retention) is subtracted from the N intake by feed (DLG 2005).

Assessment: Table 4.5 shows that the total difference in N excretion for swine between the country and CAPRI data (40%) resulted mostly from the difference in N excretion for fattening pigs (63%) (Annex 7). The CAPRI coefficient for N excretion by fattening pigs was higher than the coefficient values of the country and those found in the literature. In addition, the CAPRI model estimated much higher N-excretion coefficients for fattening pigs for Germany than for HU and IT (Annex 5).

Table 4.1 N excretions in the CAPRI and in the country datasets

	CAPRI			DE		
	Fattening pigs	**Sows (with piglets)**	**Total**	**Fattening pigs**	**Sows (with piglets)**	**Total**
N excretion coefficient (kg N/place/yr)	18.7	33.8	15.3 ***	11.3	34.5	10.6 ***
N swine excretion (Gg N/yr)	318	87	405	195	88	283
N animal excretion (Gg N/yr)			1,357			1,263
N input (Gg N/yr)			3,422			3,768

Literature values:

	Fattening pigs		Sows
N-excretion coefficient from the literature (kg N/place/yr)	12-15** (a) 11 (b) 11 (c)	11.7 (d) 14.8 (e) 11.9 (f)	32-38** (a) 26 (b) 33 (c)

Note: CAPRI data was extracted in May 2013.
*a: Ketelaars and van der Meer (1999) for EC Member States; b: OECD (1997) for OECD countries; c: Levington Agriculture (1997) for Europe; d: 2013 German GHG Inventory; e: GAINS model (Asman *et al* 2011) ; f: RAINS model (the predecessor of GAINS (http://gains.iiasa.ac.at/models/)) (Oenema *et al* 2009).
**N-excretion coefficients' range depending on N-conversion coefficient.
*** Calculated for the country by using weighted average of N-excretion coefficients for piglets, fattening pigs, sows and boars, and for the CAPRI model by using corrected animal numbers (see Section 2.2.5).

To calculate the total N-excretion coefficient of fattening pigs (e), DEnat used the weighted average of N-excretion coefficients of standard (a and b) and low feeding (c and d) fattening pigs, using two daily gain rates, i.e. 700 g/d (a and c) 800 g/d (b and d) according to (Eq. 3) (Bach *et al* 2011).

$$\boldsymbol{e} = \frac{(\boldsymbol{a}\times\mathbf{2}+\boldsymbol{b}\times\mathbf{2}+\boldsymbol{c}+\boldsymbol{d})}{\mathbf{6}} \qquad (3)$$

DEcapri feed intake was higher than DEnat by 83%, and N intake was higher by 56% (see Annex 6). DEcapri live weight, and consequently retention, was higher by 23% and 20%, respectively. This resulted in 75% more N excretion in DEcapri.

DEnat (DLG 2005) used the December survey for the animal numbers, but the N-excretion coefficient used was kg N/place/yr. An update is required from animals' herd size to places, but is likely to result in only minor changes for N excretion (from 195 Gg N/yr to 192 Gg N/yr).

Recommendation & Conclusion: Further analysis is required to understand the reason for the higher feed intake in CAPRI. DEnat should report animal numbers per place instead of per head.

France

- Δ_{abs}: 65 Gg N/yr (Table 3.1)
- A significant share (-31%) of the difference of total N animal excretion (-210 Gg N/yr)

National method: FR used N-excretion coefficients from the national GHG inventories. These coefficients were estimated by the Interprofessional Technical Centre for Studies on Air Pollution (CITEPA). CITEPA uses a model called PACRETE[11] to combine and harmonise the different data sources of livestock size, feeding, type of buildings etc. in order to calculate these coefficients. In 2012, the method was improved using

11 This system provides an integrated approach to estimate livestock emissions at regional level. It includes livestock nitrogen excretion, mass flow approach for nitrogen, updated emission factors for NH_3 and particles as well as updated data on breeding practices.

country-specific data based on national studies (CORPEN) for every species. N-excretion data now integrates time dependent data on feed and production level.

Assessment: Table 4.6 shows that there is a large difference in the N-excretion coefficient for swine between that CAPRI and the country data; literature data are closer to the CAPRI than the country data.

Table 4.6 N excretions in the CAPRI and in the country datasets

	CAPRI	**FR**
N-excretion coefficient for swine (kg N/place/yr)	11.6	7.2
Other data (kg N/place/yr)	12 (Asman *et al* 2011)	
N-excretion coefficient for fattening pigs (kg N/place/yr)	12.7	7.7 (CORPEN 2003)
Other data* (kg N/place/yr)	12-15** (a) 11 (b) 11 (c)	
N-excretion coefficient for sows (with piglets) kg N/place(=head)/yr	36.4	24.6 (CORPEN 2003)
Other data* (kg N/place/yr)	32-38** (a) 26 (b) 33 (c)	
N-excretion by swine (Gg N/yr)	172	107
N-excretion by animals (Gg N/yr)	1,610	1,820
N input (Gg N/yr)	4,714	4,857

Note: CAPRI data was extracted in May 2013.
*a: Ketelaars and van der Meer (1999) for EC Member States; b: OECD (1997) for OECD countries; c: Levington Agriculture (1997) for Europe
**N excretion coefficients' range depending on the N-conversion coefficient.

Comparison of the animal N-budgets for swine in FRnat (CORPEN 2003) and FRcapri showed higher N intake and N retention by both fattening pigs and sows in CAPRI data. The $\Delta_{absperc}$ in N intake and N retention were 166% and 68% for fattening pigs, and 95% and 62% for sows, respectively (Annex 7). For fattening pigs in standard feeding, we found higher N intake (113%) in CAPRI data, mainly resulting from higher feed intake (166%), and higher N retention (68%) resulting from higher implied live weight (126%); this lead to 54% more N excretion in the CAPRI model (Annex 8).

In the Eurostat/OECD GNB common guidelines (Eurostat 2013), the N-excretion coefficient is defined as kg N/head/yr with an explanation that it should be used as kg N/place/yr by the countries. The N-excretion coefficient is kg N/place/year according to the country source document (CORPEN 2003). But the country reported it as kg N/head/year because of the definition in the common guidelines.

Recommendation & Conclusion: Further analysis to understand the reason for the higher feed intake and higher implied live weight in CAPRI is needed. FRnat should report the N-excretion coefficient for swine per place instead of per head.

Hungary

- Δ_{abs}: 39 Gg N/yr (Table 3.1)
- A significant share (96%) of the Δ_{act} of total N animal excretion (40 Gg N/yr).

National method: Statistics on numbers of national animals were based on an annual data collection, with 1st December as the reference day. HU N-excretion coefficients were based on the national nitrate regulation, and values were determined on the basis of domestic and international literature sources, including institutes in Hungary.

Assessment: Table 4.7 shows that the CAPRI N-excretion coefficients for swine were higher than those in the national and literature data (cf Annex 5).

Table 4.7 N excretions in the CAPRI and in the country datasets

	CAPRI			**HU**		
	Fattening pigs	Sows (with piglets)	Total	Fattening pigs	Sows (with piglets)	Total
N-excretion coefficient (kg N/place/yr)	24.8	43.3	20.5*	9.24	34.4	9.6*
N-excretion by swine (Gg N/yr)	60	19	80	27	14	41
N-excretion by animals (Gg N/yr)			195			154
N input (Gg N/yr)			612			518

Literature values:

	Fattening pigs	**Sows**
Other data (kg N/place/yr)	· 12-15** (a) · 11 (b) · 11 (c)	· 32-38** (a) · 26 (b) · 33 (c)

Note: CAPRI data was extracted in May 2013.
* Calculated for the country by using a weighted average of N-excretion coefficients for piglets, fattening pigs, sows and boars, and for the CAPRI model by using corrected animal numbers (see Section 2.2.5).
**a: Ketelaars and van der Meer (1999) for EC Member States; b: OECD (1997) for OECD countries; c: Levington Agriculture (1997) for Europe
***N-excretion coefficients' range depending on N-conversion coefficient.

No detailed national data was available to allow for the comparison of the animal N-budgets for swine.

The number of swine in the CAPRI dataset (3 894 (1 000 heads)) was notably lower than that of the country data 4 275 (1 000 heads). HUnat used the end-of-year survey data for the number of pigs, whereas CAPRI used the herd size for pigs obtained from Eurostat data in maximum four annual surveys (April, May or June, August, and December). HUnat data were corrected by using CAPRI methodology in Annex 2, which eliminated the difference in animal numbers.

HUnat now uses updated methodology and the weighted average of mid-year survey data (50% for the year t) and end-of-year survey data (25% for the years t and t-1) for the number of swine for each group. However, this new methodology slightly increases HUnat swine numbers, and consequently Δ_{abs} between HUnat and HUcapri swine numbers. The country also updated N-excretion coefficients based on the country GHG reporting, and $\Delta_{absperc}$ in total N animal excretion between HUnat and HUcapri decreased from 57% to 9%.

Recommendation & Conclusion: (i) Δ_{abs} between HUnat and HUcapri swine numbers is higher than before, so the issue is 'open'. We recommend that HUnat evaluates the CAPRI methodology for calculating herd sizes of fattening pigs (see Annex 2). (ii) Even though the difference in total N–excretion by animals has been reduced considerably, further comparison of the detailed animal budget is required to assess the differences in the N-excretion coefficients.

Italy

- Δ_{abs}: 100 Gg N/yr (Table 3.1)
- A significant share (75%) of the Δ_{act} of total N-excretion by animals (134 Gg N/yr).

The share of N-excretion values for swine in the total N excretion was high for both the CAPRI and the country data, at 23% and 12% respectively.

National method: The source of the N-excretion coefficient for swine was the ELBA Model - University of Bologna. The ELBA Model is an economic model developed for the analysis of the environmental sustainability of Italian agriculture.

Assessment: The reason for the difference between N-excretion by swine in the CAPRI and the country data was the difference in N-excretion coefficients. The N-excretion coefficient for fattening pigs for ITcapri is higher than in ITnat, FRnat and DEnat (Annex 5), and higher than some literature values (Table 4.8). However, the literature data of the animal N-budgets for swine for IT, including the N-excretion coefficient for fattening pigs, are similar to ITcapri (see Annex 9).

Table 4.8 N excretions in the CAPRI and in the country datasets

	CAPRI			IT		
	Fattening pigs	**Sows (with piglets)**	**Total**	**Fattening pigs**	**Sows (with piglets)**	**Total**
N-excretion coefficient for swine (kg N/place/yr)	23.2	37.6	20.1***	9.3	46.7	9.3***
N-excretion by swine (Gg N/yr)	156	29	184	62	23	84
N-excretion by animals (Gg N/yr)			814			680
N input (Gg N/yr)			1 828			1 976

Literature values:

	Fattening pigs	**Sows**
Other Data*	12-15** (a) 11 (b) 11 (c) 22.1 (d)	32-38** (a) 26 (b) 33 (c) 36.6 (d)

Note: CAPRI data was extracted in May 2013.
*a: Ketelaars and van der Meer (1999) for EC Member States; b: OECD (1997) for OECD countries; c: Levington Agriculture (1997) for Europe; d: Oenema et al. (2014) for Italy
**N-excretion coefficients' range depends on the N-conversion coefficient.
*** Calculated for the country by using a weighted average of N-excretion coefficients for piglets, fattening pigs, sows and boars, and for the CAPRI model by using corrected animal numbers (see Section 2.2.5).

Recommendation & Conclusion: Further analysis of the detailed animal budget is required to assess the differences in the N-excretion coefficients between ITnat and ITcapri.

4.5 N EXCRETION BY OTHER CATTLE (IT)

N excretion by other cattle was only identified for Italy:

Italy

- Δ_{abs}: 52 Gg N/yr (Table 3.1)
- A significant share (39%) of the Δ_{act} of total N-excretion by animals (134 Gg N/yr).

The share of N-excretion values for other cattle in the total N excretion amount was high in both ITcapri (28%) and ITnat (26%).

National method: The N-excretion coefficient for male cattle older than 2 years and for buffaloes was from the OECD. The N-excretion coefficient for other cattle was from the ELBA Model - University of Bologna.

Assessment: The N-excretion coefficients are the main reason for the difference between the N excretion from other cattle of CAPRI and the country data. Table 4.9 shows that the country N-excretion coefficient was lower than the data of CAPRI and the literature.

Table 4.9 N excretions in the CAPRI and in the country datasets

	CAPRI	IT*
N-excretion coefficient for other cattle (kg N/place/yr)	48.5	36.0
Other Data (kg N/place/yr)	46.9 (Asman *et al* 2011) for IT 51 (IPCC 2006)* 45.5 (small breed) - 61.4 (large breed) Ketelaars and van der Meer(1999) for EC Member States)**	
N-excretion by other cattle (Gg N/yr)	229.1	177.4
N-excretion by swine (Gg N/yr)	184	84
N-excretion by animals (Gg N/yr)	814	680
N input (Gg N/yr)	1 828	1 976

Note: CAPRI data was extracted in May 2013.
* This ratio was calculated from default values for Western Europe in IPCC 2006 as N excretion [(kg N/1 000 kg animal mass/day) * Animal mass (kg) / 1 000*365]
** The weighted average values of N-excretion coefficients of suckling cattle and growing cattle calculated by using CAPRI animal numbers.

Recommendation & Conclusion: Further comparison of the detailed animal budget is required.

4.6 N EXCRETION BY SHEEP AND GOATS (FR)

N excretion by sheep and goats was only identified as an issue for France:

France

- Δ_{abs}: 91 Gg N/yr (Table 3.1)
- A significant share (-43%) of the difference of total N animal excretion (-210 Gg N/yr)

National method: The same approach as for swine (see Section 4.4) was used for the estimation of N-excretion coefficients.

Assessment: According to Table 4.10, the N excretion coefficients for sheep and goats were lower in the CAPRI model than in the country and the literature data. CAPRI N-excretion coefficients were also significantly lower than the NAT values for Germany and Hungary, and slightly lower for Italy (Annex 5).

Table 4.10 N excretions in the CAPRI and in the country dataset

	CAPRI	FR
N-excretion coefficient of sheep & goats (kg N/place/yr)	8.1	16.5
Other Data (kg N/place/yr)	11.3 for sheep (OECD 1997) for OECD countries 13.5 for goats (OECD 1997) for OECD countries 20 for sheep and goats Levington Agriculture (1997) for Europe 12 for sheep and goats for FR in GAINS database (Asman *et al* 2011) 15 for sheep and 18 kg for goats (IPCC, 2006)* 15.5 for sheep and goats (EEA 2009) (default value)	
N-excretion coefficient of sheep and goats for fattening activity (kg N/place/yr)	6.9	Not reported
N-excretion coefficient of sheep and goats for milk production activity (kg N/place(=head)/yr)	8.4	Not reported
Other Data (kg N/place/yr)	12.3 for ewes (DEFRA 2007) for UK 20.6 for female goats (DEFRA 2007) for UK 22.8 for ewes (Ketelaars and van der Meer 1999)** 20.6 for female goats ewes (Ketelaars and van der Meer 1999)	
N-excretion by sheep & goats (Gg N/yr)	80	171
N-excretion by animals (Gg N/yr)	1 610	1 820
N input (Gg N/yr)	4 714	4 857

Note: CAPRI data was extracted in May 2013.
* This ratio was calculated from default values for Western Europe in IPCC 2006 as "N excretion (kg N/1 000 kg animal mass/day) * Animal mass (kg) / 1 000 *365"
**The values are for EU Member States.

No detailed data is available for the country animal N-budgets for sheep and goats.

Recommendation & Conclusion: To understand the reason behind the different N-excretion values, it is recommended to make an in-depth assessment of the animal N-budgets for sheep and goats in the FRnat and FRcapri.

4.7 N REMOVAL BY GRAS (FR, HU, IT)

N removal by GRAS was identified as an issue for three countries:

France

- Almost one third (31%) of total N removal by crop products of the country
- Δ_{abs}: 307 Gg N/yr (Table 3.1)
- A significant share (121%) of the Δ_{act} of total estimates in N exports in crops and forage
(-253 Gg N/yr)

National method: To calculate pasture consumption, FR used a methodology based on animal requirements. Pasture consumption in FR was estimated by subtracting fodder crop production other than pasture from animal requirements. Animal requirements were estimated by multiplying numbers of livestock by a coefficient defined by animal category.

The N contents in the CAPRI model are based on adjusted literature values. FR uses country-specific coefficients from COMIFER 2013 (National expert group regarding fertilisation) who compiled data from the Institut de l'élevage (IDELE) and the Institut du végétal (ARVALIS).

Assessment: Table 4.11 shows that the N content of GRAS in the CAPRI values was lower than in the country data. The N content of GRAS for FR is 2.25% according to the MITERRA model, which was the weighted average of the N content for intensively managed grassland (3% dry matter) and for extensively managed grassland (2% (d.m)). Shares of GRAI and GRAE in GRAS for FR were assumed to be 25% and 75%, respectively (Velthof *et al* 2007). The share of GRAE (extensive permanent grasslands, permanent grasslands with traditional orchards, and summer grasslands) in total permanent grassland was 19% according to French TERUTI 2000 data, and 23% according to French Annual Agricultural Statistics 1999 (Pointereau *et al* 2007).

Using MITERRA N contents and the average shares of these two national studies of FR for GRAE and GRAI gave the N content of GRAS for FR at 2.8%. This percentage is higher than the current CAPRI and MITERRA values, and it is closer to FR country-specific value.

Table 4.11 N removal with GRAS in CAPRI and in the country dataset

	CAPRI	FR	Other data
Area (kha)	9 494	9 581	10 013 (Eurostat)
Dry Matter (DM) Yield (100 kg/ha)	43.7	38.4	43.8 (MITERRA)
DM Crop Production (kt)	41 447	36 782	
DM N content (kg N/tonme)	17.2	27.8	22.5 (MITERRA)
N removal by GRAS (Gg N/yr)	714	1 021	
N removal by crops and forage (Gg N/yr)	3 066	3 319	

Note: CAPRI data was extracted in May 2013.

Recommendation & Conclusion: CAPRI should check the GRAS N content and possibly update it using a combination of literature (Velthof *et al* 2007, e.g. Pointereau *et al* 2007)and country estimations. The possibility of using results from the GRASSDATE project (Velthof *et al* 2014) in FRnat and FRcapri should also be evaluated. For estimates of dry matter yields of grassland, the differentiation of grassland according to the proposal of the GRASSDATE project would be important (permanent grassland: grassland out of production but maintained, unimproved grassland (sole use, common land), improved grassland (by N-input levels <50, 50-100, >100 kg N/ha/yr, sole use and common land)). Thus, the issue is still open.

<u>*Hungary*</u>

- Δ_{abs}: 37 Gg N/yr (Table 3.1)
- A significant share (-36%) of the Δ_{act} of total estimates of N exports in crops and forage (-102 Gg N/yr)

National method: HU data for the area and the yield were compiled from farmers for the national annual survey on agricultural activities. The scope of data collection for agricultural enterprises was full scale. Two groups were established for collected data from private farms. The large private farms were covered completely; the smaller private farms were selected by using a sampling procedure in line with the regulation: 543/2009/EC. Approximately 8 000 agricultural enterprises and 30 000 private farms reported the data to the Hungarian Central Statistical Office for each year.

Assessment: Table 4.12 shows that HUcapri contained significantly higher values for the GRAS area and the yield than HUnat. CAPRI data were close to the permanent grassland area reported to Eurostat by the country.

The main reason for the difference in grassland yield is that the proportion of GRAI was assumed as 25% in the MITERRA model, which is the source of the CAPRI GRAS yield, whereas the country assumed almost zero intensive grassland.

Table 4.12 N removal by GRAS (permanent grassland) in the HUcapri and HUnat

	CAPRI	HU	Other data
Area (kha)	949	503	1 058 (Eurostat)
Dry Matter (DM) Yield (100 kg/ha)	35.2	14.9	39 (MITERRA) 15 (Nagy 2006) for HU 15-25 (Vinczeffy 1993) for HU
DM Crop Production (kt)	3 339	751	
DM N content (kg N/tonne)	15.2	18.5	22.5 (MITERRA)
N removal by GRAS (Gg N/yr)	51	14	
N removal by crops and forage (Gg N/yr)	396	498	

Note: CAPRI data was extracted in May 2013.

Recommendation & Conclusion: (i) The CAPRI yield value for permanent grassland in Hungary should be checked; (ii) the HUnat area for permanent grassland used and/or in the Eurostat database (crop products - annual data (apro_cpp_crop)) should be checked. The grassland area in the Eurostat database for Hungary before 2010 also includes unused grassland areas. The grassland area should only contain the utilsed agricultural area, according to Eurostat definitions.

Italy

- Δ_{abs}: 190 Gg N/yr (Table 3.1)
- A significant share (69%) of the Δ_{act} of total estimates in N exports in crops and forage (-276 Gg N/yr)

National method: Italy used a literature value (Schleef and Kleinhanb 1994) for GRAS yield. GRAS area values were taken from ISTAT. ITnat used OECD estimates for GRAS consumption, considering that 70% of the produce was consumed. The N content of GRAS was taken from the ELBA Model - University of Bologna.

Assessment. Table 4.13 shows that the difference between CAPRI and national GRAS dry matter yield values was high; Eurostat and literature data were inconclusive.

Table 4.13 N removal by GRAS in the CAPRI and in the country datasets

	CAPRI*	IT**	Other data
Area (kha)	3 895	4 350	4 381 (Eurostat)
Dry Matter (DM) Yield (100 kg/ha)	26.6	48.8	35 (MITERRA) 12.53 (Eurostat)
DM Crop Production (kt)	10 366	21 238***	
DM N content (kg N/tonne)	17.6	25.0	22.6 (MITERRA)
N removal by GRAS (Gg N/yr)	182	372	
N removal by crops and forage (Gg N/yr)	1 094	1 370	

Note: CAPRI data was extracted in May 2013.
* Three-year average (2003, 2004, 2005)
** Two-year average (2003, 2004)
*** In GNB calculations, 70% of DM crop produce is consumed.

Recommendation & Conclusion: We recommend that the values for GRAS yield of both Italy and the CAPRI model be checked; more information may be required.

4.8 N REMOVAL BY OFAR (DE AND FR)

The N removal by OFAR was identified as an issue for two countries:

Germany

OFAR is defined in the CAPRI model as a group consisting of other annual green fodder, clover and mixtures, lucerne, and other perennial green fodder, usually legumes and temporary grassland. National crop data were grouped to match this group as well as possible. Only cereals harvested while they were green and other annual green fodder data were available for grouping in OFAR in the dataset reported by the DEnat. However, DEnat included clover and mixtures, lucerne, and temporary grassland in "permanent meadows/grasses: consumption". By re-grouping these crops, the difference between the values for N-removal by OFAR of the DEcapri and DEnat datasets fell below the defined threshold.

Recommendation & Conclusion: The issue arose due to inconsistent data grouping, and has been resolved. The aggregation of these crops should be revised in DEnat.

France

- Δ_{abs}: -159 Gg N/yr (Table 3.1)
- A significant share (63%) of the Δ_{act} of total estimates in N exported in crops and forage (-253 Gg N/yr).

For comparison, FRnat data for other annual green fodder, leguminous plants and temporary grasslands were aggregated into an OFAR group. The N contents in the CAPRI model were based on adjusted literature values, while FR uses country-specific data.

Assessment: Table 4.14 shows that the N contents of the crops in the OFAR group for FR were high.

Table 4.14 N removal by OFAR in the CAPRI and in the country datasets

	CAPRI	**FR**
N content of other annual green fodder (kg N/tonne)		35.0
Other Data (kg N/tonne)	3.0 (ITnat) 3.5 (HUnat) 4.5 (DEnat) 5.8 (MITERRA)	
N content of leguminous plants (kg N/tonne)		39.0
Other Data (kg N/tonne)	27.0 (ITnat) 27.0 (HUnat) 26.0 (DEnat) 31.5 (red clover*) http://www.feedipedia.org/node/1250	
N content of temporary grassland (kg N/tonne) kg N/ton		27.8
Other Data (kg N/tonne)	18.0 (HUnat)	
N content of OFAR (kg N/tonne)	17.0	29.7
Other Data (kg N/tonne)	17.0 (ITcapri) 15.0 (HUcapri) 17.0 (DEcapri)	
N removal by OFAR (Gg N/yr)	479	638
N removal by crops and forage (Gg N/yr)	3 066	3 319

Note: CAPRI data was extracted in May 2013.
*Clover has the highest crop share (85%) in leguminous products in the FR dataset.

According to FRcapri, OFAR production was 28 726 kt (d.m.) whereas FRnat puts OFAR production data at 21 635 kt (d.m.). The country OFAR production data is 26 605 kt (d.m.) in the Eurostat crop products database.

Recommendation: We recommend that France checks the N contents of the crops in the OFAR group. With regard to the difference in OFAR dry matter production, the country should ensure that the data is consistent with the Eurostat crop products database.

Conclusion: Current FRnat N content data have been updated very recently and are unlikely to be updated again in the near future. The difference in the OFAR dry matter production figures of the CAPRI and the country datasets can be reduced in the short term by ensuring that the NAT data is consistent with the Eurostat database.

4.9 N REMOVAL BY OTHER CEREALS EXCEPT FOR WHEAT AND BARLEY (DE AND FR)

N removal by cereals other than wheat and barley was identified as an issue for two countries:

Germany

- Δ_{abs}: 48 Gg N/yr (Table 3.1)
- A significant share (26%) of the Δ_{act} of total estimates in N exports in crops and forage (184 Gg N/yr)

National method: The coefficients for other cereals used in DE GNB tables were taken from the DüV (2007) (Fertiliser Ordinance of DE). These coefficients were calculated as the mean of the coefficients of corn with different crude protein ratios in dry matter.

Assessment: $\Delta_{absperc}$ in production of other cereals except for wheat and barley between the CAPRI and the country data was not very high. Therefore, the main reason for the high $\Delta_{absperc}$ in this group was the high difference in the N contents. Most of the Δ_{abs} in other cereals between the CAPRI model and DE was accounted for by triticale (65%), followed by grain maze (20%), oats (12%) and rye and meslin(3%).

Table 4.15 shows that the OCER N content of FRcapri is significantly higher than that of the DEnat and literature data.

Table 4.15 N removal by other cereals in the CAPRI and in the country datasets

<table>
<tr><th></th><th>CAPRI</th><th>DE</th><th>Other data</th></tr>
<tr><td></td><td>OCER*</td><td>Triticale</td><td>Triticale - N content (kg N/tonne)</td></tr>
<tr><td>N content (kg N/tonne)</td><td>28.3</td><td>17.2</td><td rowspan="3">15 (MITERRA)
18.6 (Lassaletta et al 2014)
18.7 (www.feedipedia.org/node/6476)
14.5-15.5 (Akgün et al 2011) for Turkey (TR)</td></tr>
<tr><td>N removal by other cereals (Gg N/yr)</td><td>79</td><td>49</td></tr>
<tr><td>N removal by crops and forage (Gg N/yr)</td><td>2 239</td><td>2 055</td></tr>
</table>

Note: CAPRI data was extracted in May 2013.
*Cereals other than wheat, maize, barley, rice, rye, maslin and oats

Recommendation & Conclusion: The possibility of using country-specific N contents for other cereals (OCER aggregate) in CAPRI should be evaluated. The same applies for the N contents of other crop aggregates in the CAPRI database. Note that the DEnat N content of OCER, at 17.2 kg N/tonne, is close to the average N contents of the cereals other than OCER in CAPRI, at 16.7 kg N/tonne, and higher than the OCER N-content values in the literature and other countries (Annex 9).

France

- High Δ_{abs} between NAT and CAPRI data (Table 3.1)
- Δ_{absperc}: 94%

The production of other cereals except for wheat and barley was updated by the country during bilateral discussions from 10 012 kt to 16 650 kt. The N removal by other cereals was then calculated at 259 Gg N/yr, while the previous value was 151 Gg N/yr. In this situation, the Δ_{perc} in N contents of other cereals of CAPRI and FR became significantly smaller (from 94% to 20%).

Conclusion: The issue was resolved.

4.10 N REMOVAL BY OLIVES AND OTHER FRUIT (IT)

N removal by olives and fruit was identified as an issue for Italy:

Italy

- Δ_{abs}: 234 Gg N/yr (Table 3.1)
- A significant share (85%) of the Δ_{act} of total estimates in N exported in crops and forage (-276 Gg N/yr)

National method: IT used the result of the ELBA Model - University of Bologna for the estimates of the N content of olives and fruit.

Assessment: For these crops, the $\Delta_{absperc}$ in crop production between the CAPRI and the country data was not very high. Therefore, the main reason for the high $\Delta_{absperc}$ was the high differences in N contents. The national N content of olives and other fruit was much higher than CAPRI data and literature data from other countries (Table 4.16 & Annex 10).

Table 4.16 N removal by olives and fruit in the CAPRI and in the country datasets

	CAPRI*	IT**
N content of olives (kg N/tonne)	4.8	43.3
Other data for N content of olives (kg N/tonne)	8.8*** (Eurostat) 3.8 (Lassaletta *et al* 2014) 9.7 (Therios 2009)	
N content of fruit (kg N/tonne)	2.1 for fruit 1.1 for apples, pears and peaches 2.0 for other fruit	6.6 for fruit 7.7 for all fruit except for citrus fruit
Other data for N content of fruit (kg N/tonne)	0.8 for apples, pears and peaches (Lassaletta *et al* 2014)	
N removal by olives (Gg N/yr)	19	175
N removal by fruits (Gg N/yr)	32	110
N removal by crops and forage (Gg N/yr)	1 094	1 370

Note: CAPRI data was extracted in May 2013.
* Three-year average (2003, 2004, 2005)
** Two-year average (2003, 2004)
*** The average of N contents of olives for Spain, Malta and Portugal for the year 2008

Recommendation & Conclusion: We recommend that Italy should justify or revise the high N content values used for olives and other fruit. We also recommend that the CAPRI values for olives be checked, and that the possibility of using country-specific N content values for aggregates in the CAPRI model be evaluated. The issue can be considered being unresolved.

4.11 N REMOVAL BY MAIZE AND WHEAT (HU)

N removal by maize and wheat was identified as an issue for Hungary:

Hungary

- Δ_{abs}: 96 Gg N/yr (Table 3.1)
- A significant share (94%) of the Δ_{act} of total estimates for N exported in crops and forage (-102 Gg N/yr)

National method: HUnat used the N contents of wheat and maize in the Nitrate Regulation, which includes the N content of crop residues.

Assessment: Table 4.17 shows that the country data was higher than the data of other countries, the CAPRI model and the literature.

Table 4.17 N removal by wheat and maize in the CAPRI and in the country dataset

	CAPRI	**HU**
N content of wheat (kg N/tonne)	20.0	27.0
Other data for N content of wheat (kg N/tonne)	19.9 (ITnat) 21.1 (DEnat) 19.2 (FRnat) 20.0-21.8 (The range of N content in the CAPRI model) 19.5 (Lassaletta *et al* 2014) 20 (MITERRA) 20.2 (http://www.feedipedia.org/node/223)	
N content of maize (kg N/tonne)	16.7	25.0
Other data for N content of maize (kg N/tonne)	15.0 (ITnat) 14.5 (DEnat) 15.0 (FRnat) 16.7 (CAPRI for 4 countries) 15.2 (Lassaletta *et al* 2014) 13.9 (MITERRA) 14.1 (http://www.feedipedia.org/node/713)	
N removal by wheat (Gg N/yr)	93	126
N removal by maize (Gg N/yr)	120	183
N removal by crops and forage (Gg N/yr)	396	498

Note: CAPRI data was extracted in May 2013.

Conclusion: We recommended that Hungary should report the N content of crops and crop residues separately. As this recommendation was implemented, the issue was resolved.

4.12 COMPARISON AT THE REGIONAL LEVEL

A comparison of data at the regional level was only possible for FR and IT.

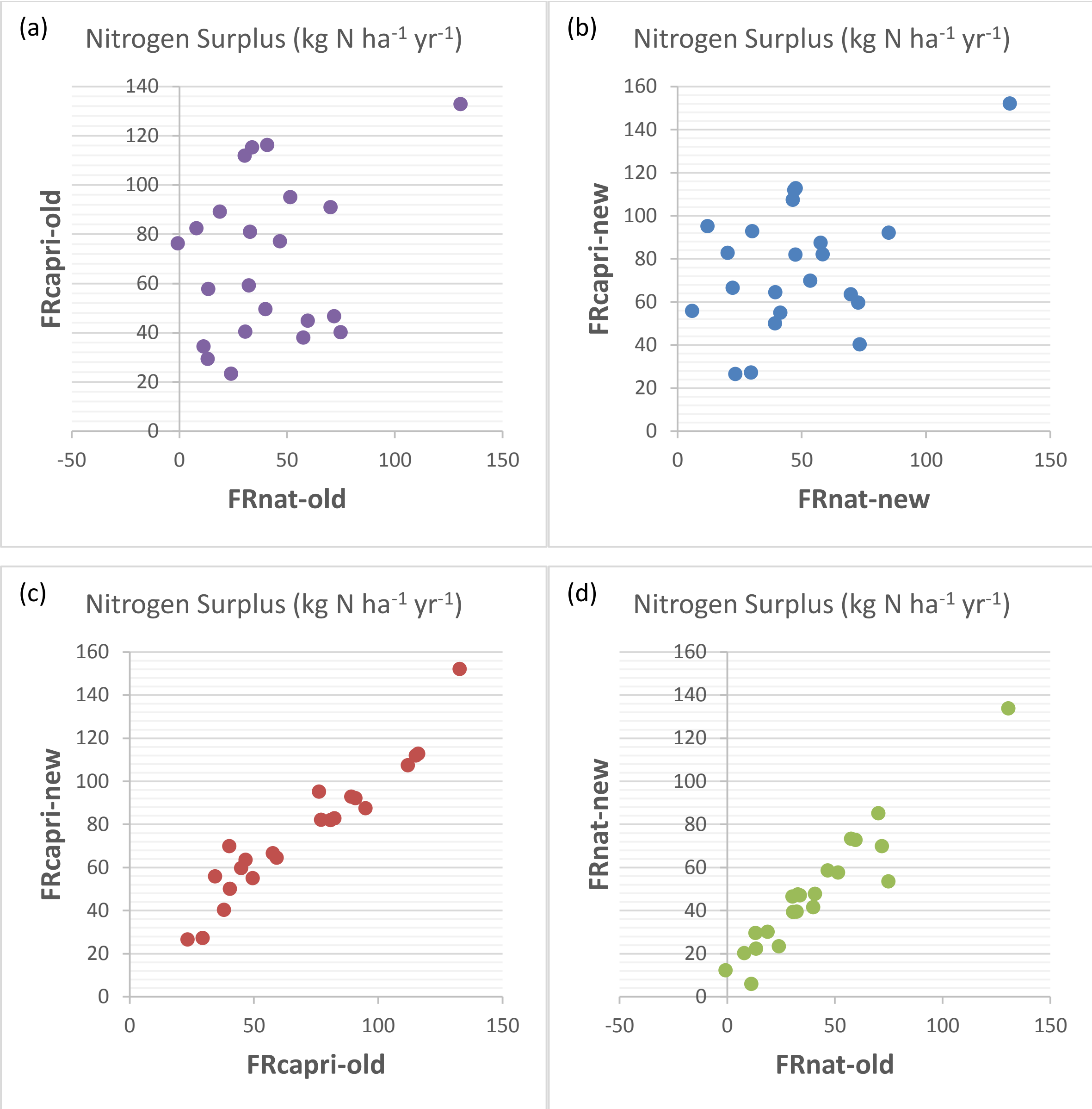
Scatter plots were used to determine whether or not there was a fit between the regional N surplus from CAPRI and from NAT data. There was a poor fit between FRcapri-old and FRnat-old (in the beginning of RegNiBal), and FRcapri-new and FRnat-new (at the end of RegNiBal) (Figure 3a and b) (the values from the chi-squared ($\chi 2$) distribution (<0.05) indicate a significant difference between FRnat and FRcapri). However, a slight increase in the p value of $\chi 2$ of FRcapri-new and FRnat-new compared to old values indicates that a slight improvement on goodness of fit between NAT and CAPRI was achieved at the regional level by the end of the project. The same situation was observed for IT (Figure 4a and b).

Some changes occurred also to the regional N surplus between in the NAT and CAPRI data (Figure 3c and d, Figure 4c).

When we compared all regional data of FRnat-new with FRcapri-new we observed the following:

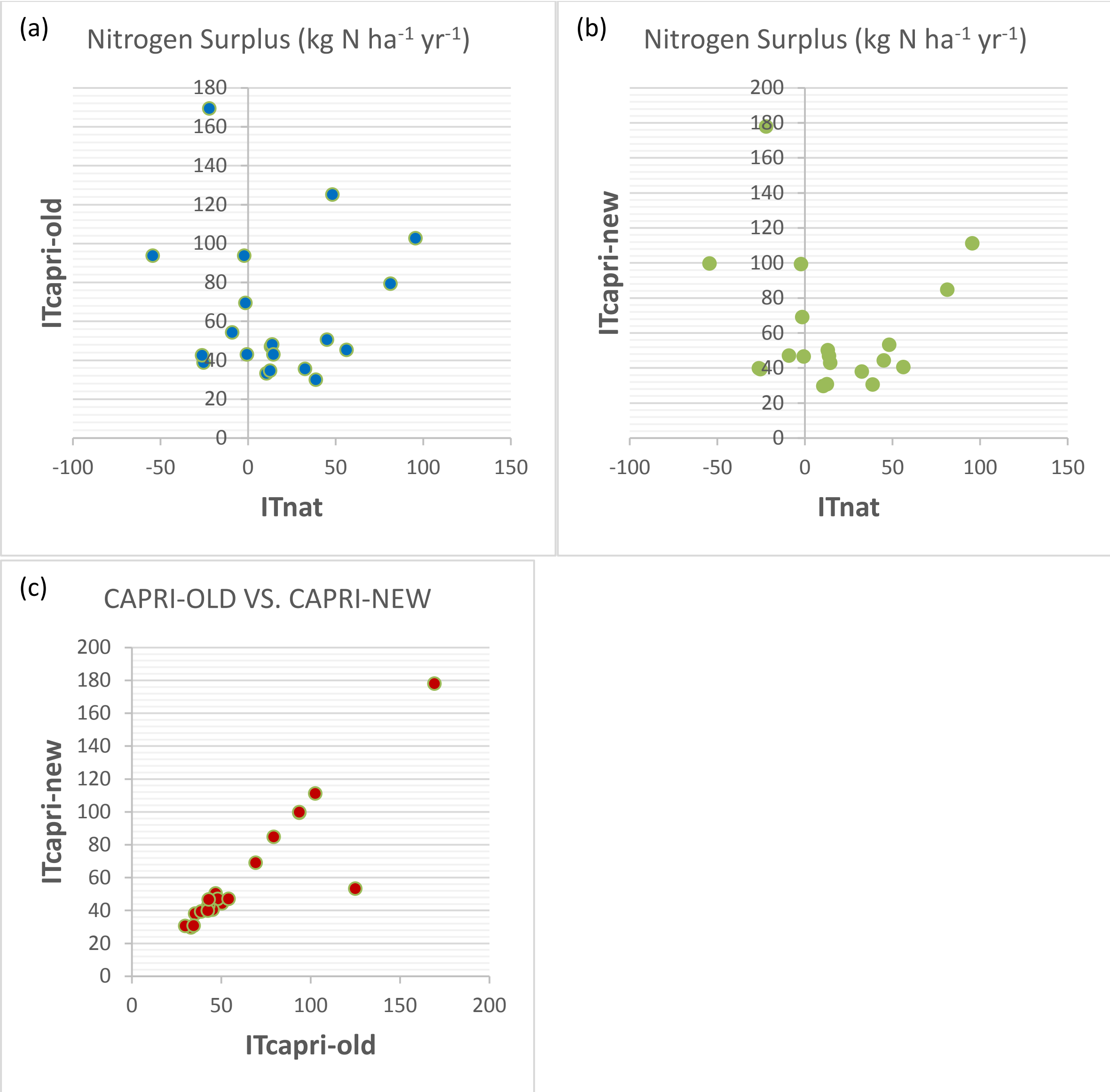
- Generally higher CAPRI N surplus
- High regional deviations in mineral N-fertiliser usage
- Generally lower CAPRI N-excretion levels
- Low regional deviations in N-excretion levels
- Generally higher CAPRI atmospheric N deposition
- High regional deviations in biological N fixation
- High regional deviations in N removed by crops and fodder, and generally lower CAPRI N removed by crops and fodder

Detailed results and assessments of the differences are summarised in the supplementary file (REGNIBAL-SUPPL.FILE.xls).



* FRcapri-old/FRnat-old: the data at the beginning of the RegNiBal project; FRcapri-new/FRnat-new: the data at the end of the RegNiBal project

Figure 3 Scatter plots for the regional nitrogen surplus data of FRcapri and FRnat



* ITcapri-old/ITnat: the data at the beginning of the RegNiBal project; ITcapri-new: the data at the end of the RegNiBal project; the assessment for IT is for the year of 2006.

Figure 4 Scatter plots for the regional nitrogen surplus data of ITcapri and ITnat

5 CONCLUSIONS

A total of 31 "issues" were identified that were related to major discrepancies between the methods and warranted further assessment. At the end of the project, 12 of the identified issues were solved, one was partially solved and 18 could not be solved, but some progress was achieved and concrete recommendations were made for almost all of them. The results and achievements of RegNiBal are summarised in Annex 12.

At the start of the RegNiBal project CAPRI data was generally judged to be more reliable than NAT data. The situation has changed with the improvements described above; at present, further analysis is needed to see whether CAPRI or NAT data is 'better' with regard to the remaining unresolved issues.

Overall**,** N excretion by swine and N removal by grass are considered the most important unresolved issues because of their considerable impact on N-input and N-output. The animal budget analysis for swine of DE and FR shows that CAPRI estimates higher feed intake than NAT. Countries are not always sufficiently accurate in estimating and/or using the average number of animals and N-excretion coefficients in N manure excretion estimations. For the estimates of dry matter yields of grassland, the differentiation of permanent grassland according to the proposal of the GRASSDATE project (Velthof *et al* 2014) would likely help (grassland out of production but maintained, unimproved grassland (including both sole use and common land) and improved grassland (by N-input levels <50, 50-100, >100 kg N/ha/yr, sole use and common land).

The CAPRI model is very strong in several parts of GNB calculations, and the RegNiBal project enabled us to identify several possible improvements in national data and methods. The use of the animal budget to estimate N excretion is a major asset in the CAPRI methodology, but runs the risk of outliers if the use of feed in the statistical sources is overestimated. There is large uncertainty in grass yield and other (non marketable) fodder yield and their N content. This affects the accuracy of national data as well. The other major areas of difficulties for the CAPRI model are the following: (i) Seed and planting materials should be explicit in the CAPRI GNB; (ii) N from organic fertilisers (other than manure) and manure withdrawal, stocks, and import estimations are not considered in the CAPRI model.

The CAPRI model can be used to calculate both land N budgets (GNB) and farm N budgets. The possibility of comparing the GNB with the farm N-budget helps to constrain the N-surplus results. For the farm N-budget, feed and fodder produced in the country (or region) and manure excreted and applied within the country (or region) are considered as 'internal flows' and thus do not need to be estimated to quantify the N-surplus; data on 'imported' feed and 'exported' animal products are needed instead (for details on the comparison of the two approaches, see Leip *et al* 2011b). In the CAPRI model, data on animal products and imported feeds are available from statistical sources and are thus more reliable than the data on the N intake of fodder and manure excretion, which would not be required.

Regional-level data were available only for FR and IT. While the focus of the project was make a comparison at the national scale, the RegNiBal project showed that some improvements could also be achieved at the regional level.

Generally, the RegNiBal project showed that the CAPRI model could be adequate to provide national (and later regional and spatially explicit) GNBs. However, for the four countries assessed, additional work needs to be carried out to understand residual disagreements in the data.

One observation that emerged from the RegNiBal project was that some 'mistakes' are made due to different interpretations of the Eurostat/OECD handbook on Nutrient Budgets (Eurostat, 2013) or due to inaccurate use of data. Differences in statistical data used for the GNBs and data reported to Eurostat in other statistical tables also lead to inconsistencies. Many data required for the regional GNBs are already available in Eurostat tables (e.g. crop production, livestock number, fertiliser use[12], land use). In order to solve the abovementioned problems, and to produce regional GNB estimations, Eurostat should evaluate the possibility to use those tables in combination with a (reduced) reporting burden on the country (for example the N content of crops, etc., see Annex 13). NUTS2&3 GNBs could be calculated using an automatic algorithm/tool. Automatic processing would also reduce any errors that arise from differences in interpretation. This would improve comparability. Annex 13 lists data and coefficients needed for GNBs, and indicates which Eurostat table would provide the relevant value, or if this needs to be delivered by the countries.

Three different options for the next steps are proposed. Any combination of these options or 'hybrid' solutions are possible. For example, a Eurostat algorithm using existing data tables could be implemented, both informed by data provided by countries and complementarily from the CAPRI model when needed.

1. Regional GNBs cannot immediately be generated that are fully consistent with national GNBs. However, the superiority of national over CAPRI estimates is not always obvious, so regional and spatially explicit CAPRI data can be regarded as a suitable dataset for policy advice. Such data will be useful proxy data that are independent of the national official GNBs.
2. Convergence of CAPRI with national official GNBs would help improve both CAPRI and national estimates, but this option requires further investment. Such investment would, however, have added value also for other areas, such as improved CAPRI scenarios for climate change mitigation assessments; use of CAPRI data as independent estimates of GHG emission inventories; harmonisation of national methodologies developed in the process; improved consistency between various datasets.
3. Another route could be the abovementioned 'simplified process' which makes use of existing information as much as possible and generates national (and regional) GNBs that are fully consistent with the Eurostat/OECD common guidelines (which are also suitable for producing regional GNBs) and using a (new) automatic algorithm/tool that is running at Eurostat. Such a system would probably be the most cost-efficient in the short term, and would provide good estimates efficiently.

12 Use of inorganic fertiliser data is available at the regional level for some countries in the Eurostat 'use of inorganic fertilisers' database (aei_fm_usefert).

6 REFERENCES

Akgün I, Kara B and Altindal D 2011 Effect of salinity (NaCl) on germination, seedling growth and nutrient uptake of different Triticale genotypes *Turkish J. F. Crop.* **16** 225–32

Arja N 2005 Soils characteristics affecting biological N fixation of organically grown red clover in Finland *Proceedings of the 14th international Nitrogen Fixation Congress. Current Plant Science and Biotechnology in Agriculture Volume 4*

Asman W A H, Klimont Z and Winiwarter W 2011 *A simplified model of nitrogen flows from manure management. Interim Report IR-11-030, IIASA, Laxenburg, 2011.* (Laxenburg, Austria: IIASA)

Bach M, Godlinski F and Greef J M 2011 *Handbuch Berechnung der Stickstoff Bilanz für die Landwirtschaft in Deutschland Jahre 1990-2008* (Germany: Julius Kühn-Institut (JKI))

Beriner J E and Hirsch P R 1984 Genetic Engineering and Nitrogen Fixation *Biotechnol. Genet. Eng. Rev.* **1**

Boddey R M, de Oliveira O, Urquiaga S, Reis V, Olivares F, Baldani V and Dobereiner J 1995 Biological nitrogen fixation associated with sugarcane and rice: contributions and prospects for improvement *Plant Soil* **174** 195–209

Bohlool B B, Ladha J K, Garrity D P and George T 1992 Biological nitrogen fixation for sustainable agriculture: A perspective *Plant and Soil1* **174** 195–209

Boiler B C and Nosberger J 1987 Symbiotically fixed nitrogen from field-grown white and red clover mixed with ryegrasses at low levels of 15N-fertilization *Plant Soil* **104** 219–26

Britz W and Leip A 2009 Development of marginal emission factors for N losses from agricultural soils with the DNDC-CAPRI meta-model *Agric. Ecosyst. Environ.* **133** 267–79 doi:http://dx.doi.org/10.1016/j.agee.2009.04.026

Britz W and Witzke H-P 2012 *CAPRI model documentation 2012* ed W Britz and H-P Witzke (Bonn: University Bonn) Online: http://www.capri-model.org/dokuwiki/doku.php?id=start.

Carter M S 2005 *Production of N2O in grass-clover pastures. PhD Thesis* Online: http://orgprints.org/10147/1/10147.pdf.

CORPEN 2003 Comité d’Orientation pour der Pratiques agricoles respectueses de L’Environnement. France.

Cowling D W 1982 Biological nitrogen fixation and grassland production in the United Kingdom *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **296** 397–404

DEFRA 2007 *Nitrogen output of livestock excreta. ADAS report to Defra – supporting paper F2 for the consultation on implementation of the Nitrates Directive in England.*

DG AGRI 2006 *Rural Development 2007-2013. Handbook on Common Monitoring and Evaluation Framework. Guidance document, September 2006* Online: http://ec.europa.eu/agriculture/rurdev/eval/.

DLG 2005 Bilanzierung der Nährstoffausscheidungen landwirtschaftlicher Nutztiere, Germany. ed Deutsche Landwirtschafts Gesellschaft e.V. *Arb. der DLG* **199**

DüV 2007 *Bekanntmachung der Neufassung der Düngeverordnung Vom 27. Februar 2007.*

EC 2006 *Development of agri-environmental indicators for monitoring the integration of environmental concerns into the common agricultural policy. Communication from the Commission to the Council and the European Parliament. COM(2006) 508 final* (Brussels: Commission of the European Communities)

EC 2014 *Impact indicators for the CAP post 2013* (Brussels, Belgium: European Commission) Online: http://ec.europa.eu/agriculture/cap-post-2013/monitoring-evaluation/.

EC 2004 *Integrating environmental considerations into other policy areas - a stocktaking of the Cardiff process. Commission Working Document. COM(2004) 394 final* (Commission of the European Communities)

EEA 2009 *EMEP/EEA air pollutant emission inventory guidebook-2009* ed Convention on Long Range Transboundary Air Pollution and European Environmental Agency Online: http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009.

Erisman J W, Galloway J N, Seitzinger S, Bleeker A, Dise N B, Petrescu a M R, Leach A M and de Vries W 2013 Consequences of human modification of the global nitrogen cycle. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **368** 20130116 doi:http://dx.doi.org/10.1098/rstb.2013.0116

EU 2013 Regulation (EU) No 1306/2013 of the European Parliament and of the Council of 17 December 2013 on the financing, management and monitoring of the common agricultural policy and repealing Council Regulations (EEC) No 352/78, (EC) No 165/94, (EC) No 2799/98 *Off. J. Eur. Union* **L 347** 549–607

European Commission 2011 *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Roadmap to a Resource Efficient Europe. COM(2011)571 final*

European Commission 2014 *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Towards a circular economy: A zero waste programme for Europe. COM(2014)398 final*

Eurostat 2013 *Nutrient Budgets, EU-27, NO, CH. Methodology and Handbook. Version 1.02* (Luxemb: Eurostat and OECD) Online: http://ec.europa.eu/eurostat/documents/2393397/2518760/Nutrient_Budgets_Handbook_(CPSA_AE_109)_corrected3.pdf.

Firth P, Thitipoca H, Suthipradit S, Wetselaar R and Beech D F 1973 Nitrogen balance studies in the central plain of Thailand *Soil Biol. Biochem.* **5** 41–6

Fowler D, Coyle M, Skiba U, Sutton M A, Cape J N, Reis S, Sheppard L J, Jenkins A, Grizzetti B, Galloway J N, Vitousek P, Leach A, Bouwman A F, Butterbach-Bahl K, Dentener F, Stevenson D, Amann M and Voss M 2013 The global nitrogen cycle in the twenty-first century. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **368** 20130164 doi:http://dx.doi.org/10.1098/rstb.2013.0164

Gauger T 2010 *Erfassung, Prognose und Bewertung von Stoffeinträgen und ihren Wirkungen in Deutschland* (BMU/UBA)

Gauger T, Haenel H D, Rösemann C, Dämmgen U, Bleeker A, Erisman J W, Vermeulen A T, Schaap M, Timmermanns R M A, Builtjes P J H and Duyzer J H 2008 National Implementation of the UNECE Convention on Long-range Transboundary Air Pollution (Effects) Part 1: Deposition Loads: Methods, modelling and mapping results, trends.

Grizzetti B, Bouraoui F and Aloe A 2012 Changes of nitrogen and phosphorus loads to European seas *Glob. Chang. Biol.* **18** 769–82 doi:http://dx.doi.org/10.1111/j.1365-2486.2011.02576.x

Helming J, Kuhlman T, Linderhof V and Oudendag D 2014 *Impacts of legume scenarios. Legume Futures Report 4.5. Available from www.legumefutures.de*

IPCC 2006 *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme - Volume 4 Agriculture, Forestry and Other Land Use* ed H Eggleston, L Buendia, K Miwa, T Ngara and K Tanabe (Japan: IGES)

Kelner D J, Vessey J K and Entz M H 1997 The nitrogen dynamics of 1-, 2- and 3-year stands of alfalfa in a cropping system *Agric. Ecosyst. Environ.* **64** 1–10 doi:http://dx.doi.org/10.1016/S0167-8809(97)00019-4

Ketelaars and van der Meer 1999 Establishment of criteria for the assessment of the nitrogen content of animal manures, AB-DLO (study carried out for DG Environment in 1999).

Lassaletta L, Billen G, Grizzetti B, Garnier J, Leach A M and Galloway J N 2014 Food and feed trade as a driver in the global nitrogen cycle: 50-year trends *Biogeochemistry* **118** 225–41 doi:http://dx.doi.org/10.1007/s10533-013-9923-4

Leip A 2011 Assessing the environmental impact of agriculture in Europe: the Indicator Database for European Agriculture *Understanding Greenhouse Gas Emissions from Agricultural Management* ed L Guo, A Gunasekara and L McConnell (Washington DC: ASC) pp 371–85 doi:http://dx.doi.org/10.1021/bk-2011-1072.ch019

Leip A 2014 *CAPRI livestock numbers - Working paper for Animal Change: Livestock classification* (European Commission, Joint Research Centre)

Leip A, Achermann B, Billen G, Bleeker A, Bouwman A F, de Vries W, Dragosits U, Döring U, Fernall D, Geupel M, Heldstab J, Johnes P, Le Gall A C, Monni S, Nevečeřal R, Orlandini L, Prud’homme M, Reuter H I, Simpson D, Seufert G, Spranger T, Sutton M A, van Aardenne J, Voß M and Winiwarter W 2011a Integrating nitrogen fluxes at the European scale *European Nitrogen Assessment* ed M Sutton, C Howard, J W Erisman, G Billen, A Bleeker, H van Grinsven, P Grennfelt and B Grizzetti (Cambridge, UK: Cambridge University Press) pp 345–76 doi:http://dx.doi.org/10.129/2003GB002060.

Leip A, Britz W, Weiss F and de Vries W 2011b Farm, land, and soil nitrogen budgets for agriculture in Europe calculated with CAPRI. *Environ. Pollut.* **159** 3243–53 doi:http://dx.doi.org/10.1016/j.envpol.2011.01.040

Leip A, Busto M and Winiwarter W 2011c Developing spatially stratified N2O emission factors for Europe. *Environ. Pollut.* **159** 3223–32 doi:http://dx.doi.org/10.1016/j.envpol.2010.11.024

Leip A, Marchi G, Koeble R, Kempen M, Britz W and Li C 2008 Linking an economic model for European agriculture with a mechanistic model to estimate nitrogen and carbon losses from arable soils in Europe *Biogeosciences* **5** 73–94 doi:http://dx.doi.org/10.5194/bg-5-73-2008

Leip A, Weiss F and Britz W 2011d Agri-Environmental Nitrogen Indicators for EU27 *Bio-Economic Models applied to Agricultural Systems* ed G Flichman (Dordrecht: Springer Netherlands) pp 109–23 doi:http://dx.doi.org/10.1007/978-94-007-1902-6_6

Leip A, Weiss F, Lesschen J P and Westhoek H 2014 The nitrogen footprint of food products in the European Union *J. Agric. Sci.* **152** 20–33 doi:http://dx.doi.org/10.1017/S0021859613000786

Leip A, Weiss F, Wassenaar T, Perez-Dominguez I, Fellmann T, Loudjani P, Tubiello F, Grandgirard D, Monni S and Biala K 2010 *Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) -final report* (European Commission, Joint Research Centre) Online: http://ec.europa.eu/agriculture/analysis/external/livestock-gas/full_text_en.pdf.

Levington Agriculture 1997 *A Report for the European Fertiliser Manufacturers Association* (Ipswich, UK: Levington Agriculture Ltd.)

Macolino S, Lauriault L M, Rimi F and Ziliotto U 2013 Phosphorus and potassium fertilizer effects on alfalfa and soil in a non-limited soil *Agron. J.* **105** 1613–8 doi:http://dx.doi.org/10.2134/agronj2013.0054

Masterton C L and Murphy P M 1976 Application of the acetylene reduction technique to the study of nitrogen fixation by white clover in the field *Symbiotic Nitrogen Fixation in Plants* ed P S Nutman (Cambridge, UK: Cambridge University Press) pp 299–316

Mulligan D T 2006 *Regional modelling of nitrous oxide emissions from fertilised agricultural soils within Europe. Submitted in candidature for the degree of Philosophae Doctorae, Prifysgol Cymru, Bangor. University of Wales, Bangor.*

Nagy G 2006 Country Pasture/Forage Resource Profiles: Hungary

Neyra C A and Dobereiner J 1977 Nitrogen fixation in grasses *Adv. Agron.* **29** 1–38

OECD 2001 *Environmental Indicators for Agriculture: Methods and Results* (Paris, France: OECD)

OECD 1997 *National Soil Surface Nutrient Balances, 1985 to 1995. Explanatory Notes. Table 2 Coefficients to convert livestock numbers into manure nitrogen quantities from national sources.* (Paris, France: OECD Secretariat)

Oenema O, Kros H and de Vries W 2003 Approaches and uncertainties in nutrient budgets: implications for nutrient management and environmental policies *Eur. J. Agron.* **20** 3–16 Online: http://www.sciencedirect.com/science/article/B6T67-

49CS184-5/2/4a9ad88844df98943014d95171abe6cb.

Oenema O, Sebek L, Kros H, Lesschen J P, van Krimpen M, Bikker P, van Vuuren A and Velthof G 2014 Guidelines for a common methodology to estimate nitrogen and phosphorus excretion coefficients per animal category in EU-28. Final report to Eurostat *Methodological studies in the field of Agro-Environmental Indictors* vol Task 5 Rep, ed Eurostat (Luxembourg: Eurostat) pp 1–108

Oenema O, Witzke H P, Klimont Z, Lesschen J P and Velthof G L 2009 Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27 *Agric. Ecosyst. Environ.* **133** 280–8 doi:http://dx.doi.org/10.1016/j.agee.2009.04.025

Özbek F S 2014 Estimation of national and regional phosphorus budgets for agriculture in Turkey *Spanish J. Agric. Res.* **12** 52 doi:http://dx.doi.org/10.5424/sjar/2014121-4327

Ozbek F S and Leip A 2015 Estimating the gross nitrogen budget under condition of soil nitrogen stock changes: a case study for Turkey *Agric. Ecosyst. Environ.* **in press**

Özbek F Ş and Leip A 2015 Estimating the gross nitrogen budget under soil nitrogen stock changes: A case study for Turkey *Agric. Ecosyst. Environ.* **205** 48–56 doi:http://dx.doi.org/10.1016/j.agee.2015.03.008

Paul E E and Clark F E 1996 *Soil microbiology and biochemistry, 2nd ed.* (San Diego, CA.: Academic Press)

Pointereau P, Paracchini M L, Terres J M, Jiguet F, Bas Y and Biala K 2007 *Identification of High Nature Value farmland in France through statistical information and farm practice surveys* (European Commission, Joint Research Centre)

Schleef K H and Kleinhanb W 1994 *Mineral Balances in Agriculture in the EU* (Braunschweig, Germany: Institute of Farm Economics, Federal Agricultural Research Centre)

Simpson D, Andersson C, Christensen J H, Engardt M, Geels C, Nyiri a., Posch M, Soares J, Sofiev M, Wind P and Langner J 2014 Impacts of climate and emission changes on nitrogen deposition in Europe: a multi-model study *Atmos. Chem. Phys.* **14** 6995–7017 doi:http://dx.doi.org/10.5194/acp-14-6995-2014

Simpson D, Benedictow A, Berge H, Bergström R, Emberson L D, Fagerli H, Flechard C R, Hayman G D, Gauss M, Jonson J E, Jenkin M E, Nyíri A, Richter C, Semeena V S, Tsyro S, Tuovinen J-P, Valdebenito Á and Wind P 2012 The EMEP MSC-W chemical transport model – technical description *Atmos. Chem. Phys.* **12** 7825–65 doi:http://dx.doi.org/10.5194/acp-12-7825-2012

Smil V 2011 Nitrogen cycle and world food production *World Agric.* 9–13

Smil V 1999 Nitrogen in crop production: An account of global flows *Global Biogeochem. Cycles* **13** 647–62

Sutton M A, Bleeker A, Howard C M, Bekunda M, Grizzetti B, de Vries W, Van Grinsven H J M, Abrol Y P, Adhya T K, Billen G, Davidson E ., Datta A, Diaz R, Erisman J W, Liu X J, Oenema O, Palm C, Raghuram N, Reis S, Scholz R W, Sims T, Westhoek H and Zhang F S 2013 *Our Nutrient World: The challenge to produce more food and* *energy with less pollution* (Centre for Ecology and Hydrology, Edinburgh on behalf of the Global Partnership on Nutrient Management and the International Nitrogen Initiative)

Sutton M A, Howard C, Erisman J W, Billen G, Bleeker A, van Grinsven H, Grennfelt P and Grizzetti B 2011a *The European Nitrogen Assessment. Sources, Effects and Policy Perspectives* ed M Sutton, C Howard, J W Erisman, G Billen, A Bleeker, H van Grinsven, P Grennfelt and B Grizzetti (Cambridge, UK: Cambridge University Press) Online: http://www.nine-esf.org/ENA-Book.

Sutton M A, Oenema O, Erisman J W, Leip A, van Grinsven H and Winiwarter W 2011b Too much of a good thing. *Nature* **472** 159–61 doi:http://dx.doi.org/10.1038/472159a

Therios I 2009 *Olives* (Wallingford, UK: CABI Publishing)

Unkovich, Herridge M D and Peoples M 2008 *Measuring plant-associated nitrogen fixation in agricultural systems'* (Australian Centre for International Agricultural Research)

Vadakattu G and Peterson J 2006 Free-living bacteria lift soil nitrogen supply *Farming Ahead* **169**

Velthof G L, Lesschen J P, Schils R L M, Smit A, Elbersen B S, Hazeu G W, Mucher C A and Oenema O 2014 *Grassland areas , production and use. Lot 2. Methodological studies in the field of Agro-Environmental Indicators* vol Report to (Wageningen, The Netherlands: Alterra Wageningen UR)

Velthof G L, Oudendaag D and Oenema O 2007 *Development and Application of the Integrated Nitrogen Model MITERRA-EUROPE. Task 1 Service Contract "Integrated Measures in Agriculture to Reduce Ammonia Emissions"* (Wageningen, The Netherlands: Alterra)

Vinczeffy I 1993 Gyeptipológia [Grassland types] *Legel és gyepgazdálkodás [Pasture and Grassland Management]* ed I Vinczeffy (Budapest, Hungary: Mezgazda Publications) p 400 pp

Vitousek P M, Cassman K, Cleveland C, Crews T, Field C B, Grimm N B, Howarth R W, Marino R, Martinelli L, Rastetter E B and Sprent J I 2002 Towards an ecological understanding of biological nitrogen fixation *Biogeochemistry* vol 57-58 pp 1–45 doi:http://dx.doi.org/10.1023/A:1015798428743

De Vries W, Leip A, Reinds G J, Kros J, Lesschen J P, Bouwman A F, Grizzetti B, Bouraoui F, Butterbach-bahl K, Bergamaschi P and Winiwarter W 2011 Geographical variation in terrestrial nitrogen budgets across Europe *European Nitrogen Assessment* ed M Sutton, C Howard, J W Erisman, G Billen, A Bleeker, H van Grinsven, P Grennfelt and B Grizzetti (Cambridge, UK: Cambridge University Press) pp 317–44 Online: http://www.nine-esf.org/ENA-Book.

Wagner S C 2012 Biological Nitrogen Fixation *Nat. Educ. Knowl.* **3** 15 Online: http://www.nature.com/scitable/knowledge/library/biological-nitrogen-fixation-23570419.

Weiss F and Leip A 2012 Greenhouse gas emissions from the EU livestock sector: A life cycle assessment carried out with the CAPRI model *Agric. Ecosyst. Environ.* **149** 124–34 doi:http://dx.doi.org/10.1016/j.agee.2011.12.015

Wichink Kruit R, Schaap M, Segers A, Banzhaf S, Schauschner T, Builtjes P and Heslinga D 2014 *PINETI (Pollutant INput and EcosysTem Impact) report. Modelling and mapping of atmospheric nitrogen and sulphur deposition and critical loads for ecosystem specific assessment of threats to biodiversity in Germany.*

ANNEXES

Annex 1. N contents of all crops in CAPRI*

N content	(kg N/tonne)	FR	DE	HU	IT	N content	(kg N/tonne)	FR	DE	HU	IT
SWHE	Soft wheat	20.0	20.0	20.0	20.0	OFAR	Other fodder from arable land	6.0	6.1	5.3	6.1
DWHE	Durum wheat	23.0	23.0	23.0	23.0	PARI	Paddy rice	22.0	NA	22.0	22.0
RYEM	Rye and meslin	16.7	16.7	16.7	16.7	OLIV	Olive oil	4.5	NA	NA	4.5
BARL	Barley	16.7	16.7	16.7	16.7	PULS	Pulses	41.0	41.0	41.0	41.0
OATS	Oats	18.3	18.3	18.3	18.3	POTA	Potatoes	3.5	3.5	3.5	3.5
MAIZ	Grain maize	16.7	16.7	16.7	16.7	SUGB	Sugar beet	1.8	1.8	1.8	1.8
OCER	Other cereals	28.3	28.3	28.3	28.3	TEXT	Flax and hemp	3.0	NA	3.0	3.0
RAPE	Rape seed	33.0	33.0	33.0	33.0	TOBA	Tobacco	30.0	30.0	30.0	30.0
SUNF	Sunflower seed	28.0	28.0	28.0	28.0	TOMA	Tomatoes	2.0	2.0	2.0	2.0
SOYA	Soya seed	58.0	NA	58.0	58.0	OVEG	Other vegetables	2.0	2.0	2.0	2.0
OOIL	Other oil	30.0	30.0	30.0	30.0	APPL	Apples pears and peaches	1.1	1.1	1.1	1.1
OIND	Other industrial crops	15.5	15.5	15.5	15.5	OFRU	Other fruit	2.0	2.0	2.0	2.0
NURS	Nurseries	15.5	15.5	15.5	15.5	CITR	Citrus fruit	2.0	NA	NA	2.0
FLOW	Flowers	65.0	65.0	65.0	65.0	TAGR	Table grapes	1.9	NA	1.9	1.9
OCRO	Other crops	15.5	15.5	15.5	15.5	TABO	Table olives	22.5	NA	NA	22.5
MAIF	Fodder maize	3.3	3.3	3.3	3.3	TWIN	Table wine	2.9	2.9	2.9	2.9
ROOF	Fodder root crops	1.8	1.8	1.8	1.8	GRAS	Grass	3.8	3.9	3.4	3.9

NA: Not applicable
* Extracted in May 2013

Annex 2. CAPRI calculation method for the herd size of animals in places per year

$$H_{pigf} = \frac{\left(S_{pigs} - i_{sows} \cdot H_{sows}\right)}{h_{pigf}} \cdot d_{pigf}$$

where

H_{pigf}	Herd size of animals in places per year [1000 pl_{pigf}/yr]
S_{pigs}	Number of animals slaughtered during the year [1000 hd_a/yr]; S_{pigs} is obtained from Eurostat database ZPA1
i_{sows}	Input coefficient (replacement rate) of young sows/sow [hd_{sowsy}/hd_{sows}]
H_{sows}	Herd size of sows in places per year [1 000 pl_{sows}/yr]
h_a	Number of days a herd location is defined for animal *a* [days/pl_a]; $a \in$ {pigf,sows} h=365 days/pl_a @ $a \in$ {pigf,sows}
d_a	Production days of a living animal *a* [days/hd_{pigf}]; $a \in$ {pigf,sows,sowsy} d_{sowsy}=240 days/hd_{sowsy}

$$i_{sows} = \frac{\boldsymbol{H}_{sowsy} \cdot \frac{h_{sowsy}}{d_{sowsy}} - \boldsymbol{\Delta}_t \left\{\boldsymbol{N}_{sows}\right\}}{\boldsymbol{N}_{sows}}$$

where

H_{sowsy}	The herd size of non-mated sows is obtained from Eurostat in maximum four annual surveys (April, May or June, August, and December). H_{sowsy} is the average number obtained from these surveys.
N_{sows}	Number of sows alive during the year [1 000 hd_a/yr]
ΔtNa	Change in animal stock from year t to year t+1

ANNEX 3. Regionalisation of the coefficients used in NAT & CAPRI

	Inputs & Outputs in N Balance	Data needed by NUTS 2 level	ITnat	FRnat	CAPRI
Inputs	1) Mineral fertiliser	The amount of mineral fertiliser			
	2) Manure production	Number of animals			
		N-excretion coefficients	Different coefficients are used at NUTS2 level except for pigs and heifers.	The same coefficients are used at NUTS2 level.	Model output; varies at NUTS2 level.
	3) Manure trade, withdrawal, and treatment	The amount of N from manure trade, withdrawal, and treatment			
	4) Other organic fertiliser	The amount of organic fertilisers			
		N content of organic fertiliser	Not estimated	The same coefficients are used at NUTS2 level.	Not estimated
	5) Biological N fixation	The area of leguminous crops			
		The fixation coefficient of leguminous crops	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.	The shares of fixed N in N requirement in aboveground biomass is used (same for all regions).
		The area of temporary and permanent grassland			
		The fixation coefficient of grass/legume mixtures	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.	The shares of fixed N in N requirement in above-ground biomass is used (same for all regions).
	6) Atmospheric N deposition	Utilised agricultural area (UAA)			
		Regional average deposition rate	The same coefficients are used at NUTS2 level.	Not the same coefficients are used at NUTS2 level.	Calculated from gridded atmospheric deposition data; varies at NUTS2 level.
	7) Seed and planting materials	Cropped areas of crops			

	Inputs & Outputs in N Balance	Data needed by NUTS 2 level	ITnat	FRnat	CAPRI
		N-conversion coefficient of seed of crops	The same coefficients are used at NUTS2 level.	The same coefficients are used at national and NUTS2 level.	Not estimated
	8) Total inputs = sum (1,2,3,4,5,6,7)				
Outputs	9) Crop production	The amount of crop production			
		N content of crops	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.
	10) Fodder production	The amount of crop production of fodder			
		N content of fodder	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.
	11) Crop residues removed/burnt	Crop residues removed/burnt of crops			
		N content of crop residues removed/burnt	Not estimated	The same coefficients are used at NUTS2 level.	The same coefficients are used at NUTS2 level.
	12) Total outputs = sum(9,10,11)				
NS	NS = (8) - (12)				

Note: The assessment for IT is for the year 2006; for the years 2003, 2004 and 2005 for FR and the CAPRI model.

Annex 4. Nitrogen balance legends in the CAPRI MODEL

EXPPRD	**Nitrogen exported in harvested material and crop residues or animal products**
ATMOSD	Atmospheric deposition
CRESID	Crop residues (input)
BIOFIX	Biological fixation
MINSAT	Mineralisation from soil organic matter
MINFER	Mineral fertiliser applied, including some parts lost in runoff or emissions
GASMIN	Losses in gaseous emissions NH_3 and N_2O and NO_X from mineral fertiliser
RUNMIN	Losses in runoff from mineral fertiliser
SURSOI	Surplus to soil
SURTOT	Total surplus is nutrient input net of exports in products
LEACHI	Leaching below rooting zone to groundwater or surface waters
DENITR	Denitrification below rooting zone
ACCUMU	Accumulation of surplus in soil organic matter
EXCRET	Nitrogen in excretion of animals
GASMAN	N in gaseous losses during manure management as NH_3 and N_2O and N_2 and NO_X
NH3MAN	N in gaseous losses during manure management as NH_3
NH3GRA	Ammonia losses from manure on grazing land
NH3HOU	Ammonia losses from manure in housing
NH3STO	Ammonia losses from manure in storage systems
NH3APP	Ammonia losses from manure during application
NH3MIN	Ammonia losses from mineral fertiliser
NH3TOT	Ammonia losses total
GASTOT	Gaseous losses of N total
RUNTOT	Runoff losses total
RUNMAN	N in runoff from manure management

Annex 5 N-excretion coefficients of selected animal groups in the CAPRI and i country datasets*

N excretion coefficient (kg N/place/yr)	DE		FR		HU**		IT**	
	CAPRI	The country	CAPRI	The country	CAPRI	The country	CAPRI	The country
Fattening pigs	18.7	11.3	12.7	NR	24.8	9.2	23.2	9.3
Sows (with piglets)	33.8	34.5	36.4	NR	43.3	34.4	37.6	46.7
Swine	15.3	10.6	11.6	7.2	20.5	9.6	20.1	9.3
Sheep & goats	6.1	18.2	8.1	16.5	10.3	15.7	9.4	12.2
Other cattle	43.9	25.2	52.9	59.3	57.1	37.3	48.5	36.0

* Extracted from CAPRI in May 2013; NAT data were reported by the countries in the beginning of the RegNiBal project.
** The countries reported N-excretion coefficients as kg N/head/yr in GNB tables. However, they were taken as kg N/place/yr here since the countries used the number of animals from official statistics in the calculations.
NR: Not reported
Note: The country N-excretion coefficients were calculated as the weighted average of the related animal groups.

Annex 6 Comparison of animal N-budgets for fattening pigs in the CAPRI and DE-nat data

Animal Budget Components	PIGF		
	DE (DLG 2005)[5]	**CAPRI**	**% Difference**
N contents of pig diet - breeding sow (28 kg – 115 kg) (g/kg feed)[1]	23.2	NA	NA
N contents of pig diet - growing–finishing pig (28 – 117 kg) (g/kg feed)	27.3	NA	NA
N contents of pig diet (g/kg feeds)[2]	25.3	21.0	17
The amount of feed intake - breeding sow (28 kg – 115 kg) (kg/head)	266.0	NA	NA
The amount of feed intake - growing–finishing pig (28 – 117 kg) (kg/head)	264.0	NA	NA
The amount of feed intake (kg/head)[2]	264.8	484.0	-83
N intake - breeding sow (28 kg – 115 kg) (kgN/place/year)	14.5	NA	NA
N intake - growing–finishing pig (28 – 117 kg) (kgN/place/year)	17.0	NA	NA
N intake (kgN/place/year)	15.7	24.6	-56
N content (g/kg LW)	25.6	25.1	2
Implied live weight (kg LW/place/year)	207.9	255.0	-23
Pork meat (kg carcass weight / head)	NR	97.6	NA
Slaughtered animals (live weight in 1 000 t)	NR	5155.4	NA
N retention - breeding sow (28 kg – 115 kg) (kgN/place/year)	4.6	NA	NA
N retention - growing–finishing pig (28 – 117 kg) (kgN/place/year)	5.8	NA	NA

Animal Budget Components	PIGF		
	DE (DLG 2005)[5]	**CAPRI**	**% Difference**
N retention (kgN/place/year)[2]	5.3	6.4	-20
N-excretion coefficient - breeding sow (28 kg – 115 kg) (kgN/place/year)	10.2	NA	NA
N-excretion coefficient - growing–finishing pig (28 – 117 kg) (kgN/place/year)	12.0	NA	NA
N excretion coefficient (kgN/place/year)[2]	10.4	18.2	-75
Herd size of animals (HERD) (1 000 places)[3]	16 999.6	16 998.6	0
Production days for a living animal (DAYS)[4]	155.3	150.7	3
Number of animals (LEVL) (1 000 heads)	39 949.0	41 184.2	-3
N excretion (Gg/year)	176.7	309.4	-75

1) The value for DE was calculated as N intake (kg N/place/year) / feed intake (kg/head) / fattening period (=2.35)
2) The values for DE were calculated as the weighted average of breeding sows (28 kg – 115 kg) and growing–finishing pigs (28 – 117 kg).
3) DE value is the average number of animals in the Eurostat database (1 000 heads)
4) The value was calculated by using fattening period given in DLG (2005). (=365 / fattening period (=2.35))
5) DE uses the weighted average of N-excretion coefficients of fattening pigs of the standard and N-low feeding daily gain with 700 g/d and 800 g/d (Bach et al., 2011).
NR: Not reported, NA: Not applicable.
Note: CAPRI data was extracted in May 2014. CAPRI values might be different from the values in the main text because of the different extraction dates.

ANNEX 7 Comparison of animal N-budgets for swine in the CAPRI and FR-nat data

Animal Budget Components	PIGF			SOWS			TOTAL		
	FR (CORPEN 2003)[8]	CAPRI	% Diff	FR (CORPEN 2003)[8]	CAPRI	% Diff	FR (CORPEN 2003)[8]	CAPRI	% Diff
N contents of pig diet - weaned piglets (8-30 kg) (g/kg feeds)[1]	30.8	NA	NA	NA	NA	NA	NA	NA	NA
N contents of pig diet - growing-finishing pig (30-112 kg) (g/kg feeds)[1]	28.2	NA	NA	NA	NA	NA	NA	NA	NA
N contents of pig diet (g/kg feeds)[1]	28.5	22.9	20	26.4	20.3	23	26.6	20.7	22
The amount of feed intake - weaned piglets (8-30 kg) (kg/head)	38.0	NA	NA	NA	NA	NA	NA	NA	NA
The amount of feed intake - growing-finishing pig (30-112 kg) (kg/head)	235.0	NA	NA	NA	NA	NA	NA	NA	NA
The amount of feed intake (kg/head)[2]	150.3	399.3	-166	1200	2342	-95	199.6	496.1	-149
N intake - weaned piglets (8-30 kg) (kgN/place/year)[3]	3.1	NA	NA	NA	NA	NA	NA	NA	NA
N intake - growing-finishing pig (30-112 kg) (kgN/place/year)[3]	17.7	NA	NA	NA	NA	NA	NA	NA	NA
N intake (kgN/place/year)[2]	11.4	24.4	-113	31.5	47.6	-51	13.8	27.2	-98
N content (g/kg LW)	18.5	25.1	-36	18.5	25.1	-36	18.5	25.1	-36
Implied live weight (kg LW/place/year)	112.0	253.2	-126	373.0	445.8	-20	224.0	276.9	-24
Pork meat (kg carcass weight / head)[6]	86.6	89.6	-3	45.8	50.5	-10	NA	NA	NA
Slaughtered animals (live weight in 1000 t)[7]	3 010	2 961	2	78.4	87.6	-12	3 089	3 048	1

N retention - weaned piglets (8-30 kg) (kgN/place/year)[3]	1.5	NA	NA	NA	NA	NA	NA	NA	NA
N retention - growing-finishing pig (30-112 kg) (kgN/place/year)[3]	5.5	NA	NA	NA	NA	NA	NA	NA	NA
N retention (kgN/place/year)[2]	3.8	6.4	-68	6.9	11.2	-62	4.1	6.9	-68
N retention - weaned piglets (8-30 kg) (kgN/place/year)	1.7	NA	NA	NA	NA	NA	NA	NA	NA
N retention - growing-finishing pig (30-112 kg) (kgN/place/year)	12.2	NA	NA	NA	NA	NA	NA	NA	NA
N excretion coefficient (kgN/place/year)[9]	7.7	12.4	-62	24.6	37.5	-53	9.6	15.5	-61
Herd size of animals (HERD) (1 000 places)[4]	10 150	9 656	5	1 336	1 352	-1	11 486	11 008	4
Production days for a living animal (DAYS)[5]	136.7	136.7	0	365.0	365.0	0	NA	NA	NA
Number of animals (LEVL) (1 000 heads)	27 101	25 783	5	1 336	1 352	-1	28 437	27 135	5
N excretion (Gg/year)	77.7	119.6	-54	32.9	50.7	-54	110.5	170.4	-54

1) The value for FR was calculated as N intake (kg N/place/year) / feed intake (kg/head) / fattening period (=365/production day of CAPRI)
2) The values for FR were calculated as the weighted average of weaned piglets (8-30 kg) and growing-finishing pigs (30-112 kg).
3) CAPRI production days were used to convert country N retention from head to place.
4) FR value is the average number of animals in the Eurostat database (1 000 heads).
5) CAPRI production days data were used for FR value.
6) Pork meat data of the country for SOWS was calculated by dividing the number of slaughtered animals by the number of sows.
7) Slaughtered animals of PIGF data for the country was calculated by multiplying number of animals and pork meat.
8) Standard feeding data in CORPEN 2003 is used for the country.
9) This value is expected to be equal to N intake – N retention. But there is an error in the CAPRI model.
CORPEN: Comité d'Orientation pour der Pratiques agricoles respectueses de L'Environnement
Note: CAPRI data was extracted in May 2014. CAPRI values might be different from the values in the main text because of the different extraction dates. NR: Not reported, NA: Not applicable.

ANNEX 8 Comparison of animal N-budgets for fattening pigs in the CAPRI AND FR-nat data

Animal Budget Components	PIGF: Fattening pigs					
	FR (CORPEN 2003)		**CAPRI**	**% Difference**		
	2-phase feeding	**Standard feeding**		**2-phase feeding - CAPRI**	**Standard feeding - CAPRI**	**Average**
N contents of pig diet - weaned piglets (8-30 kg) (g/kg feeds)[1]	29.2	30.8	NA	NA	NA	NA
N contents of pig diet - growing-finishing pig (30-112 kg) (g/kg feeds)[1]	24.9	28.2	NA	NA	NA	NA
N contents of pig diet (g/kg feeds)[1]	25.4	28.5	22.9	10	20	15
Feed intake - weaned piglets (8-30 kg) (kg/head)	38.0	38.0	NA	NA	NA	NA
Feed intake - growing-finishing pig (30-112 kg) (kg/head)	235.0	235.0	NA	NA	NA	NA
Feed intake (kg/head)[2]	150.3	150.3	399.3	-166	-166	-166
N intake - weaned piglets (8-30 kg) (kgN/place/year)[3]	3.0	3.1	NA	NA	NA	NA
N intake - growing-finishing pig (30-112 kg) (kgN/place/year)[3]	15.6	17.7	NA	NA	NA	NA
N intake (kgN/place/year)[2]	10.2	11.4	24.4	-139	-113	-126
N content (g/kg LW)	18.5	18.5	25.1	-36	-36	-36
Implied live weight (kg LW/place/year)	112.0	112.0	253.2	-126	-126	-126
Pork meat (kg carcass weight / head)	86.6	86.6	89.6	-3	-3	-3
Slaughtered animals (live weight in 1 000 t)[6]	3 010.1	3 010.1	2 960.7	2	2	2

N retention - weaned piglets (8-30 kg) (kgN/place/year)[3]	1.5	1.5	NA	NA	NA	NA
N retention - growing-finishing pig (30-112 kg) (kgN/place/year)[3]	5.5	5.5	NA	NA	NA	NA
N retention (kgN/place/year)[2]	3.8	3.8	6.4	-68	-68	-68
N retention - weaned piglets (8-30 kg) (kgN/place/year)	1.5	1.7	NA	NA	NA	NA
N retention - growing-finishing pig (30-112 kg) (kgN/place/year)	10.1	12.2	NA	NA	NA	NA
N excretion coefficient (kgN/place/year)[7]	6.4	7.7	12.4	-93	-62	-78
Herd size of animals (HERD) (1 000 places)[4]	10 150.0	10 150.0	9 656.1	5	5	5
Production days for a living animal (DAYS)[5]	136.7	136.7	136.7	0	0	0
Number of animals (LEVL) (1 000 heads)	27 101.3	27 101.3	25 782.5	5	5	5
N excretion (Gg/year)	65.1	77.7	119.6	-84	-54	-69

1) The value for FR was calculated as N intake (kg N/place/year) / feed intake (kg/head) / fattening period (=365/production day of CAPRI)
2) The values for FR were calculated as the weighted average of weaned piglets (8-30 kg) and growing-finishing pig (30-112 kg).
3) CAPRI production days were used to convert country N retention from head to place
4) FR value is the average number of animals in Eurostat database (1 000 heads)
5) CAPRI production days data were used for FR value.
6) Slaughtered animals data for the country was calculated by multiplying number of animals and pork meat.
7) This value is expected to be equal to N intake – N retention. But there is an error in the CAPRI model.
CORPEN: Comité d'Orientation pour der Pratiques agricoles respectueses de L'Environnement
Note: CAPRI data was extracted in May 2014. CAPRI values might be different from the values in the main text because of the different extraction dates.
NR: Not reported, NA: Not applicable

Annex 9 Comparison of animal N-budgets for pigs in the CAPRI and IT-nat data

Animal Budget Components	PIGF			SOWS			TOTAL		
	IT[6]	CAPRI	% Difference	IT[6]	CAPRI	% Difference	IT[6]	CAPRI	% Difference
N contents of pig diet (g/kg feeds)	25.5	24.1	5	25.0	22.4	10	25.1	22.8	9
The amount of feed intake (kg/head)[1]	745.1	620.8	17	2 216.0	2 059.7	7	841.3	704.0	16
N intake (kgN/place/year)	30.4	27.7	9	55.4	47.0	15	32.9	29.7	10
N content (g/kg LW)[2]	24.0	25.1	-5	24.0	25.1	-5	24.0	25.1	-5
Implied live weight (kg LW/place/year)	346.0	243.8	30	783.3	372.5	52	390.1	256.9	34
Pork meat (kg carcass weight / head)[3]	NR	118.5	NA	NR	36.2	NA	134.3	112.3	16
Slaughtered animals (live weight in 1 000 t)[4]	NR	1 885.7	NA	NR	35.4	NA	2 005.8	1 921.2	4
N retention (kgN/place/year)	8.3	6.1	26	18.8	9.4	50	9.4	6.4	31
N excretion coefficient (kgN/place/year)	22.1	21.6	2	36.6	37.7	-3	23.6	23.2	1
Herd size of animals (HERD) (1 000 places)[5]	6 717.7	6 712.5	0	752.5	762.1	-1	7 470.2	7 474.6	0
Production days for a living animal (DAYS)	228.1	197.4	13	365.0	365.0	0	NA	NA	NA
Number of animals (LEVL) (1 000 heads)	10 748.3	12 410.4	-15	752.5	762.1	-1	11 500.8	13 172.5	-15
N excretion (Gg/year)[7]	148.4	144.8	2	27.5	28.7	-4	176.0	173.5	1

1) The values for IT were calculated as N intake (kg N/head/year) / N contents of pig diet (kg/kg feed)
2) The value of sows for IT was taken same as the value of PIGF.
3) Pork meat data of the country was calculated by dividing slaughtered animals by number of animals.
4) Slaughtered animals data is from Eurostat database for the country (incl. home slaughterings). 0.78 was used for carcass weight / liveweight ratio of the country (Source: CAPRI).
5) IT value is the average number of animals in Eurostat database (1 000 heads)
6) The source of the country data: Regione Emilia Romagna (2007). Deliberazione dell'assemblea legislativa della regione Emilia-Romagna 16 gennaio 2007, n. 96. Attuazione del decreto del Ministero delle Politiche agricole e forestali 7 aprile 2006. Programma d'azione per le zone vulnerabili ai nitrati da fonte agricola- Criteri e norme tecniche generali. Bollettino Ufficiale Emilia-Romagna.
7) Regione Emilia Romagna (2007) used a live weight at slaughering which is not representative for the Italian pig farming systems. Oenema et al. (2014) therefore corrected the N excretion coefficients from 13.81 to 13.61 kg N/head/year (Oenema *et al* 2014). The resulting total N excretion for PIGF of 146.3 Gg/year is very close to ITcapri.
NR: Not reported, NA: Not applicable
Note: The country uses in GNB calculations 9.3 kg N/place/year for N excretion coefficient of fattening pigs (62.5 Gg N/year). The value used by the country is so lower than CAPRI and the literature.
Note: CAPRI data was extracted in May 2014. CAPRI values might be different from the values in the main text because of the different extraction dates.

Annex 10 N contents (kg N/tonne) from selected crops in the CAPRI and in country datasets

	DE		FR		HU		IT	
	CAPRI	The country	CAPRI	The country	CAPRI	The country	CAPRI	The country
Wheat	20.0	21.1	20.2	19.2	20.0	27.0	21.8	19.9
Maize	16.7	14.5	16.7	15.0	16.7	25.0	16.7	15.0
OCER*	28.3	17.2	28.3	18.6	28.3	20.7	28.3	18.1
Olives	NA	NA	4.5	0.1	NA	NA	4.8	43.3
Fruits	1.4	1.3	2.3	1.5	1.8	4.0	2.1	6.6
GRAS**	17.5	17.6	17.2	27.8	15.2	18.5	17.6	25.0
OFAR***	16.9	NA	16.7	29.7	14.7	20.8	17.0	10.3
Leguminous plants	NA	26.0****	NA	39.0	NA	27.0	NA	27.0
Temporary grassland	NA	NA	NA	27.8	NA	18.0	NA	NA

NA: Not applicable; CAPRI data was extracted in May 2013; NAT data was reported in the beginning of RegNiBal.
* Other cereals except for wheat, maize, barley, rice, rye, meslin and oats
** Permanent grassland
*** Other annual green fodder, clover and mixtures, lucerne, other perennial green fodder usually legumes and temporary grassland
**** For the clover and mixtures

Annex 11. Mineral fertiliser data in different Eurostat databases (tonnes)

	Eurostat use of inorganic fertilisers database			Eurostat GNB Database: Consumption of mineral fertilisers		
GEO/TIME	2003	2004	2005	2003	2004	2005
France*	2 237 000	2 396 000	2 346 500	2 278 707	2 330 844	2 324 000
Italy*	751 500	684 500	621 500	796 000	751 700	684 576

* Extracted on 21.10.2013

Annex 12 Summary, results & achievements of the RegNiBaL project

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
1	Germany	N-fixation in permanent grassland	Lower N fixation for clover, and lower clover share in CAPRI than in national data	Invest in revising CAPRI methodology	CAPRI has a new method implemented for N-fixation by using country-specific rates on the basis of LegumeFutures project (Helming et al., 2014)	Further effort for defining the legume share in the GRAS	The difference in N-fixation in permanent grassland between the CAPRI and the national data decreased after the CAPRI methodology was updated. However, in order to solve the issue, the legume share in the GRAS must be defined.	NS
2	Germany	N-fixation from free-living organisms	(i) Free-living organisms not considered in CAPRI. (ii) N-fixation from free-living organisms is included in the country GNB although new and better evidence for crops under national conditions are not available.	Update national data	Country decided to exclude N fixation from free-living organisms.	-	The issue was "resolved".	S
3	Germany	N from atmospheric deposition	(i) CAPRI doesn't include N from atmospheric dry deposition in GNB calculations. (ii) High N from atmospheric dry deposition in national data compared to EMEP; atmospheric export of N different from EMEP estimates	Update CAPRI and check national data	The country started to use an updated national study.	(i) CAPRI needs to update data. (ii) Germany should check the model with regard to atmospheric transport (export) of N.	The difference in total atmospheric deposition between CAPRI-updated and DEnat-updated is now small. The issue can be considered "resolved".	S
4	Germany	N excretion by swine	Higher N-excretion coefficient of fattening pigs in CAPRI than in national data	A comparison of the animal budget for fattening pigs and sows in the CAPRI	-	Further analysis to understand the reason for the higher feed intake in the	The issue can be considered "unresolved" as further analysis is needed to understand the reason	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
				and national data		CAPRI data	for the higher feed intake in the CAPRI data.	
5	Germany	N removal by OFAR	Germany reports the amount of N from the clover and mixtures, lucerne, and temporary grassland in the section on “permanent meadows/grasses: consumption”.	Update Germany’s reporting for this crop group	-	Germany needs to update its reporting for this group. This won't affect the GNB calculations.	The issue was due to inconsistent data grouping and can be considered "resolved". However, Germany needs to update its reporting of this group.	S
6	Germany	N removal by other cereals other than wheat and barley	Higher N content for other cereals (OCER aggregate) in CAPRI than in national data	Update CAPRI	-	Assessment of feasibility of country-specific N content in CAPRI	CAPRI update is pending.	S
7	France	N input from organic fertilisers, seed and planting	N input from organic fertilisers, seed and planting not included in national data	Include the data	The country included the data.	-	The issue was "resolved".	S
8	France	N removal by other cereals	Lower amount of production of other cereals in national data than in CAPRI	Check the data	The amount of production of other cereals was updated by the country.	-	The issue was "resolved".	S
9	France	Biological fixation	Higher N fixation in CAPRI than in national data	Check the data	The biological fixation coefficients were updated in the latest French National Working Group	-	The issue was "resolved".	S
10	France	N excretion by swine	Lower N swine excretion coefficients in national data than in CAPRI	A comparison of the animal budgets for fattening pigs and sows in the CAPRI	-	Further analysis to understand the reason for the higher feed intake and	The issue can be considered "unresolved" as further analysis is needed to understand the reason	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
				and national data		higher implied live weight	for the higher feed intake and higher implied live weight in the CAPRI model.	
11	France	N excretion by sheep and goats	Lower N-excretion coefficients in CAPRI than in national data	Make an in-depth assessment of the animal N-budgets for sheep & goats	-	A comparison of the animal budgets for sheep & goats	The issue is "open" as no detailed data is available for the country's animal N-budgets for sheep & goats.	NS
12	France	N from atmospheric deposition	(i) The CAPRI data doesn't include N from atmospheric dry deposition in GNB calculations. (ii) Higher N from atmospheric wet deposition in CAPRI than national updated data & EMEP data	CAPRI update	The country updated the atmospheric N deposition.	CAPRI update	CAPRI update is pending. The issue was "resolved". However, we recommend that the country use the updated CAPRI method (see section 4.1 of the text)	S
13	France	N removal by OFAR	(i) Higher N contents for the crops in the OFAR group in national data in CAPRI, (ii) Lower OFAR production data in national data than in CAPRI and in Eurostat database	(i) France should check the N contents for the crops in the OFAR group (ii) France should ensure data consistency with the Eurostat database	-	France update	The country mentioned that they updated the present N contents very recently, so to update them again would be difficult for the country. Therefore this part of the issue is "closed" but not "resolved".	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
14	France	N removal by GRAS	Lower N content for GRAS in CAPRI than in the country data	The CAPRI GRAS-N content values should be checked	-	(i) CAPRI evaluation of the GRAS-N content update by using a combination of literature (Velthof *et al* 2007, Pointereau *et al* 2007) and country estimations. (ii) The evaluation of results from the GRASSDATE project (Velthof et al., 2014) in national data and the CAPRI	The issue is "open".	NS
15	Hungary	N excretion by swine	(i) Higher N-excretion coefficients for swine in CAPRI than in the national & literature data. (ii) Lower number of swine in national than CAPRI data	A comparison of the animal budgets for fattening pigs and sows in the CAPRI and national data	Hungary updated N-excretion coefficients and the number of swine for each groups	(i) A comparison of the animal budgets for swine (ii) The evaluation of the country to use the CAPRI methodology for the herd size for fattening pigs	The issue is "open" as no detailed data is available for the country's animal N-budgets. (ii) The difference in swine numbers between national and CAPRI data is higher than before, so that the issue is 'open'.	NS
16	Hungary	N from mineral fertiliser	Higher N from mineral fertiliser in CAPRI than in national data	CAPRI update	-	Further investigation	The issue is 'open'. There is the need to check the national and CAPRI data against the information from EFMA.	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
17	Hungary	N removal by GRAS	(i) Higher area and yield of permanent grassland in CAPRI than in national data	(i) CAPRI re-evaluates the GRAS yield for Hungary (ii) Hungary permanent grassland area in Eurostat database should be revised for the related years	-	(i) CAPRI evaluation of the GRAS yield for Hungary (ii) Hungary update of permanent grassland area in Eurostat database	The issue can be considered "unresolved".	NS
18	Hungary	N removal by maize and wheat	Higher N contents of maize and wheat in national than in CAPRI data	Hungary should report the N content of crops and crop residues separately.	The country updated the N contents.	-	The country agreed with the recommendation, and updated N contents. The issue can be considered "resolved".	S
19	Italy	N from mineral fertiliser	Lower mineral fertiliser data in CAPRI than in national data & the FAO database	(i) Italy clarifies the values to be used and the reason for different data in different databases. (ii) Difference between CAPRI and database should be checked.	-	The data of CAPRI and Italy need to be checked.	The issue is "unresolved".	NS
20	Italy	N excretion by swine	Higher CAPRI N-excretion coefficient for fattening pigs than in national data and the literature values	A comparison of the animal budgets for fattening pigs and sows in the CAPRI and national data	-	Further investigation	The ITcapri N-excretion coefficient for fattening pigs is higher than in ITnat, FRnat and DEnat, and some literature values. However, the literature data of the animal N-budgets for swine, including the N excretion coefficient for fattening pigs for IT, are	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
							similar to ITcapri. Further analysis of the detailed animal budget is required to assess the differences in the N-excretion coefficients between ITnat and ITcapri. The issue is "open".	
21	Italy	N excretion by other cattle	Lower N-excretion coefficient in national than in CAPRI & literature data	A comparison of the animal budgets for fattening pigs and sows in the CAPRI and national data	-	A comparison of the animal budgets for other cattle	The issue is "open" as no detailed data is available for the country's animal N-budgets.	NS
22	Italy	N fixation by OFAR	Lower N fixation by OFAR in CAPRI than in national & literature data	Invest in revising CAPRI methodology	CAPRI has implemented a new method for N-fixation by using country-specific rates on the basis of LegumeFutures project (Helming et al., 2014)	NITF value for OFAR of CAPRI needs to be checked.	The issue is "unresolved" as the difference in the symbiotic N fixation by OFAR of the new CAPRI method and the country is still big.	NS
23	Italy	N fixation from free-living organisms	(i) Free-living organisms not considered in CAPRI. (ii) N-fixation from free-living organisms is included in the country GNB, although new and better evidence for crop under national conditions are not available.	Update national data	-	Italy needs to update data.	The issue can be considered "resolved" after country update.	S
24	Italy	Biological N fixation from grass-legume mixtures	The biological N fixation from grass–legume mixtures is not considered in national data.	Italy should include the biological N fixation from grass–legume mixtures in the GNB	-	Italy needs to update data.	The issue is "unresolved".	NS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
				calculations.				
25	Italy	N removal by GRAS	High absolute difference in N from GRAS between national and CAPRI data, mostly resulting from the difference in GRAS yield	GRAS yield should be checked for both Italy and CAPRI	-	GRAS yield should be checked for both Italy and CAPRI	The issue is "unresolved".	NS
26	Italy	N removal by olives and fruit	Higher N contents of olives and fruit in national than CAPRI, literature, and other countries' data	(i) Italy justifies or revises N contents of olives and fruit (ii) CAPRI checks the values for olives and evaluates the possibility to use country-specific N-content values for aggregates.	-	CAPRI and Italy needs to check data.	The issue is "unresolved".	NS
27	Italy	N output	The components of temporary grassland and crop residues from field is not considered in national data.	Italy should include the components of temporary grassland and crop residues from fields in the GNB calculations.	-	Italy needs to update data.	The issue is "unresolved".	NS
28	FR, HU, IT	Some GNB data	The following GNB data reported by the countries are different from the data of these countries in Eurostat databases: N excretion by swine for FR, data on permanent grassland area for HU, IT and FR.	It is recommended to ensure full convergence between the country data used in GNB calculations and the data in Eurostat databases.	N excretion by swine for FR became convenient.	Countries' evaluation	The issue is "partially resolved".	PS

Nr	Country/ CAPRI/ Eurostat	Flow	Initial finding summary	Recommendation	Implemented changes since start of RegNiBal (CAPRI or country)	Next action	Conclusion	S PS NS*
29	CAPRI	N input	The components of N from organic fertilisers (excl. manure), seed & planting materials, manure withdrawal, stocks, and import estimations are not considered in the CAPRI model.	CAPRI should include N from organic fertilisers (excl. manure), seed & planting materials, manure withdrawal, stocks, and import estimations into the GNB calculations.	-	CAPRI evaluation	The issue is “unresolved".	NS
30	CAPRI	N excretion by fattening pigs	The N-excretion data stored in CAPRI (MANN) for fattening pigs is higher than would be expected {= N intake (sum(FEEDS*CRPR(FEEDS))/6) - N retention (CRPR_EXPT)}.	CAPRI should correct this error.	CAPRI corrected.	-	The issue is "resolved".	S
31	CAPRI	N from atmospheric deposition	N from dry atmospheric deposition was not included in CAPRI.	CAPRI should update deposition flows including both wet and dry deposition.	CAPRI initiated the update.	CAPRI update	The issue is "resolved".	S

*S: Solved, PS: Partially solved, NS: Not solved

Annex 13 Data needs and data sources for regionalisation of Gross Nitrogen Balances of EU Member States

	Inputs & Outputs in N Balance	Data needed by NUTS 2 level	Data source	Explanations
Inputs	1) Mineral fertiliser	The amount of mineral fertiliser	Use of inorganic fertilisers (aei_fm_usefert) from Eurostat database	The data on inorganic fertiliser use in agriculture are reported by countries at NUTS 0 level. In some cases, data have also been provided at NUTS 2 level.
	2) Manure production	Number of animals	(i) Animal populations (December) by NUTS 2 regions (agr_r_animal) from the Eurostat database; (ii) The data of the surveys of other periods from country delivery	
		N-excretion coefficients	Country delivery by NUTS 2 regions	
	3) Manure trade, withdrawal, and treatment	The amount of N from manure trade, withdrawal, and treatment	Country delivery by NUTS 2 regions	(i) Data on manure exports and imports are required if significant (net imports or net exports >=5% of manure nutrient production). (ii) Data on manure treatment and non-agricultural use are optional.
	4) Other organic fertilisers	The amount of organic fertilisers	Country delivery by NUTS 2 regions	
		N content of organic fertilisers	Country delivery by NUTS 2 regions	
	5) Biological N fixation	The area of leguminous crops	Areas harvested, yields, production by NUTS 2 regions (agr_r_crops) from the Eurostat database	* The fixation coefficient of grass/legume mixtures by NUTS 2 regions can be provided by the countries. If the countries did not have data available, the tool can make the estimations by using the shares (the shares of fixed N in the Nitrogen requirement in aboveground biomass (harvested and crop residues)) taken from the report of the EU research project Biological nitrogen fixation (BNF) in Europe (LegumeFutures).
		The fixation coefficient of leguminous crops	Country delivery by NUTS 2 regions	
		The area of temporary and permanent grassland	Areas harvested, yields, production by NUTS 2 regions (agr_r_crops) from the Eurostat database	
		The fixation coefficient of grass/legume mixtures	Country delivery by NUTS 2 regions OR Tool estimation*	

	Inputs & Outputs in N Balance	Data needed by NUTS 2 level	Data source	Explanations
	6) Atmospheric N deposition	Utilised agricultural area (UAA)	Land use by NUTS 2 regions (agr_r_landuse) from Eurostat database	
		Regional average deposition rate	EMEP database OR Country delivery & Land use by NUTS 2 regions (agr_r_landuse)	National average deposition rate is calculated by dividing total N deposition by total area when using the EMEP database. In other cases, it is calculated by dividing total agricultural deposition of N by UAA.
	7) Seed and planting materials	Cropped areas of crops	Areas harvested, yields, production by NUTS 2 regions (agr_r_crops) from Eurostat database	In case countries do not have data available, Eurostat estimates nutrient seed input by applying Eurostat default values to areas of wheat and potatoes from crop statistics (Areas harvested, yields, production by NUTS 2 regions (agr_r_crops))
		Sowing rates of crops	Country delivery by NUTS 2 regions	
		N content of seed of crops	Country delivery by NUTS 2 regions	
	8) Total inputs = sum (1,2,3,4,5,6,7)			
Outputs	9) Crop production	The amount of crop production of crops	Areas harvested, yields, production by NUTS 2 regions (agr_r_crops) from Eurostat database	
		N content of crops	Country delivery	
	10) Fodder production	The amount of crop production of fodders	Areas harvested, yields, production by NUTS 2 regions (agr_r_crops) from Eurostat database	
		N content of fodders	Country delivery by NUTS 2 regions	
	11) Crop residues removed/burnt	Crop residues removed/burnt of crops	Country delivery by NUTS 2 regions	
		N content of crop residues removed/burnt of crops	Country delivery by NUTS 2 regions	
	12) Total outputs = sum(9,10,11)			
N Surplus	NS = (8) - (12)			

Annex 14 Data on area, yield, and N content of permanent grassland in the CAPRI and in countries' databases

GEO	Area (kha)			Dry Matter (DM) Yield (100 kg/ha)			DM Crop Production (kt)		DM N content (kg N/tonne)		N removal (Gg N/yr)	
	A	B*	CAPRI	A	B*	CAPRI	A	CAPRI	A	CAPRI	A	CAPRI
Germany	NR	4 937	4 955	NR	70.0	74.0	34 541	36 669	17.6	17.5	608	642
France	9 581	10 013	9 494	38.4	38.4	43.7	36 782	41 447	27.8	17.2	1 021	714
Italy	4 350	4 381	3 895	48.8	12.5	26.6	21 238	10 366	25.0	17.6	372**	182
Hungary	503	1 058	949	14.9	8.1	35.2	751	3 339	18.5	15.2	14	51

A: Reported data by the country; B: Eurostat Database
NR: Not reported; CAPRI data is extracted in May 2013; NAT data was reported in the beginning of the RegNiBal project.
Note: The data reported by Italy is a two-year average (2003, 2004).
* http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpp_crop&lang=en. Extracted on 19.09.2013.
**The GRAS consumption calculated as 70% of the production is used in GNB calculation)

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