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Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)

Final Report- GGELS Work Packages 2 to 4
Administrative Arrangement (AA) No. AGRI-2008-0245

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GGELS

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Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)

Administrative Arrangement (AA) No. AGRI-2008-0245

GGELS

Phase 1 Report (final)

GGELS Work Packages 2 to 4

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Executive summary

The study “Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)”, formally started on June 20 2008, seeks to assess such emissions following a food chain approach at sub-national level for the EU27. The assessment at hand is thus of considerable complexity. It has therefore been split up into a large number of activities and sub activities of a varied nature and led by different JRC actions.

This interim report constitutes the third and final deliverable of the study “Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)”, in accordance with the terms of reference of the Administrative Arrangement (AA) No. AGRI-2008-0245. It reports on Work Packages 2, 3 and 4. A report on Work package 1 constituted the project’s first deliverable, which was accepted in October 2008. It is thus not covered in this report.

This report aims to provide DG AGRI, as well as other possible users of the GGELS project results, with a clear though exhaustive insight in the work preformed during GGELS Phase 1 and the intermediate results produced. GGELS being a multi-disciplinary research project spanning across three JRC institutes and 5 actions, this GGELS Phase 1 report is largely a collection of output produced by the different partners. Each of these contributions constitutes a separate section in this report. Some contributions being fairly large, they have been annexed to this report.

The work implemented by the four JRC actions concerned by Phase 1 has achieved, in accordance with the Administrative Arrangement between DG AGRI and the JRC, the objectives of GGELS Phase 1 and complete Work Packages 2 to 4:

- task 2.1: describes the importance of livestock production per species throughout the EU27, from an economic and land use point of view;
- task 2.2: a preliminary livestock production system typology and zoning was established on the basis of CAPRI databases. This product has constituted an important input to subcontracted work aiming to obtain production system specific information on manure management practices, which will constitute an important element completing the regional production system descriptions. Task 2.2 is to be finalized under WP6;
- task 3: an extensive literature review highlighting the negative and positive impact of livestock production on the EU’s biodiversity. It shows that impacts vary substantially among species and production systems;
- task 4.1: important preparative work for the core task of quantifying all EU livestock sector emissions (WP 7, GGELS Phase 2) has been performed. Nearly all details (parameters, equations, tables) needed under WP 7 have been selected and retrieved;
- task 4.2: emission levels of various greenhouse gases as induced by the production of three selected meat products constituting major EU animal product import flows have been determined in a detailed and transparent manner. They vary strongly in emission intensity, with Brazilian beef having by far the highest level of about 80 kg CO_2 eq. per kg, due mainly to induced land use change and enteric fermentation.

While the various elements presented constitute worthwhile information in their own right, the interim nature of this report means that the final objective – namely, the localisation, production system modelling, gas specific impact assessment, and the preliminary evaluation of selected remedial policies – is still under way. Nevertheless, the results presented here are required steps on the path to achieving the final objective, and demonstrate that the project is on track towards achieving this goal, which will further leverage the information presented here.

Acronyms

AA	Administrative Arrangement
AFOLU	Agriculture, Forestry and Land Use action of the Climate Change unit, Institute of environment and sustainability, JRC
AGRI-ENV	Agriculture and Environment action of the Rural, Water and Ecosystem Resources unit, Institute of environment and sustainability, JRC
AGRITRADE	Support to Agricultural Trade and Market Policies action of the Agriculture and Life Sciences in the Economy unit, Institute for Prospective Technological Studies, JRC
CAPRI	Common Agricultural Policy Regionalized Impact model
COPA-COGECA	Union of European farmers and agri-cooperatives
EAA	Economic Accounts on Agriculture: Eurostat database
EDGAR	Emission Database for Global Atmospheric Research
EU	European Union, 27 member states
EU-15	The 15 MS that integrated the EU up to 2004.
EU-10	The MS which accessed the EU in 2004. EU-12 includes those MS and Bulagria and Romania
FADN	Farm Accountancy Data Network
GeoCAP	Geo-information for the Common Agricultural Policy action of the Agriculture unit, Institute for the Protection and Security of the Citizen, JRC
GGELS	Project acronym "Greenhouse Gas from the European Livestock Sector" of the JRC project "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions"
GHG	Greenhouse Gas
ICPA	Integrated Climate Policy Assessment action of the Climate Change unit, Institute of environment and sustainability, JRC
IE	Institut de l'Élevage: French livestock board
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center
LPS	European Livestock Production System
NUTS	Nomenclature of Territorial Units for Statistics; harmonized EU administrative region denomination
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

This interim report constitutes the third and final deliverable of the study "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)", in accordance with the terms of reference of the Administrative Arrangement (AA) No. AGRI-2008-0245. It reports on Work Packages 2, 3 and 4. A report on Work package 1, covering the methodological approach for the study, was accepted in October 2008 and it has not been included in this final report.
This report aims to provide DG AGRI, as well as other possible clients of the GGELS project results, with a clear though exhaustive insight in the work preformed during GGELS Phase 1 and the intermediate results produced. GGELS being a multi-disciplinary research project spanning across three JRC institutes and 5 actions, this GGELS Phase 1 report is largely a collection of output produced by the different partners (GGELS Phase 1: JRC actions GeoCAP, AFOLU, ICPA and Agri-Env). Each of these contributions constitutes a separate section in this report, with the main contributors identified at the start of each section. Some contributions being fairly large, they have been annexed to this report, including only a summary in the report itself. The sections follow the order of the Phase 1 tasks as they were set out in the Administrative Arrangement.

2. WP 2: Typology and characterisation of the EU livestock sector

2.1. Task 2.3: initial overview of the EU livestock sector

Lead: T. Wassenaar, GeoCAP
Status: completed
This task has constituted the object of a separate deliverable, completed and submitted in December 2008 and annexed to this report (Annex 1). The main results are copied here from the report's summary:
The task 2.3 report aims to provide insight into the European livestock sector, describing its importance from various perspectives at EU and Member state level.
From an economic perspective, livestock production accounted for 41% of agricultural output in value terms in 2007, representing 1.2% of the European Union's GDP. Highest GDP shares are found in EU-10 Member states (with Bulgaria, 4,4%, and Romania, 3,8%, standing out), while lowest shares are found in Luxemburg (0,5%), United Kingdom (0,6%) and Sweden (0,7%). At EU level the spread over the different output categories is important, illustrating the diversified nature of the EU livestock sector. The dairy sector comes out as a relative heavyweight in economic terms.
From a production perspective the EU is the world's largest dairy producer and the world's second largest producer of beef after the United States. But pork accounts for 45 percent of the meat consumed in the EU, followed by poultry, at 25 percent, and beef/veal at 19 percent.
Very important differences in productivity are observed among MS, reflecting differences in production systems. This has implications in terms of the emissions intensity. Production systems still evolve considerably, particularly but not exclusively in the transition economy MS, with a general trend towards intensification as well as concentration.
Production systems of most species remain characterized by an important diversity. Diversity is largest for the complex beef and dairy systems, while for monogastrics the diversity mainly regards the structure and size of farms.
This task also assesses the land dedicated to the production of animal feed for a range of crops. The estimates, resulting from the combination of various databases, will be useful for the validation of

GGELS' subsequent quantification tasks. The resulting picture also constitutes valuable information on the EU livestock sector's "footprint" in its own right. We estimate that about **60% of the EU's utilised agricultural area (UAA) is dedicated to the production of animal feed**, corresponding to about 50% of the EU arable land.
The land used for producing animal feed imported to the EU represents around 10% of the EU's arable land. About 90% of feed imports concerns soya beans.

2.2. Tasks 2.1 and 2.2: Building an EU livestock typology

Lead: D. Grandgirard, GeoCAP *Contributor: T. Wassenaar, GeoCAP*
Status: completed, the work to be performed under the follow-up WP6 has been prepared
Reasons for building a European Livestock Production System (LPS) typology have been detailed in the first deliverable, the interim report covering the methodological approach. This report also extensively explains the choice of the CAPRI model as the central platform of the project. While highlighting the interest of this model's underlying database for the typology work, it also underlines several shortcomings.
The "complete and consistent" (Coco) NUTS2 level CAPRI database has been used to obtain a first approximation of an **EU livestock system typology and zoning**. This has allowed to test the statistical approach while, more importantly, it has allowed stratifying an **EU wide questionnaire on manure management practices**. A separate report has been produced on this NUTS2 level LPS zoning for submission to the manure study contractor. This detailed report constitutes the main output under tasks 2.1 and 2.2 and as such has been annexed to this Phase 1 report (Annex 2).
It is important to recall that the livestock typology work exceeds WP2. Work is still ongoing and will continue, as foreseen, under WP6 of Phase 2. As such Annex 2 does not exactly represent the current state of progress on this task. As also explained in the first interim report, it is important for the project's objectives that the typology considers separately the following broad dimensions:

1. **feeding strategy** and the related upstream inputs used;
2. **livestock production characteristics**, with farm type and herd composition sub dimensions;
3. **output** characteristics, covering products, productivity and by-products;
4. **other dimensions** related mainly to biodiversity and (pedo-)climate.

Dimensions 1 and 2 have been fully covered by the work carried out in the 1st work phase (see Annex 1), whereas dimensions 3 and 4 are partly covered. An important omission so far is the manure management, which is key to the project's objectives. The outsourced **manure management study** is still running, with support from COPA-COGECA. Questionnaires have been sent to experts in February 2009 and results will be available at the start of GGELS Phase 2. Under dimension 4 so far only climate has been considered. Work on biodiversity indicators is ongoing.
Important **recent achievements on the path towards establishing a sound EU wide livestock typology** that allows a differentiated estimation of GHG emissions are:

- The detailed definition of the **methodology** for establishing the final typology, in collaboration with the French livestock board, the "Institut de l'Élevage" (IE). Building on the preliminary zoning work (Annex 2), the former will, through comparison with the CAPRI-based zoning, serve to validate certain dimensions of the Coco database (or identify the need for further verification or even update), while the resulting typology will replace the current preliminary version;
- The **gathering and analysis of datasets** needed to perform this analysis. A very extensive data set has been extracted from the FADN database by the responsible services of DG

Agriculture and prepared for the analysis by the project team. While manure management information is currently being collected, data sets covering information not provided by the FADN data have already been collected. A noticeable example is data on live animal movements extracted from the DG SANCO managed TRACE database.

Discussions between the JRC and the IE have resulted in a **hybrid expert-statistical approach**. Within the different dimensions, expert-based thresholds will be set on variables of interest in order to differentiate the LPS, each of which will be statistically validated. The order of considering variables/dimensions in the (statistical) analysis will be the order of decreasing impact on GHG emissions. Tools and data needed to perform this work are now available.
In addition to the manure management information, the **pasture yield** is another important element that needs to be further considered in the next work phase. The feasibility of spatially distributed modelling of pasture growth is currently being studied. Alternatively a statistics-based approach will be followed.

3. WP3: Overview of the impact of the livestock sector on EU biodiversity

Lead: K. Biala, Agri-Env
Status: completed; this chapter might need revision and shortening when drafting the final study report at the end of the next work phase to ensure consistency.

3.1. Introduction

This report provides an overview of livestock sector activities for the conservation and loss of biodiversity in order to view emissions in a broader frame and help to gain a better understanding about the potential synergies and trade-offs between different policy objectives, such as climate and biodiversity protection.
The contents of the report are based on an extensive research of reports from European or national research projects evaluating links between livestock and biodiversity, models, field studies and literature reviews on aspects of pressures as well as benefits for biodiversity originating from livestock production systems. To date, however, a more comprehensive review of those complex relationships for European agriculture has been lacking.

3.2. Agriculture as a driving force of biodiversity changes in Europe

Europe has a great variety of landscapes resulting from the interaction of human activities with different biophysical conditions. Along centuries, agriculture has created a profound influence in the shaping and management of these landscapes (Baldock and al., 1995; Vos & Meekes, 1999). Traditional land use systems, including livestock production and mixed farming systems, have contributed positively to the preservation of biodiversity, providing the suitable conditions in the landscape to host a wide spectrum of flora and fauna species (Bignal and McCracken, 1996). Plieninger et al. (2006) point out that traditional land use in Europe, instead of damaging biodiversity, has, in fact, fostered habitat and species richness and created rural landscapes with a high nature conservation value. Semi-natural habitats in farmland are European biodiversity hotspots. This is in contrast with the situation in most of the other parts of the world (Hampicke, 2006), where conservation aims at restoring conditions prior to anthropogenic impacts. For example, at European scale, agricultural habitats have the highest overall bird species richness among all other habitats (Tucker, 1997) and more than half of European butterfly species live in traditionally managed grassland habitats (Ouin and Burel, 2002; van Swaay and Warren, 2003). Links with livestock raising and, in particular, grazing or mowing, is crucial for the overwhelming majority of those areas (Baldock et al., 1995) and for the conservation of High Nature Value farmland.

Concerns over negative impacts of farming on biodiversity are a result of unprecedented rapid agricultural intensification over the past 60 years (Benton et al., 2003), which has caused widespread farmland biodiversity decline and affected other plant and animal communities. Intensification and specialisation also bring about landscape changes, resulting in its homogenisation and destruction of traditional landscape elements and, consequently, loss of habitats. Marginal areas, on the other hand, are threatened with cessation of agricultural practices and land abandonment. All these factors of agricultural polarisation lead, directly or indirectly, to loss of genetic, species and community biodiversity

Intensification and specialization of the livestock production has undoubtedly been an important driver of biodiversity decline, in contrast to biodiversity conservation in traditional, extensive land use. Those impacts occur predominantly via effects (direct and indirect) on land use (changes) and nutrient element cycling (Oenema et al. 2007). However, evaluating livestock sector impacts on biodiversity is not a straightforward task. To date, literature search through various search engines has not yielded any reviews that would provide this kind of assessment for Europe. The challenge for such an assessment is linked to the complexity of the interrelationships between biodiversity, environment and agriculture, as explained by Firbank et al. (2008):

The biophysical processes relating agriculture and biodiversity are so numerous and interacting that it is difficult to ascribe a particular biodiversity response to an individual agricultural cause. Rather, most biodiversity changes are responses to a suite of agricultural changes that can be regarded together as agricultural intensification on the one hand, or habitat restoration or abandonment on the other.

Bearing in mind the complexity of the issue the following chapters will aim at providing comprehensive analysis of the livestock impacts on biodiversity, taking as a point of departure the intensity levels of European agriculture and then identifying evidence of causal links with animal production based on extensive research of the currently available source materials.

3.2.1. Major livestock categories and intensity of production systems

Livestock in EU-27 is dominated by cattle (both dairy and beef), pigs and poultry (Oenema et al., 2007; GGELS 2nd Interim Report). Small ruminants – sheep and goats are particularly important in the Mediterranean Member States (incl. Portugal), as well as in Bulgaria, Romania, Hungary, Czech Republic and the UK (sheep).

Pigs and poultry are generally associated with intensive, indoor methods of production, where environmental impacts are in the main negative. Outdoor, free-range husbandry of pigs and poultry is marginal, although the latter has been on the increase recently. The information about this kind of pig and poultry raising on biodiversity is very scarce and anecdotal only.

Dairy farming systems show high diversity throughout Europe. However, most of the dairy production is the high input/output systems (83% of total EU dairy cow numbers and 85% of total EU milk production) whereas low input/output systems account for 6-8% of total EU dairy cow numbers and 4-5% of total EU milk production (GGELS, 2008). Modern dairy systems are largely dependent upon intensively managed grassland where the structure and composition of the sward is very limited (Adas, 2007). Dairy units are typically fed silage rather than hay. Grassland grown for silage is typically highly fertilised and reseeded low in biodiversity. Cutting for silage – earlier and more frequent than for hay – is a restrictive factor for plants to flower and set seed (Noesberger et al., 1998; Adas, 2007) and those grasslands often do not provide adequate source of food and shelter for beneficial arthropods and vertebrate fauna.

Beef production systems are equally varied in Europe. However, as beef cattle can utilise unimproved pasture, coarse vegetation or wet grassland they may be an important tool in managing such areas (Adas, 2007).
Sheep and goat production vary in intensity between the Mediterranean zone (more intensive) and other areas in Europe. Sheep grazing is considered vital for maintaining many biodiversity-rich habitats.
The overview of the importance of livestock grazing for biodiversity conservation is presented in section 3.6.

3.3. Effects of emissions from livestock production systems on biodiversity

Emissions from livestock production systems and nutrient loading contribute to terrestrial and aquatic habitat pollution. The in-depth analysis of those emissions is provided in other parts of the GGELS study. However, in view of the complex relationships between biodiversity and farming practices mentioned before, it is necessary to provide here a brief description of agricultural emissions in order to evaluate the magnitude of the problem with regard to livestock.
The major impacts are caused by housing of livestock and, in grazing systems, by high stocking densities of grazing ruminants leading to the excess of nitrogen in the system (Milne 2005). The surplus N may accumulate in soils, or be lost to air, groundwater or surface water (Eickhout et al, 2006). Nitrogen deposition, especially ammonia (NH_3), contributing to acidification and eutrofication of soils and water has been identified as one of key driving forces of biodiversity loss (Eppink et al., 2008; Fraser & Stevens, 2008, Wammelink et al.,). Eutrofication results in depauperation of plant assemblages thorough the increase of a small number of species which become dominant in conditions of increased nutrient availability (Firbank et al. 2008)
Erisman et al. (2008) analysed primary drivers of agricultural emissions between the years 1960 and 2002, corresponding to the period of agricultural intensification in Europe (Fig. 1).

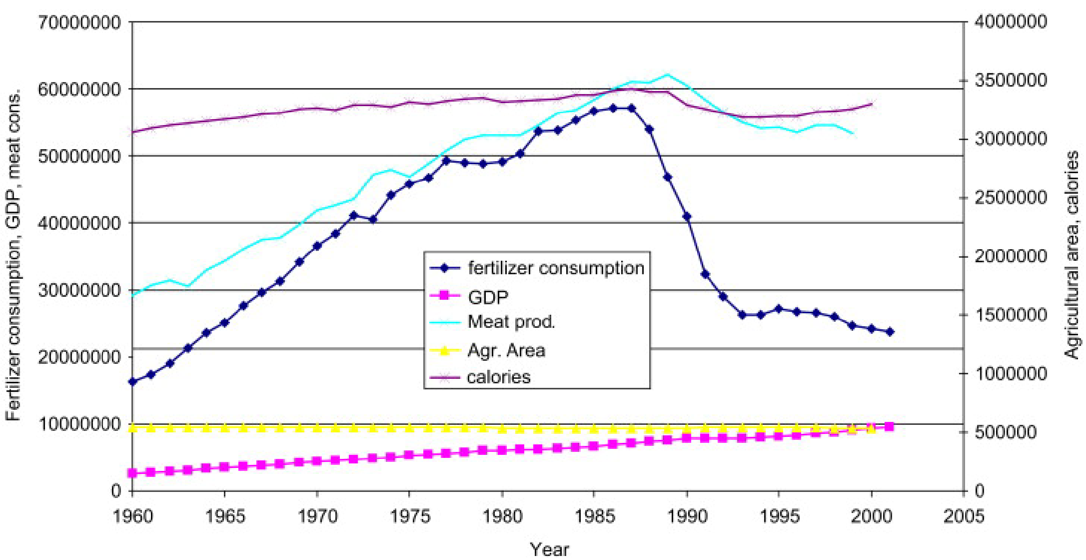

Fig. 1. Changes over time in primary drivers relevant for agricultural emissions in Europe (Source: Erisman et al., 2008)

Gross Domestic Product (GDP) increased gradually during that period. There was a very small extent change in agricultural area and a steady increase in fertilizer use was required to increase the food production. The 40% drop in fertilizer consumption which can be observed from the 1980s was a result of the transformation of centrally planned economies into market economies in Eastern European countries and related to drastic decrease of external inputs. Currently the level of fertilizer use is stable. It is remarkable that meat production decreased very slightly, despite the drop in fertilizer use.

Several literature sources provide estimations of livestock production emissions. Webb et al. (2005) state that around 75% of European NH_3 emissions come from livestock production. There are also some data available at country level, broken down into livestock categories. For instance, in 2000 44% of all UK ammonia emissions came from cattle, including both dairy and beef. Grazing sheep were responsible for ca. 5% of the total UK emissions, pigs 9% and poultry 14% (Adas, 2007). A study by Gac et al. (2007) on gaseous emissions from livestock manure management in France identified cattle as the major contributor, with 70% of the total emissions for CH_4, 88% for N2O and 72% for NH_3. Pig and poultry manure contributed to N_2O and NH_3 emissions in almost the same proportions with 7% and 6% of the total N_2O emissions and 14% and 15% of the total NH_3 emissions, respectively. Despite some differences in figures, related to methods of data collection or models used the results are highly convergent. It is therefore clear that livestock production is an important contributor of GHG emissions in Europe.

With regard to aquatic ecosystems, agriculture impacts both on physical (drainage and modification of river channels and the catchment) and chemical properties (nutrient, particulate and biocide pollution) of freshwater systems. However, it is very difficult to simply and quantitatively relate the component activities of agriculture to their impacts on freshwater systems and even to differentiate them from urbanization or other effects (Moss, 2008). It is even more difficult to identify the magnitude of those impacts for activities associated with livestock production. Lord et al. (2002) attempted to quantify the links between agriculture nitrogen balance and water quality in the UK for various production systems. They identified livestock as a dominant factor determining the national N surplus, 85% of which was within the grassland sector (fertilizer to grass and livestock feed) and the rest was from pig and poultry sectors – approximately 6% and 9%, respectively.

3.3.1. Effects of atmospheric nitrogen pollutants on European vegetation

Reviews by Bobbink et al. (1998) and Krupa (2003) provide a comprehensive analysis of the N pollution (Krupa concentrating on ammonia) on terrestrial and freshwater vegetation in Europe. Those two reviews are the main source of the information below. They have been enhanced by other relevant case studies. It has to be pointed out, however, that not all of those impacts may be attributed solely to livestock production. In case such a relationship is evident it will be clearly identified.

Increased atmospheric nitrogen inputs affect diversity in many semi-natural and natural ecosystems. Its severity depends on the amount and the duration of inputs as well as on bio-physical conditions in a particular ecosystem, such as buffering capacity, soil nutrient status and soil factors influencing the nitrification potential and nitrogen immobilization rate. Therefore, the sensitivity to air-borne nitrogen of plant communities varies significantly. Ammonia (NH_3) is considered to be the foremost factor of vegetation changes and the major sources of NH_3 are agricultural activities and animal feedlot operations, followed by biomass burning (including forest fires) and to a lesser extent fossil fuel combustion.

Most to least sensitive plant species to NH_3 are native vegetation > forests > agricultural crops. In Europe many of the threatened species and biodiversity-rich semi-natural habitats (i.a. grassland and heathlands) depend on the management which mainly consists in removal of nutrients. Ecological modification and successional change by means of N deposition is particularly evident oligotrophic plant communities (= poor in nutrients, including N) as species adapted to N deficiency will be outcompeted by nitrophilous species with higher N demand. This again highlights the importance of maintaining grazing or mowing management for those communities in order to remove excess nutrients.

Direct toxicity of NH_3 emissions from livestock production was observed on forest vegetation. In the former GDR (East Germany) in the vicinity of huge pig farms with up to 20 000 pigs, forest decline (foliar injury) attributable to NH3 was observed over areas of 2000 ha. At distances less than approximately 1 km from the source, the forests were completely destroyed.
Apart from direct foliar injury negative effects of N on higher plants include alterations in: growth and productivity, tissue content of nutrients and toxic elements, lowered drought and frost tolerance, weakened response to insect pests and pathogenic microorganisms, inhibition of development of beneficial root symbiotic or mycorrhizal associations or inter-species competition and species loss.
There are a number of valuable European habitats which have been shown to be seriously threatened by N deposition.

Fresh waters

Fresh waters are among the most sensitive ecosystems with respect to atmospheric acidification. Soft-water lakes (with *Littorelletea uniflorae* plant communities) are characterized by the *presence of rare and endangered plants* (e.g. *Littorella uniflora, Lobelia dortmanna, Isoetes lacustris*) which disappear due to dense plankton blooms or are replaced by common ubiquitous species.

Ombrothrophic (= raised) bogs and wetlands – fens and marshes

Ombrothrophic bogs, which receive all their nutrients from the atmosphere, are particularly sensitive to airborne N loads. Characteristic species include Sphagnum ssp. (bog mosses), sedges and heathers (*Andromeda, Calluna, Erica*) and insectivorous species (e.g. *Drosera*). Absence of those species has been reported from the Netherlands, Denmark and the UK, Germany and Sweden. Fens are alkaline or slightly alkaline wetlands. Although they have an intermediate sensitivity to N enrichment, their most valuable rare species, orchids, are in decrease. For marshes, on the other hand, N deposition is only a minor threat.

Species-rich grassland

Calcareous grassland (Festuco-Brometea)

Petit & Elbersen (2006) using the MIRABEL assessment framework (Petit et al., 2001) showed that the number of calcareous grasslands potentially at risk of eutrophication and grazing is rapidly increasing in Europe.

Acid and neutral-acidic grasslands

The species of acidic grassland are especially sensitive to N deposition. Research on 68 acid grasslands across Great Britain indicated that long-term, chronic N deposition has significantly reduced plant species richness (Stevens et al., 2004). Species richness declines as a linear function of the rate of the rate of inorganic Ncdeposition, with a reduction of one species per 4-m2 quadrat for every 2.5 kg N ha-1 year of chronic N deposition.

Montane-subalpine grasslands

They may be sensitive both to eutrophication and acidification.

Heathlands

The negative impacts have been shown for a wide range of European heathlands, including: dry lowland heathlands, inland wet heathlands, upland Calluna vulgaris moorlands and arctic and alpine (grass) heaths.

Forest ground vegetation

Beside the leaf injury of trees N deposition is a significant threat to the ground vegetation and causes the loss of rare species.

3.4. Livestock production and habitat loss and fragmentation

Agricultural activities resulting in habitat loss and fragmentation are widely recognized as one of the major causes of biodiversity loss. It has to be remembered, however, that in Europe habitat loss,

fragmentation and degradation are also affected by anthropogenic pressures other than agriculture, mainly urban sprawl and soil sealing.
The following effects of habitat fragmentation and loss on plant and animal populations are known (source: Opdam & Wascher, 2004):

- Population decline and extinction,
- Loss of genetic diversity;
- As little as 50% of patches in a sustainable habitat network may yearly be occupied;
- Lower densities due to less effective distribution on individuals over habitat network;
- Effects of large-scale disturbances stronger in more fragmented habitat, causing temporary extinction at the regional level,
- Reduced growth rate causing recovery time from large-scale disturbances to be extended,
- Disruption of biotic interactions, reducing seed setting and rates of parasitism.

Benton et al. (2003) reviewed extensively the empirical literature and showed that habitat heterogeneity is a key to restoring and sustaining biodiversity in temperate agricultural systems. Agricultural intensification resulted in homogenisation of large areas of European rural landscapes. Main mechanisms of this process with special importance for livestock systems included:

- Farmland unit specialization (livestock versus arable) with the loss of mixed farming systems, incompatible with the mainstream intensive practices;
- Consolidation of farm units – larger contiguous areas under common management system;
- Removal of non-cropped areas – loss of semi-natural habitat features, such as ponds, uncropped field margins and scrub;
- Removal of field boundaries – larger fields and hence larger contiguous areas under identical management, as a consequence of maximizing efficiency of agricultural operations where hedgerows and other field boundary structures no longer serve stock-proofing functions.
- Increased duration and intensity of grazing on improved fields – reduced vegetation height and structural heterogeneity.

There are numerous studies which demonstrate that heterogeneity (which also allows for greater habitat connectivity) is associated with diversity for various groups of fauna: birds (Hinsley & Bellamy, 2000, Herzog et al., 2005), butterflies (Collinge et al., 2003) and invertebrates (Duelli et al., 1999).
The benefits of non-cropped habitats and field margins for both flora and fauna are evidenced by Marshall & Moonen (2002). They are crucial for maintaining both stocks and flows of biodiversity.

3.5. Identification of areas under risk of biodiversity loss caused by the EU livestock sector

Identification of areas under risk to biodiversity from livestock sector in Europe is based on the results of EnRisk project (Delbaere & Nieto Serradilla, 2004). EnRisk was coordinated by the ECNC – European Centre for Nature Conservation and aimed to assess where the areas of highest risk for environmental damage from agriculture are in Europe. The risks from agriculture to biodiversity and landscapes were quantified and risk indicators developed. The following data and maps come from the ECNC report of the project (Delbaere & Nieto Serradilla, 2004) and are reproduced with permission.

At the species level, breeding birds were chosen as a representative group for the risk assessment as their preferences for habitat are known better than for other species groups and because birds are a good indicator of broader biodiversity and sustainability. They are high in the food chain, integrating changes at lower levels and occupy a broad range of ecosystems and have varied natural histories. Risk assessment was carried out separately for arable land and livestock systems, where it was based on livestock density. The maps below show which areas in Europe are likely to loose breeding bird species that are associated to selected agro-ecosystems due to selected pressure – livestock density in our case.

3.5.1. European biodiversity risk zones linked to livestock production

Dry grassland (or steppe) in Europe has decreased dramatically in extent and only a few fragments remain. The map of sensitivity of dry grassland (or steppe) for birds (Fig. 2) shows a very patchy pattern with a relatively high number of species with higher sensitivity score. Hotspots of sensitivity are found in northern Spain, southern France, southern Bulgaria and in the Hungarian puszta (Delbaere & Nieto Serradilla, 2004).

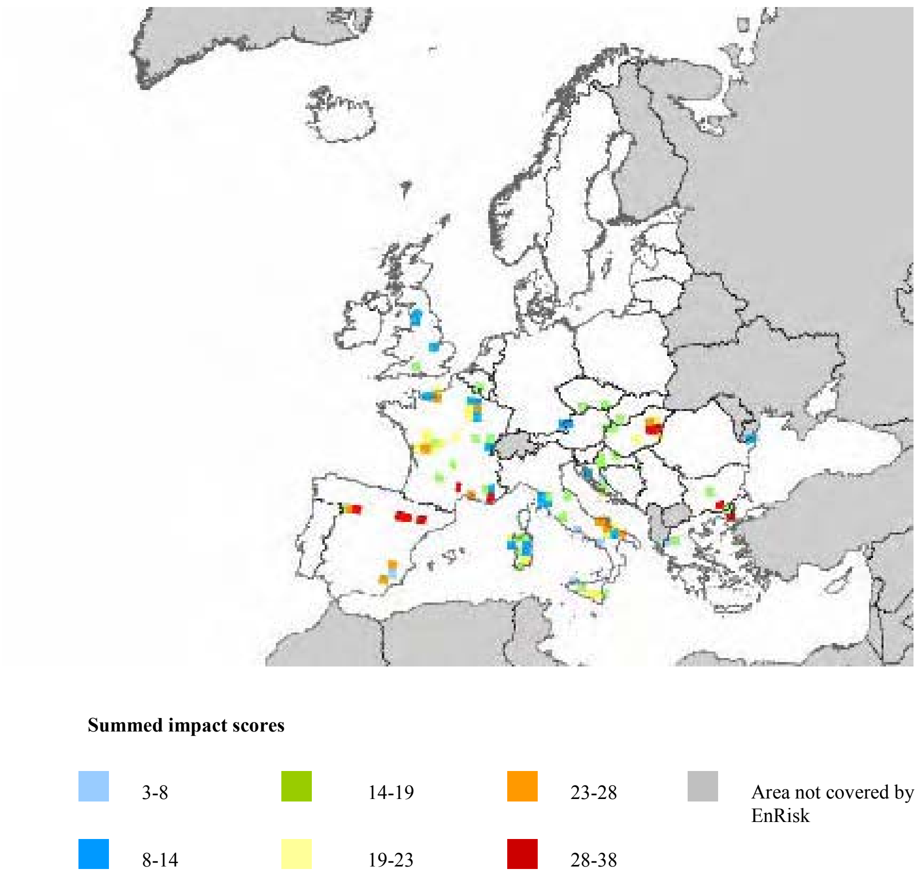

Fig. 2. Summed livestock density impact scores for breeding birds on dry grasslands. Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission

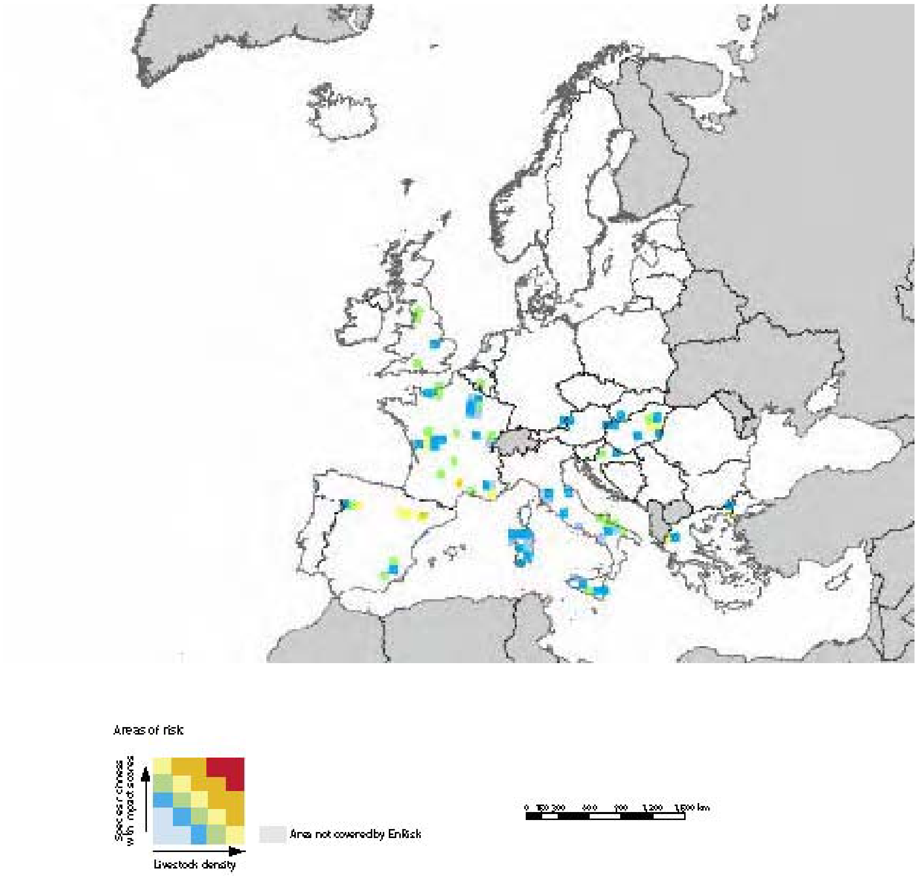

Fig. 3. Risks from livestock density to breeding birds on steppe grassland. Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission.

The risk map for dry grassland birds in relation to eutrophication (Fig. 3) shows no high-risk zones. Areas with highest sensitivity have a medium risk scores, due to relatively low pressure values.

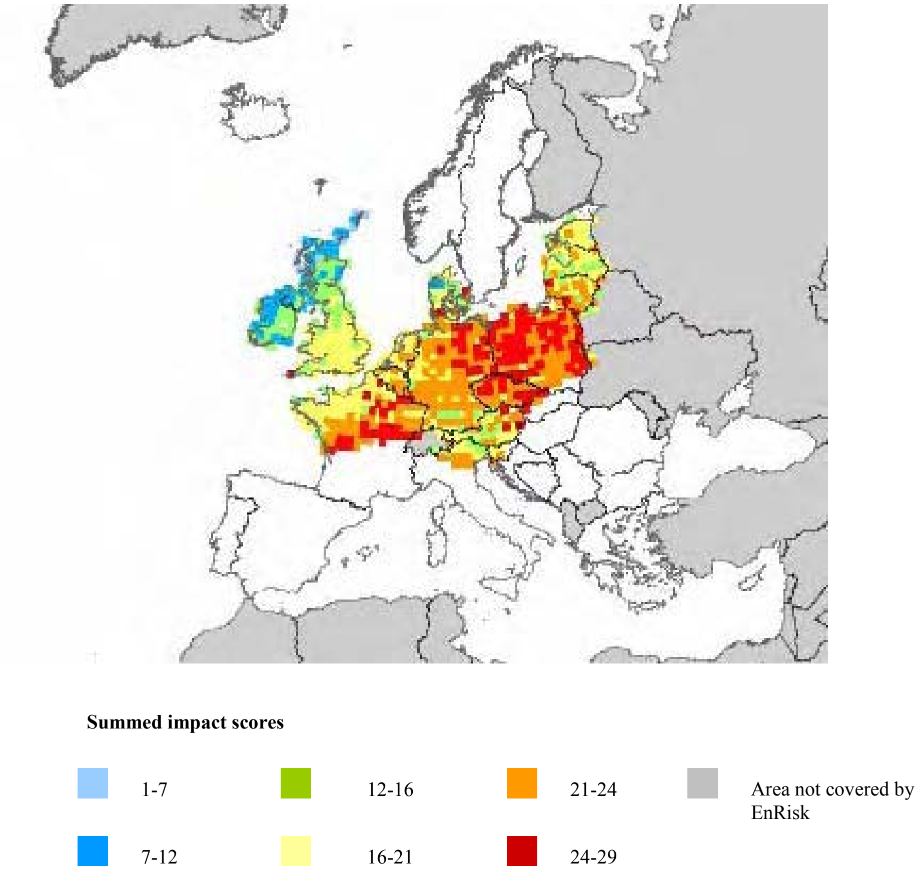

Fig. 4. Summed livestock density impact scores for breeding birds from wet grasslands. Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission.

The map of wet grassland birds sensitivity to nutrient pollution (Fig. 4) presents a clear west-to-east gradient on increasing sensitivity, with most of Poland, the eastern part of Germany and the Lorraine region in northeastern France with the highest threat scores. It is a result of a combination of higher number of species with higher threat scores.

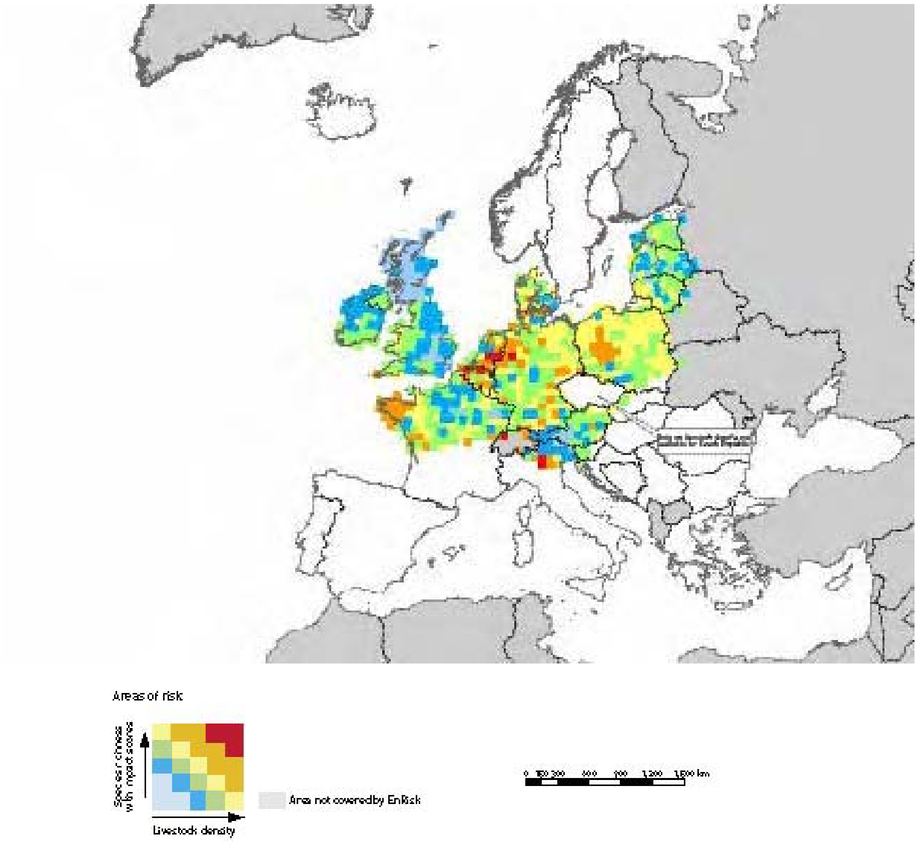

Fig. 5. Risks from livestock density to breeding birds on wet grassland. Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission.

Interestingly, the map representing the risk from eutrophication pressure to wet grassland birds (Fig. 5)shows a completely different pattern. The areas of the highest risk are located in Belgium, the Netherlands, Rheinland Westphalia in northwestern Germany and the northern part of Italy – Lombardy and partly Veneto. The high risks are directly linked to very high pressure levels in these regions.

The areas of lowest risk (combined low sensitivity and low pressure values) are in Scotland, northern part of Ireland, northwestern France, northern Italy (Alto Adige and Friuli Venezia Giulia regions) as well as in the Baltic states.

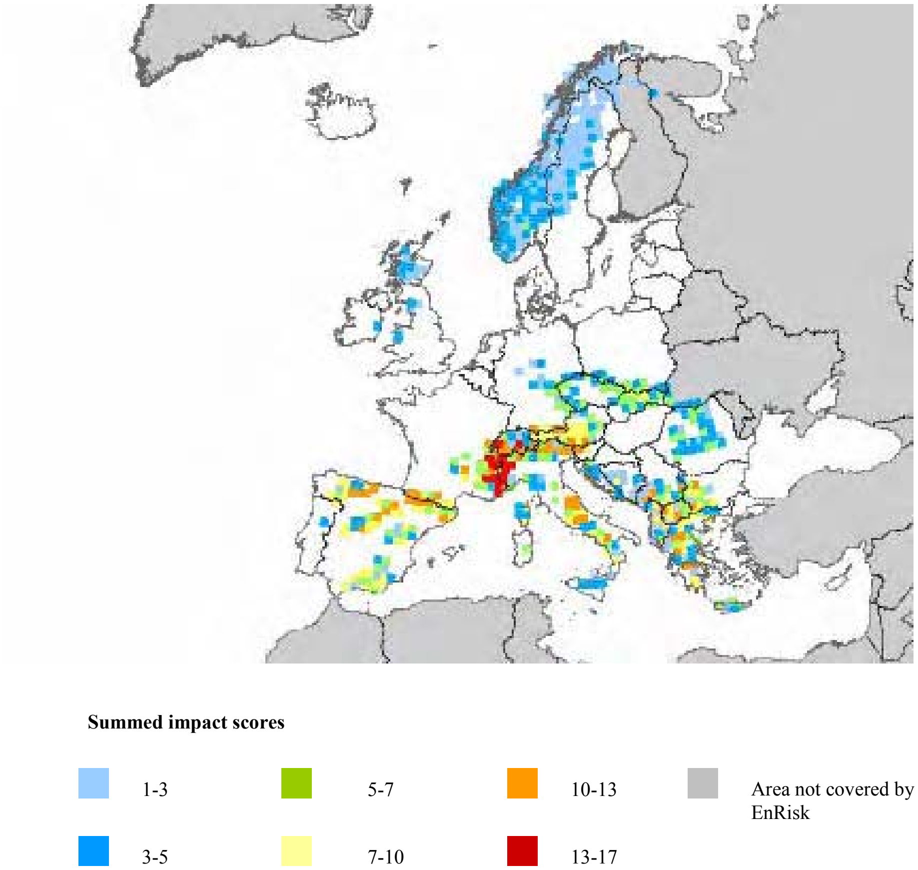

Fig. 6. Summed livestock density impact scores for breeding birds from montane grasslands.
Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission.

Highest sensitivity of montane grassland birds to nutrient pollution (Fig. 6) can be found in the Alpine region in the boarder area between France and Italy. It is suggested, though, that most of the variation here is explained by the species richness and not by geographic variation in the sensitivity values.

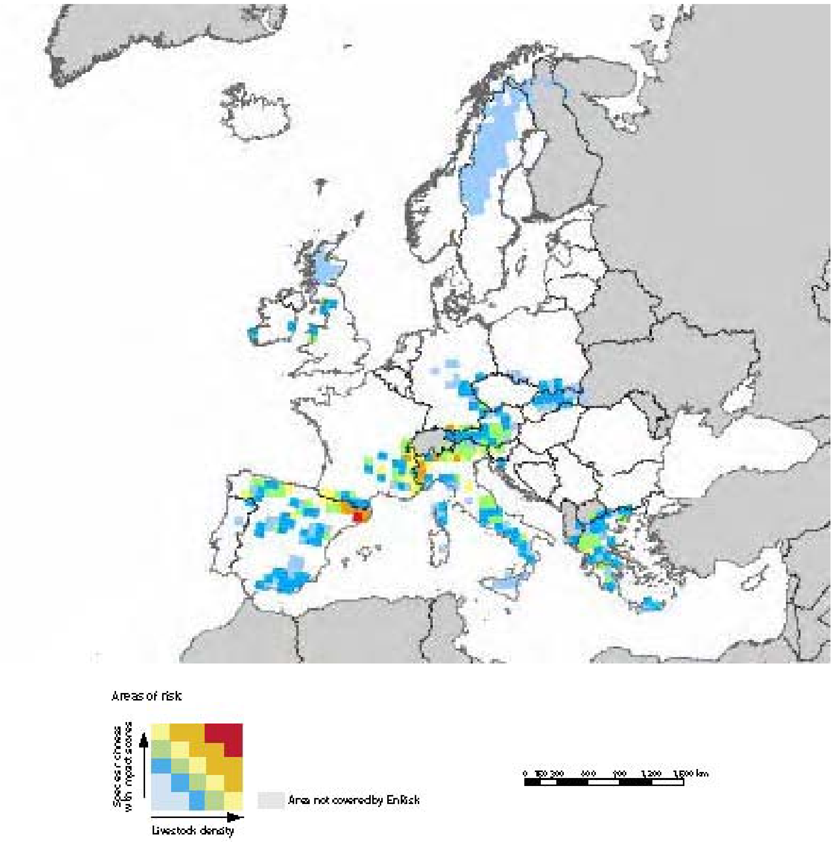

Fig. 7. Risks from livestock density to breeding birds on montane grassland. Source: Delbaere & Nieto Serradilla, 2004, ECNC Report, reproduced with permission.

With regard to risks on montane grasslands (Fig. 7), Switzerland and Catalonia in Spain have the highest scores. These are the only mountain regions with very high pressure values.

The EnRisk report advises for all the agro-biodiversity sensitivity and risk maps produced in the project to be interpreted with caution, due to quality of available data and a coarse scale of assessment. The results seem, however, highly relevant and can be interpreted in relation to available data on farming practices, derived from the FADN database.

Comparison of the biodiversity risk values with the farm level data at the regional level, shows the following relationships (Delbaere & Nieto Serradilla, 2004):

- the top five highest risk zones for wet grasslands correspond to the top five highest livestock density regions in the EU. They have one third to over half of their UAA (utilized agricultural area) covered with average livestock densities of 5.8 to 6.9 LU/ha. It is, however, more the extent of the area with high livestock densities that defines the pressure than the density level itself. Many regions in Spain have much higher values but on a very small part of the land;
- the areas of lowest risk for wet grasslands have 50% to 85% of their UAA with livestock density less than 1 LU/ha;
- for montane grasslands, the high risk area in Catalonia corresponds to a value of 23% of UAA with 10.9 LU/ha;
- the lack of high risk zones for dry grasslands corresponds to overall low livestock density (all cells in the regions with less than 1.5 LU/ha);

- although predictive data on future pressure values are lacking it might be possible to conclude that the actual risk areas for negative impacts on bird diversity due to intensification might be located in countries such as Poland and the Baltic states (even though the map does not show them as the highest risk areas).

3.6. Livestock grazing and benefits for biodiversity

Grazing animals cause major alterations to botanical composition and vegetation structure (Hester et al. 2005). Grazing herbivores interact dynamically with the vegetation; the structure and quality of vegetation affect the diet of grazing animals and, in turn, the components of grazing (defoliation, excretal return and treading) impact on the species composition and structure of the vegetation (Marriott & Carrère, 1998). Livestock grazing modifies habitats and consequently populations of invertebrates and other organisms at higher trophic levels. Herbivores are thus key drivers of ecosystem function and nutrient dynamics (Duncan 2005). Changes in grazing intensity and the species mix of grazing livestock can therefore exert important influences on biodiversity. There are important differences between domestic grazing species on the grazed plant communities and they may be related to differences in dental and digestive anatomy, but also, and it seems more significantly, to differences in body size (Rook et al. 2004).

Grazing at unsustainable high stocking rates may obviously exert adverse impact on the environment and cause biodiversity loss. The negative impacts of the intensification, were, however, widely discusses in preceding chapters. Here we concentrate on providing evidence for benefits of grazing (and mowing of grassland and meadows) for biodiversity.

Many European grasslands are productive but species-poor as a result of intensification of agriculture. In the recent decades, there was, however, a noticeable phenomenon of de-intensification of those grasslands. It was a result of either the implementation of agri-environmental schemes or the abandonment due to low profitability of animal production based on them. Grazing is suggested as optimum management of de-intensified grassland to enhance biodiversity (Isselstein et al., 2005; Pöyry et al., 2005; Luoto et al., 2003). Extensive grazing was reported to positively influence sward species composition and structure which, in turn, provided favourable conditions for colonizing fauna.

In the Mediterranean region of Europe grazing is essential for the prevention of shrub encroachment (Zaravali et al., 2007). Such a management may include high stocking rates, mixed flocks of sheep and goats, periodic burning and fuelwood collection (Papanastasis & Chouvardas, 2005). If it is altered or becomes less intensive than natural succession leads to the invasion by woody plants.

3.6.1. Grazing and High Nature Value farmland conservation

Many habitats important for biodiversity conservation are inherently linked to livestock farming. Natural and semi-natural grasslands are biodiversity hotspots in Europe. They are a core component of NATURA 2000 Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive (Council Directive 92/43/EEC) and considered as being of European importance for their biodiversity value. However, not only natural and semi-natural grasslands but, indeed, the majority of habitats forming NATURA 2000 network, depend to various extent on management practices related to livestock production – grazing or cutting regime or mixed. They can be as diverse as e.g heaths, sclerophyllous grazed forests (dehesa) or freshwater habitats such as turloughs and their biodiversity value may be threatened by the cessation of appropriate management practices.

Semi-natural vegetation (e.g heaths, dehesa and species rich grasslands) is a key component of High Nature Value (HNV) farmland in Europe. Originally, the term HNV was introduced by

Baldock et al. (1993, 1995) in their studies of the general characteristics of agricultural low-input systems in terms of management practices.

The analysis presented here is based on a conceptual definition for HNV farmland as proposed by Andersen et al. (2003) "*those areas in Europe where agriculture is a major (usually the dominant) land use and where agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European conservation concern or both*". Three types of HNV farmland are defined:

Type 1 - Farmland with a high proportion of semi-natural vegetation.

Type 2 - Farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers etc.

Type 3 - Farmland supporting rare species or a high proportion of European or World populations.

Areas of the first type are generally very species-rich, by definition require extensive agriculture for their maintenance and have a well-recognised conservation value. The second type is defined because small-scale variation of land use and vegetation and low agricultural inputs are generally associated with relatively high species richness. The farmed habitats within this type may not necessarily qualify as semi-natural, but the management should be sufficiently extensive to allow for floristic variation. The third type is defined because locally more intensive farming systems may also support high concentrations of species of conservation concern. The three types are not mutually exclusive. Semi-natural grasslands as a rule support many rare species and would thus also qualify as type 3. To a lesser extent the same is true for the mosaics of type 2. In addition, the farmed habitats in type 2 may be partially semi-natural and thus qualify as type 1. Common to all types should be a high contribution to biodiversity conservation at the European level (Paracchini et al., 2008).

HNV farmland is independent of policy designations such as NATURA 2000 (but may overleap with these areas) (Keenleyside & Baldock 2007). The European Environement Agency (EEA) in a preliminary estimate established that around 15 – 25% of the European countryside is HNV farmland (EEA 2004). Afterwards, the methodology for the HNV farmland identification has been developed and refined jointly by EEA and the JRC (see Paracchini et al., 2008, for the recent updates). Fig. 8 presents the likelihood of HNV farmland presence at EU level.

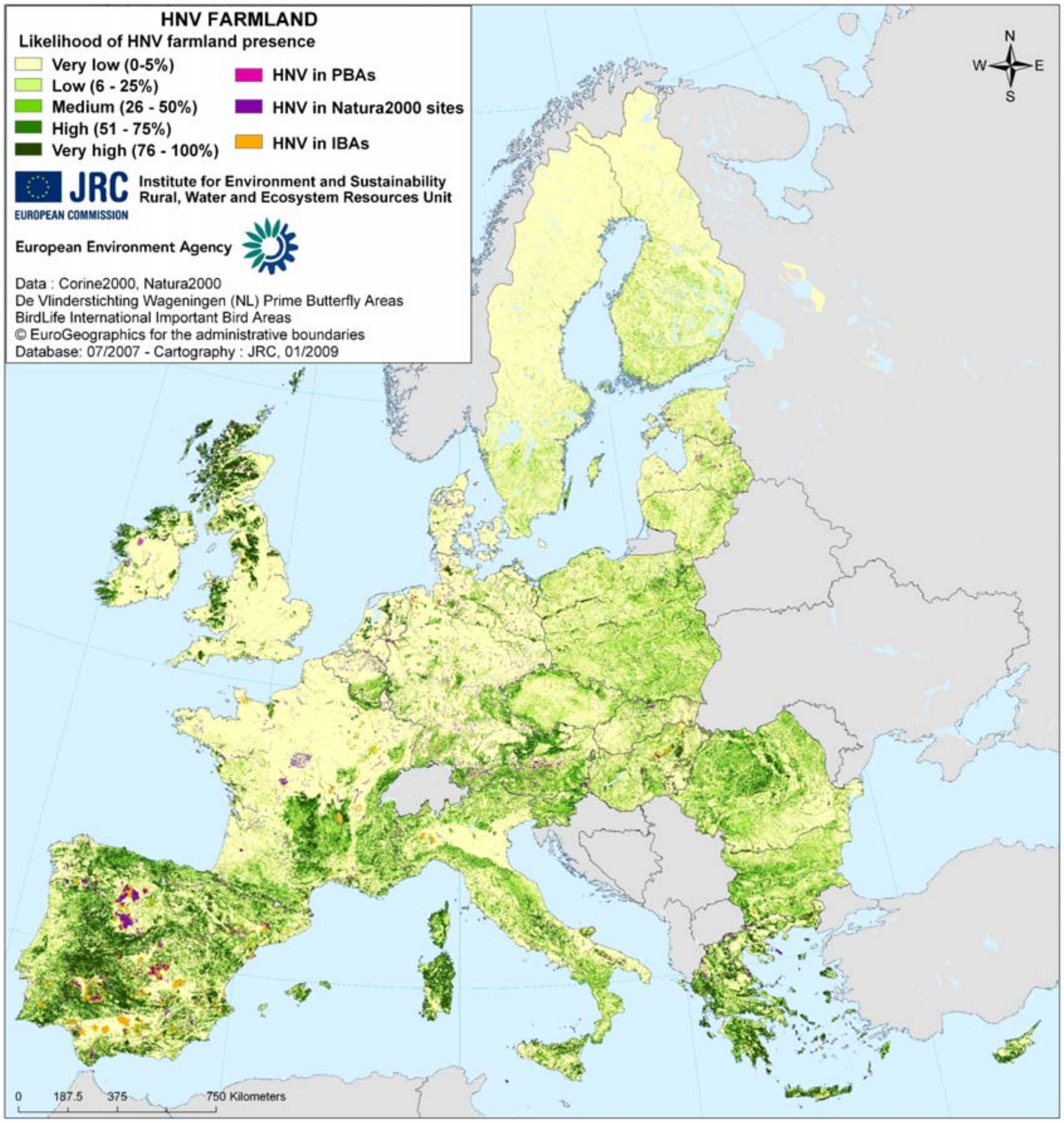

Fig. 8 Likelihood of HNV farmland presence at EU level (Source: Paracchini et al., 2008)

Utilization through grazing and mowing is essential for the conservation of the majority of HNV farmland habitats. Ostermann (1998) analysed the list of habitats in the Habitat Directive and estimated that this list contains 65 pasture types that are under threat from intensification of grazing and 26 that are under threat from abandonment.

During the process of methodology development for HNV farmland identification a new list of habitats from Annex 1 of the Habitats Directive that depend on, or are associated with, extensive agricultural practices has been proposed. This list built on a review by the EEA Topic Centre for Nature Protection and Biodiversity and revised a previous proposal by Ostermann, 1998. Following the country consultation period the list of proposed habitats was reviewed again on the basis of country feedback, EEA internal discussions and some expert advice (Paracchini et al., 2008).

Table 1 contains the final selection by the EEA of habitats that are characteristic of HNV farmland as they generally depend on extensive farming practices. These habitats have been grouped into two categories: those that clearly fulfil the conditions to be listed, and those where doubts exist or the relationship with extensive farming practices only holds true for part of their distribution in Europe.

The latter ones are also marked with a ° and were not considered by the EEA/JRC in the selection of relevant Natura 2000, IBA (Important Bird Areas) and PBA (Prime Butterfly Areas) sites. This selection is necessarily subjective to some degree; relevant information simply does not exist for all habitats across their range in Europe. Inclusion in the first category required a clear dependence on extensive agricultural land use and an increase in the diversity or extension of the relevant habitat type is not enough. Some habitats proposed by countries were excluded from the final list if they represent pioneer habitats (e.g. class 2120 - shifting dunes along the shoreline) or appeared to be climax habitats (e.g. Olea and Ceratonia forests). In addition, those habitats that still underlie a more natural dynamic (e.g. coastal dunes) were less likely to receive a 'full status' than those in more transformed landscapes (e.g. Pannonic inland dunes).

Code	**Habitat name**	**D**	**Comment**
1330 °	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	f *	* some types only
1340	Inland salt meadows	p	
1530	Pannonic salt steppes and salt marshes	p	
1630	Boreal Baltic coastal meadows	p	
2130 °	Fixed coastal dunes with herbaceous vegetation (grey dunes)	p	* at least some sub-types dependent on grazing
2140 °	Decalcified fixed dunes with Empetrum nigrum	p	
2150 °	Atlantic decalcified fixed dunes (Calluno-Ulicetea)	p	
2160 °	Dunes with Hippophae rhamnoides	p	
2170 °	Dunes with Salix repens ssp. argentea (Salicion arenariae)	p	
21A0	Machairs (* in Ireland)	f	rotational cultivation
2310	Dry sandy heaths with Calluna and Genista	f	
2320	Dry sandy heaths with Calluna and Empetrum nigrum	f	
2330	Inland dunes with open Corynephorus and Agrostis grasslands	f	
2340	Pannonic inland dunes	f	
4010	Northern Atlantic wet heaths with Erica tetralix	f	
4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix	f	
4030	Dry heaths (all subtypes)	f	
4040	Dry Atlantic coastal heaths with Erica vagans	f	
4090	Endemic oro-Mediterranean heaths with gorse	p	
5130	Juniperus communis formations on heaths or calcareous grasslands	p	

Code	Habitat name	D	Comment
5420	Sarcopoterium spinosum phryganas	p	
5430	Endemic phryganas of the Euphorbio-Verbascion	p	
6110	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi	p	
6120	Xeric sand calcareous grasslands	p	
6140	Siliceous Pyrenean Festuca eskia grasslands	p	
6150	Siliceous alpine and boreal grasslands	p	
6160	Oro-Iberian Festuca indigesta grasslands	p	
6170	Alpine and subalpine calcareous grasslands	p	
6180	Macaronesian mesophile grasslands	p	
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)	f	
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco Brometalia)(*important orchid sites)	f	
6220	Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea	f	
6230	Species-rich Nardus grasslands, on siliceous substrates in mountain areas (and sub-mountain areas, in continental Europe)	f	except in natural alpine and sub-alpine grasslands
6240	Sub-pannonic steppic grassland	f	
6250	Pannonic loess steppic grasslands	f	
6260	Pannonic sand steppes	f	
6270	Fennoscandian lowland species-rich dry to mesic grasslands	f	
6280	Nordic alvar and precambrian calcareous flatrocks	f	
62A0	Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae)	f	
6310	Sclerophyllous grazed forests (dehesas) with Quercus suber and/or Quercus ilex	f	
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)	f	
6420	Mediterranean tall humid herb grasslands of the Molinio-Holoschoenion	p	
6430 °	Eutrophic tall herbs	p	some types
6440	Alluvial meadows of river valleys of the Cnidion dubii	f	

Code	Habitat name	D	Comment
6450	Northern boreal alluvial meadows	f	
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)	f	
6520	Mountain hay meadows	f	
6530	Fennoscandian wooded meadows	f	
7140 °	Transition mires and quaking bogs	p	
7230	Calcareous (and alkaline) fens	p	
8230 °	Siliceous rocky slopes with pioneer vegetation	p	
8240	Limestone pavements	p	
9070	Fennoscandian wooded pastures	f	

Table 1- Final selection of habitats that are characteristic of HNV farmland (marked in yellow the habitats where doubts exist about the relationship habitat/HNV, or the relationship with extensive farming practices only holds true for part of their distribution in Europe) (Source: Paracchini et al., 2008).
Notes: D – degree of habitat dependence on agricultural practices (usually extensive ones):
f – fully dependent;
p - partly dependent, the agricultural practices prolong the habitat existence or enlarge its area of distribution.

3.7. Impacts of imported feed or animal products

Feed imported from outside the EU is a very significant component of intensive livestock production systems. Currently, soybeans are the most important imported feed. Most imports originate from Brazil and Argentina (Profundo Report, 2008). Annual EU livestock consumption demands a soybean acreage of 5.0 million hectares in Brazil and 4.2 million hectares in Argentina (Profundo Report, 2008). Soy farms in Brazil are expanding at the expense of world's biodiversity hotspots – Brazilian natural unique habitats and ecosystems. These are in particular Amazonia, the Atlantic forest and the Brazilian Cerrado. Deforestation of Brazilians Amazonia has reached very high levels. The original extent of Brazilian Amazon forest was approximately the area of Western Europe (Fearnside, 2005). Nowadays, the rate of deforestation is frequently described in terms of 'Belgiums' as annual loss is approaching this country's area, whereas the cumulative amount is compared with France (Fearnside, 2005).
The biodiversity impacts of continued deforestation are even greater in areas with little remaining forest and high levels of endemism, such as the Atlantic Forest. Laurance et al. (2001) presented the results of a 22-year investigation of fragmentation effects on ecosystem processes and biodiversity. They discovered that forest fragmentation alters species richness and abundance, causes species invasions, changes in trophic structure and a variety of ecological and ecosystem processes. Moreover, forest fragmentation seems to interact in a synergistic way with other factors of change, such as hunting, fires and logging, collectively posing an even greater threat to rainforest biota.
The Cerrado has the richest flora among the world's savannas (>7000 species) and high levels of endemism (Klink & Machado, 2005). Species richness is equally rich for birds, fish, reptiles, amphibians and insects. In the last 35 years, however, more than 50% of its approximately 2

million km2 has been transformed into pasture and agricultural lands planted in cash crops, especially soy. Imported feed may therefore constitute an important threat to biodiversity if they are produced in an unsustainable way in biodiversity-rich areas.

3.8. Conclusions

Interrelationships between livestock and biodiversity are highly complex.
Historically, livestock production in Europe was a decisive factor for the creation and maintenance of traditional landscapes with species-rich, heterogeneous habitats.
In the last decades, though, intensification of agriculture resulted in significant biodiversity loss. There is a wide body of scientific evidence which leaves no doubt that intensive livestock production negatively affects biodiversity not only in farmland but also in other terrestrial and aquatic ecosystems. This is mainly a result of environmental pollution and habitat fragmentation and loss.
Quantifying those impacts separately for the livestock sector is very difficult or impossible, due to enormous variety of biodiversity components and the complexity of ecological relationships between them as well as gaps of knowledge of cause-effect links between farming practices and biodiversity.
On the other hand, it is equally evident that extensive, low-input livestock systems are crucial for maintaining High Nature Value farmland in Europe with its biodiversity-rich semi-natural habitats. Those biodiversity hotspots are also targeted by many EU nature protection instruments, in particular Natura 2000.
As Europe strives for agricultural sustainability (EC, 1999) livestock sector must therefore be an inherent element of any proposed mitigation options. It is, however, very important not to forget that it is generally not so much livestock itself but the production system in which it is put by humans, that defines the direction of livestock impacts on biodiversity.

4. WP4: preliminary assessment of GHG emissions

4.1. Task 4.1: Definition of emissions parameters

Lead: F. Weiss, AFOLU *Contributor: A. Leip, AFOLU*
Status: completed. Work to be continued in the forthcoming WP 7
The output of task 4.1 is a rather technical report with exhaustive listings of emission factors and parameters selected for use in GGELS Phase 2. This report has been annexed to this Phase 1 report (Annex 3), and its contents are summarized in this section.
The objective of Task 4.1 was to provide the emission factors and parameters to be used for the calculation of GHG-emissions (CO_2, CH_4, and N_2O) and emissions of NH_3 related to livestock production in the EU27. With a few exceptions, the basic tool for the calculation will be the CAPRI modelling system, which, on the one hand, provides an extensive database on agricultural production, and, on the other hand, has already incorporated the calculation of agricultural GHG-emissions. The calculation of GHG, however, is not based on a unique methodology, since the CAPRI modelling system has been developed and successively extended in several research projects and by several research teams.

- The basic module for the calculation of GHG-emissions was developed in the course of a PhD thesis, strictly following the methodology recommended by the Intergovernmental

Panel on Climate Change (see IPCC, 1996). CH_4-emissions will be determined according to this approach, using updated parameters and emission factors.

- During the MITERRA-EUROPE project the calculation of nitrogen-emissions from agriculture was incorporated into CAPRI using a mass-preserving nitrogen flow approach, which is considered to be more precise and detailed than the IPCC default approach. Therefore, for the calculation of nitrogen emissions, like NH_3 and N_2O, the MITERRA-approach will be applied.
- Finally, direct and indirect CO_2-emissions from on-farm energy use have been introduced into the CAPRI system recently as an outcome of another PhD thesis, and, therefore, will be used for the calculation of those emissions in the present project.

At the beginning of the project a detailed documentation was only available for the calculation of methane emissions and the on-farm energy use, but not for the MITERRA implementation into CAPRI. However, even those available documentations do not provide all necessary information in order to assess the reasonability of the applied parameters. Moreover, the calculations have partly been based on default parameters of the old IPCC guidelines, which have been updated recently. Hence, the main effort within Task 4.1 was devoted to providing a **detailed documentation of those CAPRI components, which will be in use for the calculation of emissions, and to update the parameters** in accordance with the latest values recommended by the IPCC. To a minor extent, also changes in the calculation method have been carried out, as far as it was considered to be reasonable for consistency reasons. Finally, for most emission sources **an initial estimation of emissions on member state level is provided** together with the documentation, and presented in comparison with the respective values provided by the member states in the national inventories. However, those estimations should rather be seen as an additional tool in order to evaluate the used parameters, than a provisional assessment of total emissions from livestock production. The full documentation can be found in the annex of the attached report.

The following **work steps remain open for the second phase of the project**:

- First, the current presented parameters will be evaluated by a subcontractor. The outcome of this evaluation process will be the delivery of alternative parameter values, wherever the currently applied values are considered to be wrong, weak or insufficiently detailed for the production of reliable estimates. These required changes will have to be implemented together with those parameter values being an output of WP2 (i.e.: data on manure management systems on NUTS2-level).
- Secondly, the use of different calculation methods for the various gases, developed by different research groups, creates a consistency problem, which, so far, has not been solved. So, for the calculation of methane emissions some of the required parameters might be the same as for the calculation of nitrogen emissions. However, the two modules use different values for the same or similar parameters, which are not consistent among each other. One of the mayor efforts for the second project phase will be to overcome those inconsistencies and to use the same parameter values in all three modules as far as possible. Sometimes this will require not only changing the values but also slight changes in the methodology. Most of the inconsistencies are mentioned in the documentation.
- Another shortcoming of the current CAPRI version, with respect to the study objectives, is the fact that a life cycle approach, except for the energy module, is not yet implemented. There is no methodology implemented, which allows allocating emissions of inputs to their sources. This, above all, affects the allocation of feedings and manure to livestock and crops, since i.e. it is not straightforward to know to which extent the emissions of manure used as fertilizer are caused by the excreting animal or by the fertilized crop. Defining and

implementing a methodology for this allocation will, therefore, be an important goal of phase 2 of the project.

- Furthermore, the on-farm energy module is currently not integrated in the standard version of the CAPRI modelling system. Therefore, for the current documentation, only data of past runs could be used, while carrying out new runs, as in the case of the other modules, is for the moment not possible. This has to be changed in cooperation with the CAPRI-developers in Bonn and will require outsourcing of some of those development activities.
- Finally, emissions from land use changes induced by EU livestock production (the imports of feeding) are not estimated by CAPRI. Until now, parameters and data for a reliable assessment of those emissions could not be found, ensuing that a considerable share of time has to be devoted to this task during the second project phase.

4.2. Task 4.2: Estimation of emissions of imported animal products

Lead: S. Monni, ICPA *Contributor: T. Wassenaar, GeoCAP*
Status: completed

4.2.1. Main imports and sources of emissions

The most important imported animal products, in terms of quantity, were identified based on Eurostat statistics on EU animal product imports as presented in Table 2.

No	Product	Partner	Amount (ktons)
1	0210 Meat and edible meat offal, in brine, dried or smoked; edible flours and meals of meat or meat offal	BRA	214
2	**0204 Meat of sheep or goats, fresh, chilled or frozen**	**NZE**	**192**
3	**0201+0202 Meat of bovine animals, fresh, chilled, frozen**	**BRA**	**180**
4	**0207 Meat and edible offal, of the poultry (Gallus domesticus, ducks, geese, turkeys and guinea fowls), fresh, chilled or frozen**	**BRA**	**170**
5	160232 Other prepared or preserved meat, meat offal or blood other than sausages and similar products, of fowls of species Gallus domesticus	BRA	150
6	160232 Other prepared or preserved meat, meat offal or blood other than sausages and similar products, of fowls of species Gallus domesticus	ARG	93
7	0405 Butter, incl. dehydrated butter and ghee, and other fats and oils derived from milk; dairy spreads	NZE	78
8	04051019 Natural butter of a fat content, by weight, of >= 80% but <= 85% (excl. in immediate packings of a net content of <= 1 kg, and dehydrated butter and ghee)	NZE	72
9	0201+0202 Meat of bovine animals, fresh, chilled, frozen	ARG	58
10	0406 Cheese and curd	CHE	44

Table 2. Main animal product imports to EU by product and partner in order of importance (Eurostat, 2007).

The three most important import flows are sheep meat from New Zealand, beef from Brazil and chicken from Brazil (see also GGELS 1st interim report). Thus, the analysis is carried out for the products presented in bold in the table (numbers 2, 3 and 4). These are typically primary animal

products, and allocation of all the food chain emissions to these meat products covers partly also emissions of the products in categories 1 and 5.
The emissions considered for these products are presented in Table 3. This approach does not include the emissions from meat processing[1] or capital in the farms (e.g. vehicles, machinery, farm buildings, fences, water supply), which are outside the boundaries of the food chain approach defined in this study. Emissions due to fossil fuel manufacture, or indirect emissions related to electricity production are also excluded.
A brief analysis of the main production characteristics of the main animal products imported to the EU has been carried out for assessing the GHG emissions from a food chain perspective induced by these products.

Emission source	Beef BRA	Chicken BRA	Sheep NZL	Compounds
Use of fertilizers (pastures and feed production)	NR	X	X	N_2O, NH_3
Manufacturing of fertilizers	X	X	X	CO_2, N_2O
Lime application (pastures and feed production)	NR	X	X	CO_2
Crop residues left to soils (feed production)	NO	X	NO	N_2O
Feed transport	NO	NR	NO	CO_2
Land-use change due to grasslands expansion/cropland expansion for feed production	X	X	NR	CO_2
On-farm energy use	X	X	X	CO_2
Enteric fermentation	X	NO	X	CH_4
Manure management (storage)	NO	X	NO	NH_3, N_2O, CH_4
Manure deposition by grazing animals	X	NO	X	NH_3, N_2O, CH_4
Application of manure to agricultural soils	NO	X	NO	NH_3, N_2O
Indirect N_2O from leaching and runoff	X	X	X	N_2O
Indirect N_2O from deposition of NH_3	X	X	X	N_2O
Transport of animal products	X	X	X	CO_2

Table 3. Overview of emission sources for each of the import flows. 'X' denotes that the emission source is included, 'NO' denotes not occurring and 'NR' denotes not relevant (minor emissions).

4.2.2 Sheep meat from New Zealand

Production characteristics

According to Eurostat, **191kton** of sheep meat[2] were imported by the EU from New Zealand in 2007, classified under category '0204 Meat of sheep or goats, fresh, chilled or frozen'. Inclusion of also goat meat in the same category is not likely to cause noticeable bias in the estimates as imports are small and goat population is about 0.4% of the total goat and sheep population in New Zealand (Emission Database for Global Atmospheric Research, EDGAR; FAOSTAT, 2008).
The average sheep stock in New Zealand between 2000 and 2005 was 40090 thousand heads, whereas the average number of animals slaughtered per year was 29996 thousand heads in the same period (FAOSTAT, 2008). This indicates that the annual average sheep stock is **1.34** times the number of sheep slaughtered for meat production.
According to ABARE and MAF (2006), the number of sheep slaughtered for export in 2004-2005 (July-June) was about 24.6 million head, and the product exports were 295 kton. Consequently, the

[1] It is stated in the TOR of GGELS that "Emissions from processing and refrigeration of animal products will not be covered, so as not to lengthen the study."

[2] The categorization of Eurostat groups sheep meet together with goat meat.

average meat production would be **12 kg/head**, whereas the average carcass weight is 17.4 kg. The carcass weight of the same magnitude as reported in FAOSTAT (2008).

Item	Value	Unit
Sheep meat imports from NZE to EU	191	kton
Average sheep stock in NZE 2000-2005	40090	thousand heads/a
Average number of heads slaughtered 2000-2005	29996	thousand heads/a
Average carcass weight	17	kg/head
Average meat production	12	kg/head
Average pastureland used	0.157	ha/head/a

Table 4. Main production characteristics of sheep from New Zealand.

In New Zealand, all sheep are in pasture (Ministry for the Environment, 2008; Saggar et al., 2007). Thus there are no emissions related to feed production or transportation, manure management, manure application to soils or animal housing. It is also assumed that no land-use change is occurring in New Zealand due to grazing.
According to Saggar et al. (2007), sheep grazing occupies 7.1 million hectares. However, based on data from Statistics New Zealand (2008), sheep and cattle farming is often practiced together, and sheep can be found in almost any type of farm (Table 5). In the agricultural statistics of New Zealand, the land-use by farm type is divided into the following subcategories: (1) Grassland, (2) Tussock and danthonia used for grazing (whether oversown or not), (3) Grain, seed and fodder crop land, and land prepared for these crops, (4) Horticultural land and land prepared for horticulture, (5) Plantations of exotic trees intended for harvest, (6) Mature native bush, (7) Native scrub and regenerating native bush, and (8) Other land. All these land uses are occurring in sheep farms (e.g. category 'sheep farming (specialized)'). For the purposes of this study, only land-use categories (1) and (2) are considered, as they are assumed to represent the grazing land of sheep, whereas other land uses are assumed to be primarily used for other farm activities.

Importance	Farm type (ANZSIC06)	Total sheep	Grassland (ha)	Tussock and danthonia used for grazing (ha)	Cumulative share of sheep
1	**A0144 Sheep-beef cattle farming**	**19,874,190**	**3135493**	**1229761**	**51.7%**
2	**A0141 Sheep farming (specialised)**	**14,815,823**	**1598446**	**1339470**	**90.2%**
3	**A0142 Beef cattle farming (specialised)**	**925,430**	**983588**	**196143**	**92.6%**
4	A0145 Grain-sheep and grain-beef cattle farming	680,905	62570	0	94.4%
5	A0180 Deer farming	521,572	229772	75086	95.7%
6	A0160 Dairy cattle farming	382,677	1742242	13297	96.7%
7	A0149 Other grain growing	361,309	24113	1251	97.7%
8	A0123 Vegetable growing (outdoors)	301,014	34030	369	98.4%
9	A0301 Forestry	190,566	83387	24180	98.9%
10	A0159 Other crop growing nec	99,924	62920	4811	99.2%
11	A0131 Grape growing	68,954	14921	1970	99.4%
12	A0199 Other livestock farming nec	42,549	19587	0	99.5%
13	A0112 Nursery production (outdoors)	35,284	3843	88	99.6%
14	A0192 Pig farming	34,246	12460	189	99.7%
15	A0134 Apple and pear growing	26,432	3874	0	99.7%
16	A0191 Horse farming	26,414	41213	205	99.8%
17	A0133 Berry fruit growing	15,015	2264	0	99.8%
18	A0135 Stone fruit growing	12,380	2458	321	99.9%

19	A0132 Kiwifruit growing	9,675	6970	31	99.9%
20	A0136 Citrus fruit growing	7,245	1849	0	99.9%
21	A0139 Other fruit and tree nut growing	6,247	5104	160	99.9%
22	A0115 Floriculture production (outdoors)	3,128	846	0	99.9%
23	A0172 Poultry farming (eggs)	2,260	0	0	100.0%
24	Other	1,987	4851	0	100.0%
25	A0114 Floriculture production (under cover)	970	721	0	100.0%
26	A0137 Olive growing	737	513	0	100.0%
27	A0111 Nursery production (under cover)	227	227	0	100.0%
	TOTAL New Zealand	**38,460,477**	**8080900**	**2887332**	

Table 5. Sheep numbers and farm area by farm type in 2007 (Statistics New Zealand, 2008).

The cumulative share of sheep in different farm types is presented in Table 5. For the purposes of this study, the three most important farm types are chosen to represent the grazing practice in New Zealand.
In the case of farming of both beef cattle and sheep, the area of grazing land has to be divided between the two animal types. According to the National Inventory Report of GHG emissions of New Zealand to the UNFCCC (Ministry for the Environment, 2008), all sheep and beef cattle are fed in pasture. In this study, the area needed by head is divided between sheep and beef cattle by using the livestock units, i.e. assuming that for example an adult beef cow needs six times as much feed (in this case, grazing land) as sheep (Barber & Lucock, 2006). Based on the data, the average area of grazing land for sheep is **0.157 ha/head**.

Estimation of emissions from different sources

Fertilizer manufacture and use

Statistics New Zealand also provides data on the use of fertilizers in each farm type. In the calculation of average N input per hectare, we first leave out land uses 'Mature native bush', 'Native scrub and regenerating native bush' and 'Other land' assuming that no fertilizers are applied to these lands. By leaving these land types out, grasslands cover 96-97% of total area in the three farm types. Therefore crop cultivation is not assumed to cause bias to the estimated fertilizer application rates. By estimating also the average N contents of each fertilizer type, we obtain an average N fertilizer application rate of **7.6 kg N/ha grazing land**. The ARGOS study (Barber & Lucock, 2006) that was based on a small sample of farms reports the following N fertilizer application rates: 0 for organic, 11.1 for integrated and 8.6 kg N/ha for conventional sheep and beef farms without crops.
Based on the same statistics, use of urea (included in the N fertilizer numbers) is **9.6 kg urea/ha**, and use of lime **92 kg/ha**.
The emission factors for fertilizer and lime use are presented in Table 6. Emission factors are from the EDGAR database, and are based on IPCC methods and scientific literature. The NH_3 emission factor is calculated based on an average fertilizer mix used in New Zealand between 2000 and 2005 (IFA, 2007).

Type	Emission compound	Emission factor
N fertilizer use	N_2O	0.0157 kg N_2O/kg N
N fertilizer use	NH_3	0.23 kg NH_3/kg N
Urea use	CO_2	3.67 kg CO_2/kg C in urea
Lime use	CO_2	0.44 kg CO_2/kg limestone

Table 6. Emission factors for fertilizer and lime use (IPCC, 2006; EDGAR).

The emission factors for N fertilizer manufacture are based on a review of Wood & Cowie (2004). The emission factors, expressed as CO_2 equivalents, include CO_2 emissions from ammonia production, N_2O emissions from nitric acid production and CO_2 emissions from energy use for fertilizer production. The emission factors used here are averages of emission factors presented as "European average". For the fertilizer types for which no information was available, emission factors of CAPRI are used. The emission factors used for each fertilizer type are presented in Table 7.

Fertilizer type	Emission factor	Source
Ammonium phosphate	6047kg CO_2-eq/ton N	CAPRI
Ammonium sulphate	6047kg CO_2-eq/ton N	CAPRI
Calcium Ammonium nitrate	7175kg CO_2-eq/ton N	Wood & Cowie
Compound NPK-N	5287kg CO_2-eq/ton N	Wood & Cowie
Urea	2351kg CO_2-eq/ton N	Wood & Cowie
Ammonium nitrate	6854kg CO_2-eq/ton N	Wood & Cowie
Compound NK-N	6047kg CO_2-eq/ton N	CAPRI
Phosphate fertilizers	2261 kg CO_2-eq/ton P_2O_5	CAPRI
Potassium fertilizers	326 kg CO_2-eq/ton K_2O	CAPRI

Table 7. Emission factors for fertilizer manufacture.

The average emission factor for N fertilizer production in New Zealand – based on average mix of fertilizers used – is **3153 kg CO_2-eq/ton N**.
For the production of phosphate and potassium fertilizers, we use emission factors from CAPRI (Table 7). The phosphate application rate, leaving out the N containing phosphate fertilizers, is calculated at 18 kg P_2O_5/ha and thus the emission factor is **41.2 kg CO_2-eq/ha**[3].
According to IFA (2007), the potassium fertilizers used in New Zealand (those not containing N) are potassium chloride (95%) and potassium sulphate. The use of these in New Zealand sheep farms accounts for 1 kg K_2O/ha, and based on the emission factors in Table 7, the emissions are **0.34 kg CO_2-eq/ha**.
The CO_2 emission factors for sulphur and agrichemical application are taken from Saunders et al. (2006), and are **7.9** and **8.3 kg CO_2/ha**, respectively. The emissions due to lime manufacture are **0.43 kg CO_2/kg lime**.

Enteric fermentation

The emission factor for enteric fermentation, **11 kg CH_4/head,** is based on the national GHG inventory of New Zealand (Ministry for the Environment, 2008). It is higher than the estimate in EDGAR, 8 kg CH_4/head, which is based on IPCC (2006) default for industrial countries.

Manure management

The national GHG inventory report gives an estimate of nitrogen excretion in pasture of **15 kg N/head** (average over the years 2000-2005), which is used in this study. This coefficient is slightly higher than the 2000-2005 average in EDGAR, 14 kg N/head.
The emission factors for manure excreted in pasture are based on EDGAR and presented in Table 8.

Emission factor	unit
0.0157	kg N_2O/kg N excreted
0.049	kg NH_3/kg N excreted
0.11	kg CH_4/head

Table 8. Emission factors for manure excreted in pasture.

[3] Excluding P_2O_5 fertilizer containing nitrogen

Indirect N_2O
Indirect emissions due to leaching and runoff of fertilizer and manure N are estimated based on EDGAR approach. The emission factor is **1.77 kg N_2O/ton N**. In addition, the deposition of NOx and NH_3 emissions causes indirect N_2O emissions. The emission factors from EDGAR are **0.0048 kg N_2O/kg NOx** and **0.013 kg N_2O/kg NH_3**. However, only the indirect emissions from NH_3 are included in this study.

On-farm energy use and meat transportation
According to Saunders et al. (2006), CO_2 emissions from diesel and electricity use allocated to sheep in mixed cattle and beef farms are 46.5 and 2.2 kg CO_2/ha, respectively. However, they consider mixed beef and sheep farms and allocate 47% of emissions per area to sheep. Thus, the following emission factors are used in this study: **98.9 kg CO_2/ha** for diesel and **4.7 kg CO_2/ha** for electricity.
Emissions from ocean transport of sheep meat are estimated based on the approach used by FAO (2006), which excluded road transport. As the report did not include transportation from New Zealand to Europe, it is assumed that the vessels and related parameters are similar to the ones used to transport cattle meat from New Zealand to USA. The distance between New Zealand and EU is set to 18 000 km (**9719 nautical miles**) based on Saunders et al. (2006). Thus the emission due to transportation is **73.2 kg CO_2/t** meat. This is a lower estimate than the one of Saunders et al. (2006), 125 kg CO_2/t carcass.

Total GHG emissions
The emissions are allocated between the market value of different products, which in the case of sheep are meat, edible offal and wool. According to Chapagain & Hoekstra (2004), the value fraction of sheep meat is **81%**, which is used in this study. This is in line with the study of Sainz (2003), according to which the share of emissions allocated to sheep meat varies between 57 and 84%.
The calculated emissions per ton of meat are presented in Table 9 and the contribution of each source to the CO_2 equivalent emissions in Figure 9. The GWP values used are 21 for CH_4 and 310 for N_2O.

Compound	Emissions by substance	Total emissions of imported meat in 2007	Share of GHG emissions
CO_2 without fertilizer production	3.0 kg CO_2/kg meat	575 kton CO_2 eq	9%
$CO_2 + N_2O$ from fertilizer production	0.9 kg CO_2-eq/kg meat	178 kton CO_2 eq	3%
CH_4	1.0 kg CH_4/kg meat	4047 kton CO_2 eq	63%
N_2O without fertilizer production	0.03 kg N_2O/kg meat	1582 kton CO_2 eq	25%
GHGs	33 kg CO_2-eq/kg meat	6382 kton CO_2 eq	
NH_3	0.1 kg NH_3/kg meat	17 kton NH_3	

Table 9. Emissions of sheep meat imported from New Zealand to EU (per kg of meat and per total imports to the EU). CO_2 and N_2O emissions from fertilizer production could not be separated as the data source used gives emission factors as CO_2 equivalents.

The most important GHG emission sources are enteric fermentation (63% of CO_2-equivalent emissions) and manure excreted in pasture (20%). Indirect emissions from leaching and runoff of manure N accounts for additional 2%. On-farm energy use accounts for 4%, and the rest of the sources for less than 2% each. Regarding NH_3 emissions, 73% is from manure in pasture, and the rest from N fertilizer application.

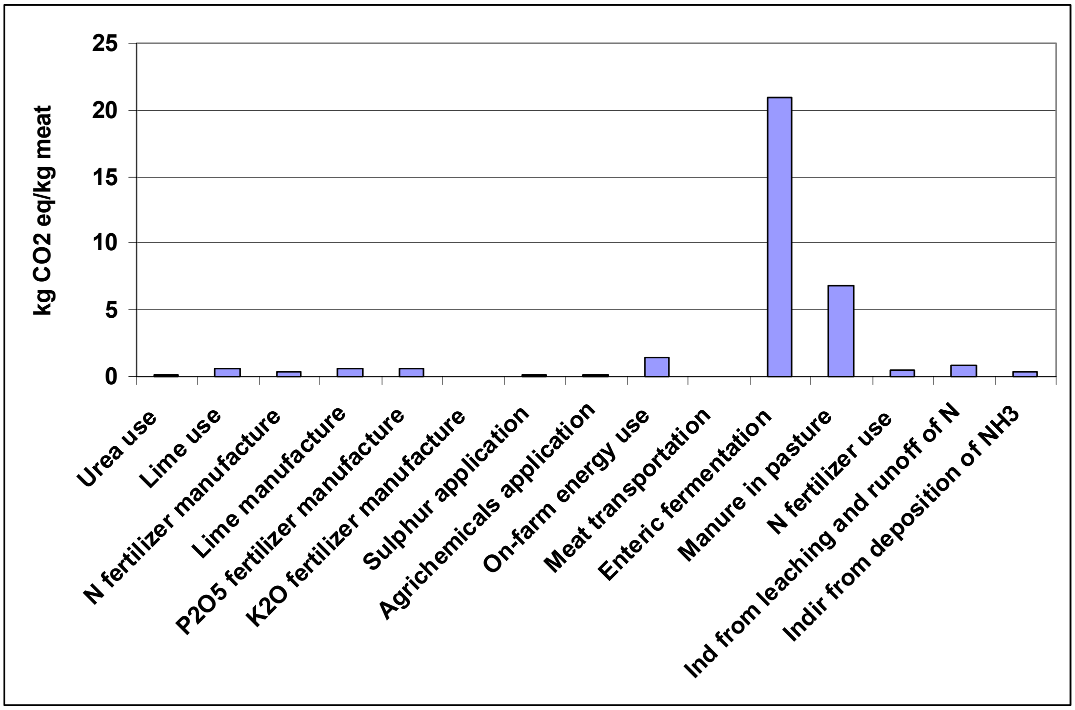

Figure 9. Contribution of different emission sources to the CO_2 equivalent emissions of sheep meat imported to the EU.

4.2.3 Beef meat from Brazil

Production characteristics

The export share of Brazilian beef is on the rise, but still represents only some 10% of national production. We can thus assume that EU beef imports from Brazil originate from (central and eastern) South Brazil, an important beef production area where slaughterhouse density is highest, located near the main harbours. Beef meat import to EU from Brazil in 2007 was **180 kton** based on Eurostat category 'Meat of bovine animals, fresh, chilled' (80 kton) and 'Meat of bovine animals, frozen' (100 kton).

Cattle farming in Brazil is almost entirely based on grazing (Carvalho, 2006; IPCC, 2006), and according to FAO (2006) fertilizer use in pasture in Brazil is negligible. Therefore, the emissions from animal housing, feed production and manure management are negligible[4]. In addition, on-farm energy use can be neglected, as there is no housing and no fertilizer application which usually represent a major share of the energy use. The pasture stocking rate is about **0.9 head/ha** annually (Carvalho, 2006).

The sheer exclusive dependence of bovine feeding on pastures makes seasonal lack of feed the main factor explaining the rather low productivity (a slaughter weight between 400 and 480 kg, but a long production cycle of 5 to 7 years) (Embrapa, 2003). The legume ratio in pastures is low, limiting digestibility and thus productivity (while increasing methane from enteric fermentation) (Carvalho, 2006). Carvalho (2006) reports a reduction of herd age to slaughter over the last decade that would now be around 4 years. He also states that the absence of pasture fertilization leads to

[4] The study of Cederberg et al. (2009) also includes only pasture-based production, but it is mentioned that feedlot systems have been introduced in Brazil and represent a minor but increasing fraction of beef production.

increasing pasture degradation. Although this might lead to significant soil carbon loss, lack of data impeded us from further considering this issue.
Feedlots exist and increase in importance, but still represent only some 1% of the total Brazilian production. Fattening and finishing are also largely pasture based. Indoor feeding occurs in the dry period and for unweaned claves, but even here feeding is grass silage and cane residue based (Embrapa, 2003). The value fraction of cane residue is low, so little land can be attributed to this use, which is anyway a long standing, rather stable production involving little greenhouse gas emissions. Despite the important Brazilian maize production, no significant amounts of maize are reported to be used as fodder, so no additional land use will be considered.

Average carcass weight of cattle in Brazil was **213 kg** (FAOSTAT) in the 5-year period 2003-2007. Based on USDA report (Silva, 2007), total meat, beef and veal exports from Brazil were 1945 kton carcass weight equivalent in 2006, whereas exports were 1431 kton as meat. This would give a conversion factor of 0.735 from carcass to exported meat, and thus a meat yield of **156 kg/head**. The conversion factor used here is in a good accordance with the value used by Cederberg et al. (2009), 0.70.
In the period 2000-2005, average non-dairy cattle stock in Brazil was 170.4 million of heads (FAO data in EDGAR). In the same period, on average 35.1 million heads were slaughtered for cattle meat in Brazil. The slaughter statistics include both dairy and beef cattle. The share of dairy cattle in Brazil is about 10% of the total cattle stock, and if we assume that the lifetime of dairy cattle is twice the lifetime of beef cattle, we can allocate 5% of the slaughters to dairy cattle. Based on this data we can calculate that the annual average beef cattle stock is approximately **5** times the number of animals that are slaughtered[5]. Thus the meat production per head in living stock is 31 kg/head, which is in agreement with FAO (2006), according to which beef production per animal in grazing systems is 36 kg/head and year globally and 29 kg/head and year in developing countries.

Item	Value	Unit
Beef meat imports from Brazil to EU	180	kton
Average beef stock in Brazil 2000-2005	170	million head
Average number of heads slaughtered 2000-2005	35	million head
Average carcass weight	213	kg/head
Average meat yield	156	kg/head
Pasture stocking rate	0.9	head/ha

Table 10. Most important production characteristics of beef from Brazil.

Estimation of emissions from different sources

Fertilizer manufacture and use

According to FAO (2006) fertilizer use in pasture in Brazil is negligible. Cederberg et al. (2009) estimate that in cultivated pastures, fertilizer application rate is 4 kg/ha as P_2O_5 content of single superphosphate. If we assume that 60% of the pastures are cultivated, the average fertilizer application rate is **2.4 kg/ha** grassland. The emission factor used for fertilizer manufacture is reported in Table 7.

Enteric fermentation

The emission factor for enteric fermentation is **60.7 kg CH_4/head** based on EDGAR. FAO (2006) applies an emission factor of 57.9 kg CH_4/head for grazing beef cattle in Central and South

[5] According to Cederberg et al. (2009) share of slaughtered cattle to total population in Legal Amazon is 0.19 and for the rest of Brazil 0.25.

America, and in the National Communication of Brazil to the UNFCCC (Ministry of Science and Technology, 2004), the emission factor for 1990-1994 is 55.8 kg CH_4/head.

Manure in pasture

The emission factors for manure deposition in pasture are taken from EDGAR (Table 11), and compared with the estimates of FAO (2006) for Central and South America (weighted averages across different production systems).

Compound	EDGAR (average 2000-2005), kg/head	FAO (2006) kg/head
CH_4	1	0.98
N_2O	1.27	1.14
NH_3	4.0	

Table 11. Emission factors for manure in pasture from EDGAR and FAO (2006).

Indirect N_2O

The emission factors for indirect emissions due to leaching and runoff of manure N and that for atmospheric deposition of NH_3 are the same as in the case of New Zealand[6].

Land-use change

There is evidence that deforestation in tropical regions is partly driven by the need to expand pastures for grazing livestock. In Brazil, most of the recent growth in cattle herd has taken place in the Legal Amazon[7], where deforestation mainly occurs for expansion of grazing land (McAlpine et al., in press; Cederberg et al., 2009). Based on FAOSAT/COMTRADE data and Cederberg et al. (2009), beef consumption in Brazil has remained relatively stable over the last years, whereas beef production has increased together with increasing exports. Therefore, the pasture expansion could be attributed to export products (while ignoring displacement of beef pasture by elsewhere expanding dairy production)[8].

On the other hand, Cederberg et al. (2009) also point out that beef production in Legal Amazon has contributed little to exports by 2006, whereas the most important beef-exporting states of Brazil have traditionally been situated in the southern and central-western parts of the country. However, in 2006 the share of export value of beef produced in Legal Amazon grew to 22% and further to 24% in 2007. The growth can be partly explained by the outbreak of foot-and-mouth disease and followed bans for some of the states that were important exporters before.

Pasture area in Legal Amazon has increased from 51.2 Mha to 61.6 Mha between 1995 and 2006, whereas the meat production as carcass weight equivalent has increased from 1.096 to 2.021 million tons between 1997 and 2006. This means that an increase of carcass weight production by ton has required on average 9.2 ha additional grazing land, and, consequently, increase of meat

[6] In EDGAR calculations, the average emission factor for leaching and runoff in Brazil is somewhat lower than that of New Zealand due to non-irrigated dryland regions in which leaching and runoff are assumed not to occur. However, export products are not estimated to be produced in these regions.

[7] The largest socio-geographic division of Brazil, which contains all of its territory in the Amazon Basin. It is officially designated to encompass all seven states of the North Region (Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins), as well as Mato Grosso state in the Center-West Region and most of Maranhão state in the Northeast Region.

[8] This may look like a strong assumption, but even if it is likely to be not far off from the truth, it's strength is much weakened by the accompanying assumption that EU imports originate uniformly from all Brazilian beef pasture area, resulting in a small portion originating from the deforested area.

production by ton has required additional 12.5 ha grazing land[9]. Following the IPCC (2006) method, the emissions from land use change are calculated for a period of 20 years, and therefore to estimate the emissions occurring in 2006, deforestation between 1987 and 2006 has to be considered.
From 2000 to 2006, the beef meat imports to Europe have increased by an average rate of 29000 ton/year. Cederberg et al. (2009) present the export of beef from Legal Amazon and other regions in Brazil for the years 1996-2006, showing an increasing trend in exports from Legal Amazon. If we assume that the EU exports follow the same trend (i.e. increasing share originating from Legal Amazon), the average increase in the exports from Legal Amazon is 2300 ton/year. If we conservatively assume that this same increase rate occurred also from 1998 to 2000 (as before that there were no exports from Legal Amazon), the average increase in exports between the 20 year time period 1987-2006 would be 940 ton/year, which would mean, by using the average land requirement of 12.5 ha/ton of meat, deforestation rate of 11 thousand ha/year[10] for exports to the EU.
According to FAO (2006), the carbon losses due to forest conversion to grassland are 605 t CO_2/ha and 117 t CO_2/ha in plants and soil, respectively, based on difference in the carbon stocks of forest and grassland[11]. However, according to Cederberg et al. (2009), regrowth of 'secondary forest' occurs on degraded pasture, and therefore we do not allocate the full loss of carbon to beef production. There is not enough data on the carbon stock of secondary forest, but we tentatively estimate that the carbon loss due to forest conversion to grassland, taking into account the subsequent growth of secondary forest is about 570 t CO^2/ha.

<u>On-farm energy use and meat transportation</u>
The on-farm energy use in beef production in Brazil is minor, as there is practically no housing of animals and fertilizer application occurs only to a small extent. The study of Cederberg et al. (2009) estimated that cultivated pastures are renovated every ten years, and that the fuel use for this purpose is **12 litres diesel/ha**. We use this estimate, together with IPCC (2006) default NCV of **43 TJ/Gg** and emission factor of **74.1 t CO_2/TJ**, and estimated diesel density of **0.85 kg/l**.
Emissions from transatlantic transportation of beef are estimated based on the approach of FAO (2006), again ignoring prior and post road transportation. The emissions from transportation of beef are **68.8 kg CO_2/t meat.**

Total GHG emissions
According to Chapagain & Hoekstra (2004), the beef carcass represents about **87%** of the live animal's value. The rest of the value comes from offal and hide. Consequently, 87% of the emissions are allocated to meat.
The total GHG emissions per ton of meet are presented in Table 12, and contribution of each factor to total emissions in Figure 10. The GHG emissions are estimated at 80 kg CO_2-eq/kg meat

[9] Note that other changes in beef productivity occurred simultaneously in Legal Amazon.

[10] This estimate depends largely on the years chosen for consideration. For example, the imports to EU dropped in 2007, and the average import growth rate from 2000-2007 would have been -830 ton, and following the method presented above we would not have allocated any emissions to deforestation. Total beef imports from Brazil to EU declined further in 2008 because of bans due to deficiencies in the Brazilian cattle identification and certification system and in the Brazilian government oversight and testing (Cederberg et al., 2009). Another important factor is that we are not able to identify whether deforestation in Legal Amazon occurs also due to relocation of domestic production to Legal Amazon as a result of increased exports from other parts of the country (indirect land use change). This could explain why the animal herds have increased more in Legal Amazon than exports from that region. In a more detailed life-cycle analysis, also these indirect land-use changes should be taken into account.

[11] The data are based on IPCC Third Assessment report (IPCC, 2001, p. 192).

including emissions from land use changes (LUC) and 48 kg CO_2-eq/kg meat excluding emissions from LUC.

Compound	Emission per kg meat	Total emissions of imported meat in 2007	Share of total emissions
CO_2 without fertilizer production	31 kg CO_2/kg meat	5651 kton CO_2 eq	39%
CO_2 + N_2O from fertilizer manufacture	0.2 kg CO_2-eq/kg meat	30 kton CO_2 eq	0.2%
CH_4	1.7 kg CH_4/kg meat	6506 kton CO_2 eq	45%
N_2O without fertilizer production	0.04 kg N_2O/kg meat	2170 kton N_2O	15%
GHGs	80 kg CO_2-eq/kg meat	14357 kton CO_2 eq	
GHGs without deforestation	48 kg CO_2-eq/kg meat	8733 kton CO2-eq	
NH_3	0.11kg NH_3/kg meat	20 kton NH_3	

Table 12. Emissions from beef meat imported from Brazil to EU. CO_2 and N_2O emissions from fertilizer production could not be separated as the data source used gives emission factors as CO_2 equivalents. CO_2 emissions from land-use change include also other emission compounds from burning, but their importance is small.

The total GHG emissions are dominated by two factors: enteric fermentation (45%) and land-use change (39%). The emissions from manure in pasture account for 15%, and the rest of emissions sources are negligible.
The only NH_3 emission source is manure from pasture.
Our estimates of emissions from enteric fermentation per unit of meat are about 20% higher than those of Cederberg et al. (2009), mainly due to the differences in estimated age structure of the herd and lifetime of an animal before slaughter, which are uncertain factors and vary largely between different regions in Brazil.
The estimates of land use change triggered by livestock production are the most uncertain ones in this study. A precise allocation of emissions from land use change to exported beef is a challenging task, and no agreed methodology and accurate data exists. This chapter presents a simplified approach, and the results should be used with extreme caution.

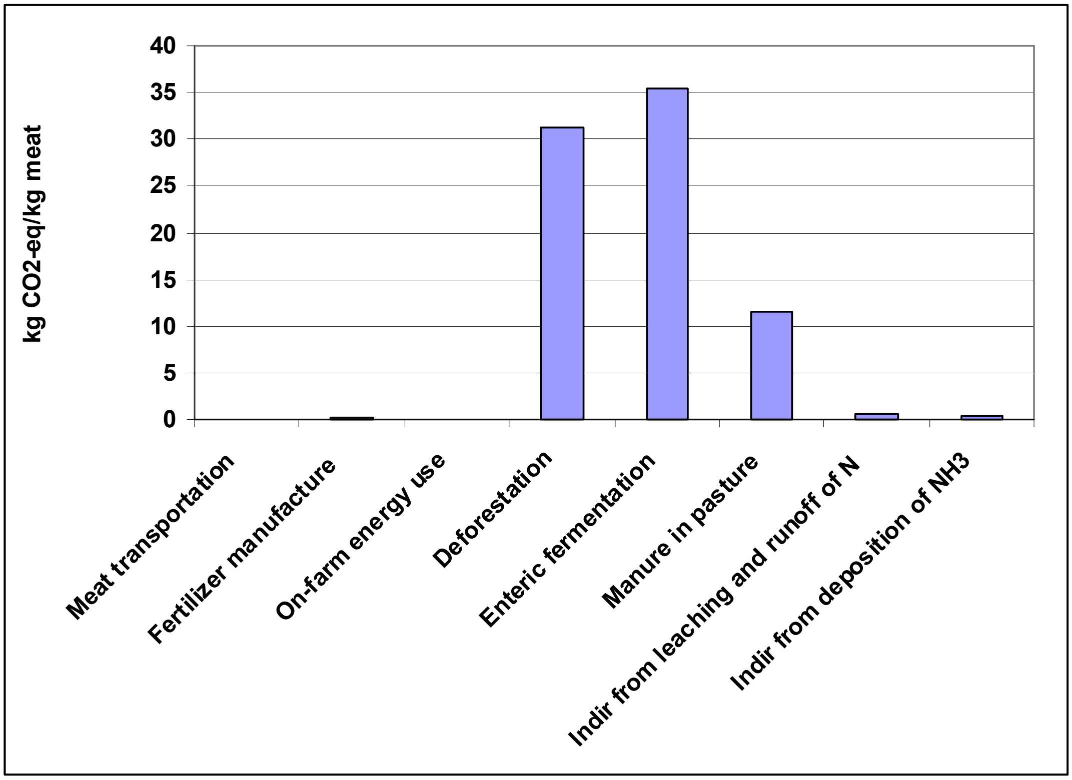

Figure 10. Contribution of each emission source to CO_2 equivalent emissions from beef imported to the EU from Brazil.

4.2.4. Chicken meat from Brazil

Production characteristics

According to Eurostat, poultry meat[12] imports to the EU from Brazil were **170 kton** in 2007. According to EDGAR, chicken represent a share of 98% of the population of chicken, turkeys and ducks in Brazil, and therefore the poultry imports are used to represent chicken meat imports from Brazil.

The chicken meat imported to EU is assumed to come entirely from the intensive systems in Southern Brazil. The feed consumption/head is estimated to be **1.7** times live weight at slaughter, which is assumed to be **1.9 kg** as in the CAPRI model.

The five-year (2003-2007) average carcass weight of chicken in Brazil is **1.55 kg/head** (FAOSTAT) and therefore 109.5 million heads are needed to produce the meat imported to Europe. If we assume that broilers are alive for 60 days, the average annual stock needed for meat imports is 18 million heads. The total population (109.5 million) is used to calculate emissions related to feed production, whereas the average annual population (18 million) is used to calculate emissions from manure management.

Item	Value	Unit
Chicken meat imports from Brazil to EU	170	kton
Estimated lifetime	60	days
Average carcass weight	1.55	kg/head

[12] Meat and edible offal, of the poultry (Gallus domesticus, ducks, geese, turkeys and guinea fowls), fresh, chilled or frozen

Feed consumption	3.23	kg/head

Table 13. Most important production characteristics of chicken from Brazil.

Estimation of emissions from different sources

Feed production, including fertilizer production and use

Table 14 presents parameters related to chicken feed. According to FAO (2006, p. 43), soybeans yield 18-19% oil and 73-74% soymeal, which thus is a by-product of soybean oil industry. Chapagain and Hoekstra (2004) allocate 34% of the value to crude oil of soybeans, and therefore we allocate 66% of the emissions from soybean cultivation to soymeal. The share of "other" is dealt as a weighted average of wheat, soymeal, sorghum and maize.
Feed imports to Brazil are considered negligible, as the domestic production of all the four feedcrops is higher than consumption as feed based on FAO Supply Utilisation Accounts and Food Balances statistics (FAOSTAT, 2008).

Crop	Share of feed	Yield (kg/ha)	Fertilizer use			Crop residues (kg N/ha)
			kg N/ha	kg P_2O_5 /ha	kg K_2O /ha	
Wheat	2%	1905	80	40.0	60.0	20
Soymeal	24%	2524	10	50.0	60.0	26
Sorghum	1%	1978	60	30.0	40.0	16
Maize	66%	3223	60	30.0	50.0	21
Other	7%					

Table 14. Chicken feed composition in Brazil (FAO, 2006, p. 41), average yield of crops (FAOSTAT) 2000-2005, average N fertilizer use by crop (FAO/IFA), and N in crop residues left to soils (EDGAR).

The N_2O emission factor for N fertilizer use and the CO_2 emission factor for urea use are the same as used for sheep from New Zealand. However, the NH_3 emission factor is **0.19 kg NH_3/kg N** based on fertilizer mix in Brazil and EDGAR NH_3 emission factors. The national fertilizer mix is based on IFA (2007), and the share is assumed to be the same for each of the feed crops.
There is no detailed data on lime use in Brazil by crop. However, Bernoux et al. (2003) estimated that a mean CO_2 flux due to liming of soils is 3.96 g/m^2 in Southern Brazil and 3.33 g/m^2 in Southeastern Brazil. We use an average of **3.65 g CO_2/m^2** to estimate the emissions from liming related to feed production.
The emission factors for fertilizer and lime manufacture are the same as used in the case of sheep from New Zealand (Table 7). Due to lack of data, we neglect the other chemicals that may be applied to soils.
The emission factors for crop residues left in soils are based on EDGAR approach, and are **0.012 kg NH_3/kg N** and **0.0157 kg N_2O/kg N**.

Manure management

CH_4 emissions from manure management are estimated based on the IPCC (2006) emission factor for broilers: **0.02 kg CH_4/head**. The nitrogen excretion rate is also based on IPCC (2006), and is **0.36 kg N/head**.
Table 15 presents emission factors for manure management and manure application to soils. It is assumed that all chicken manure is use to fertilize the crops used as feed.

Category	Emission factor	Unit
Manure management	0.00157	kg N_2O/kg N excreted

Manure management	0.364	kg NH_3/kg N excreted
Manure applied to soils	0.006	kg N_2O/kg N excreted
Manure applied to soils	0.124	kg NH_3/kg N excreted

Table 15. N_2O and NH_3 emission factors for manure management and manure application to soils based on EDGAR.

Land-use change

According to FAOSTAT/COMTRADE data, the chicken meat exports from Brazil to the EU increased between 2003 and 2005 and decreased thereafter, being lower in 2007 than 2003. Due to this development, we do not allocate emissions from deforestation to chicken meat, as in average the exports to Europe have not required extension of cropland for feed production.

On-farm energy use and meat transportation

The on-farm energy use and related CO_2 emissions from intensive systems are estimated based on data in CAPRI on chicken meat imported to the EU: **31.25 MJ/kg carcass.**
The emission factor for chicken meat transport from Brazil to Europe is the same as for beef.

Total GHG emissions

In the case of chicken, all emissions are allocated to meat.
The calculated emissions per ton of meet are presented in Table 16, and contribution of each of the factors to GHG emissions in Figure 11.

Compound	Emission	Total emissions of imported meat in 2007	Share of total GHG emissions
CO_2 without fertilizer production	0.55 kg CO_2/kg meat	94 kton CO_2-eq	44%
CO_2 + N_2O from fertilizer production	0.19 kg CO_2-eq/kg meat	33 kton CO_2-eq	16%
CH_4	0.00 kg CH_4/kg meat	8 kton CO_2-eq	4%
N_2O without fertilizer production	0.00 kg N_2O/kg meat	77 kton CO_2-eq	37%
GHGs	1.2 kg CO_2-eq/kg meat	211 kton CO_2-eq	
NH_3	0.02 kg NH_3/kg meat	4.2 kton NH_3	

Table 16. Emissions from chicken meat imported from Brazil to EU (per kg of meet). CO_2 and N_2O emissions from fertilizer production could not be separated as the data source used gives emission factors as CO_2 equivalents.

On-farm energy use is the most important source of GHGs (34%) from chicken meat imported to the EU. Use and manufacture of fertilizers account for 28% of GHG emissions, and indirect N_2O emissions for 12%. Manure management and use of manure as fertilizers cause 11% of emissions. Meat transportation is responsible for 6% and crop residues for 5% of emissions.
In the case of NH_3, manure management is the most important emission source (56%) followed by use of nitrogen fertilizers (24%) and application of manure to soils (19%).

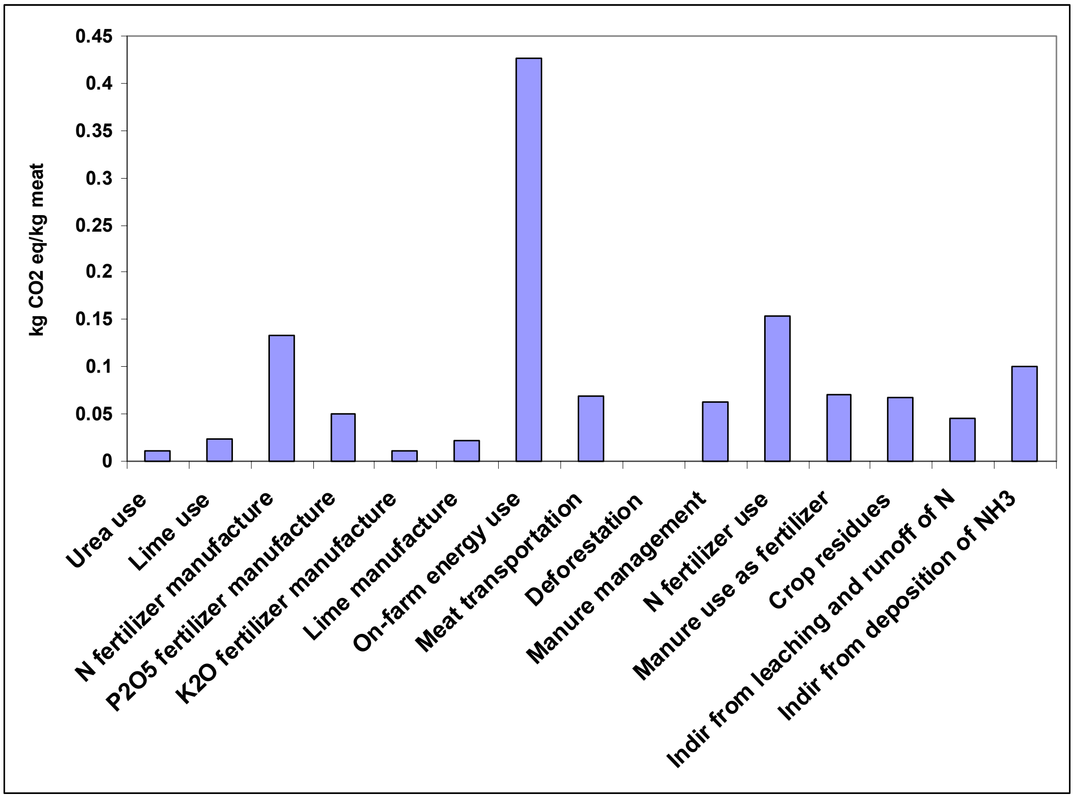

Figure 11. Contribution of different emission sources to CO_2-equivalent emissions from chicken imported to the EU from Brazil.

4.2.5 Conclusions

The emission levels per unit of production (emissions intensity) vary a lot among the three products considered (Table 17).

Methane emissions levels of the two ruminant meat products differ mainly because of the less optimal feeding of Brazilian beef cattle compared to New Zealand sheep. Their nitrous oxide emission levels are fairly similar. Direct livestock emissions (from enteric fermentation and manure) strongly dominate all other food chain emissions of these two products. The single very noticeable exception is land use change related to Brazilian beef. Adding this factor takes Brazilian beef emissions from a level of about 1.4 times that of New Zealand sheep to 2.4 times that level. Compared to the former two, Brazilian chicken GHG emissions are much less significant (about 65 times less that of Brazilian beef). Its emissions are dominated by energy use.

Multiplying the emission intensities with the volume of the import flows the GHG emissions "imported" by the EU through New Zealand sheep meat, Brazilian beef and Brazilian chicken amount respectively to 6.4, 14.4 and 0.2 million ton CO_2 eq., i.e. a total of 21 million ton CO_2 eq. Compared to all GHG emissions produced within the EU (5143 million ton CO_2 eq. in 2006[13]) this is a rather insignificant amount (0.4%), but it constitutes 4.4% of all agricultural emissions produced in the EU. The essential information which will be provided by GGELS Phase 2 is how this compares to per unit product emissions of the same products but from EU origin.

	Sheep NZE	Beef from BRA	Chicken from BRA

[13] Total GHG emissions excluding net CO2 emissions from LULUCF

		(without LUC)	
GHG emissions (kg CO_2-eq/kg meat)	33	80 (48)	1.2
GHG emission from product imports (million ton CO_2-eq)	6.4	14.4 (8.7)	0.2
Most important GHG sources	-Enteric fermentation (63%) -Manure in pasture (20%)	-Enteric fermentation (45%) -Land-use change (39%) -Manure in pasture (15%)	-On-farm energy use (34%) -Fertilizer manufacture (16%) -N fertilizer use (12%)
NH_3 emissions (kg NH_3/kg meat)	0.1	0.1	0.02
NH_3 emission total of imported products (kton NH_3/kg meat)	17	20	4.2
Most important NH_3 sources	-Manure in pasture (73%) -N fertilizer use (27%)	-Manure in pasture (100%)	-Manure management (56%) -N fertilizer use (24%)

Table 17. Comparison of emissions of the three most important import products.

5. Conclusions

Since the start of GGELS Phase 1 in late June 2008 an important amount of data, literature, methods and tools have been gathered and used. Once the approach had been collaboratively defined in detail in September (WP1, first interim report), the work implemented by the four JRC actions concerned by Phase 1 has allowed to timely achieve the objectives of GGELS Phase 1 and complete Work Packages 2 to 4:

- task 2.1: a separate deliverable (second interim report) describes the importance of livestock production per species throughout the EU27, both from an economic and land use point of view;
- task 2.2: through the use of elaborate statistical procedures a preliminary livestock production system typology and zoning was established on the basis of CAPRI databases. This product has constituted an important input to subcontracted work aiming to obtain production system specific information on manure management practices. This work, the result of which constitutes an important element completing the regional production system descriptions, is currently still ongoing. Running about one month behind schedule, this is the only element of Phase 1 not delivered in time. It does not hamper GGELS progress though since task 2.2 is to be finalized under WP6, GGELS Phase 2 and the results of the subcontracted work will be available before the start of WP6;
- task 3: an extensive literature study highlighting the negative and positive impact of livestock production on the EU's biodiversity. It demonstrates that impacts vary substantially among species and production systems, which constitutes important information to consider when assessing the greenhouse gas footprint of respective systems as to be produced under GGELS Phase 2. It also concludes that it is hard to qualify the impact of livestock production throughout the historic development of the EU, but that given the current environmental situation and the corresponding set of threats to remaining biodiversity, livestock production can (and sometimes does) play a role in its conservation;
- task 4.1: important preparative work for the core task of quantifying all EU livestock sector emissions (WP 7, GGELS Phase 2) has been performed. Nearly all details (parameters,

equations, tables) needed under WP 7 have been selected and retrieved. They will be submitted to external parties for validation prior to the start of WP 7;

- task 4.2: emission levels of various greenhouse gases as induced by the production of selected meat products constituting major EU animal product import flows have been determined in a detailed and transparent manner. The resulting total GHG emission levels per unit product constitute a useful relative indication of their magnitude: an assessment of the uncertainty of the absolute figures is a harsh task falling out of task 4.2's scope, but uncertainty levels are expected to be similar per emission among the three products, and certainly much below the large emission differences found among them. These indications will be important when assessing the GHG impact of the forthcoming prospective simulations results (WP 8, GGELS Phase 2).

The interim nature of this report makes that the various elements it reports on appear as a rather disparate group of disconnected components. Above comments as well as the general approach as set out in Annex 1 to the AA and in the first interim report though demonstrate that they all contribute an important element on the path to achieving the final result, i.e. the location, production system and gas specific impact assessment, and the first approximate evaluation of the feasibility for selected policies to remediate worst situations encountered. We consider that GGELS is well on track towards achieving this goal, which will have an incommensurably higher value to its clients than the elements presented in this report, even if some of them surely constitute worthwhile information on their own.

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Annex 1

Tasks 2.3
Initial overview of the EU livestock sector

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(document embedded as pdf on the following page: double click to open)

JRC IPSC/G03/P/TWA/twa D(2008)(10215) /

Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)

Administrative Arrangement (AA) No. AGRI-2008-0245

GGELS

Second Interim Report

Task 2.3: Initial overview of the EU livestock sector

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Contents

Executive summary

The study “Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)”, formally started on June 20 2008, seeks to assess such emissions following a food chain approach at sub-national level for the EU27. The assessment at hand is thus of considerable complexity. It has therefore been split up into a large number of activities and sub activities of a varied nature and led by different JRC actions.

This report constitutes the second deliverable of the study, in accordance with the terms of reference of the Administrative Arrangement (AA) No. AGRI-2008-0245. This report aims to provide insight into the European livestock sector at a broad level, describing its importance from various perspectives at EU and member state (MS) level.

From an economic perspective, livestock production accounted for 41% of agricultural output in value terms in 2007, representing 1.2% of the European Union’s GDP. Highest GDP shares are found in “new” member states (with Bulgaria, 4,4%, and Romania, 3,8%, standing out), while lowest shares are found in Luxemburg (0,5%), United Kingdom (0,6%) and Sweden (0,7%). At EU level the spread over the different output categories is important, illustrating the diversified nature of the EU livestock sector. Still the dairy sector comes out as a relative heavyweight in economic terms.

From a production perspective the EU is the world’s largest dairy producer and the world's second largest producer of beef after the United States. But pork accounts for 45 percent of the meat consumed in the EU, followed by poultry, at 25 percent, and beef/veal at 19 percent.

Very important differences in productivity are observed among member states, reflecting differences in production systems. Production systems still evolve considerably, particularly but not exclusively in the transition economy MS, with a general trend towards intensification as well as concentration.

Production systems of most species remain characterized by an important diversity. Diversity is agrguable largest for the complex dairy systems. On the side of monogastrics it is mainly the farm structure and size that vary.

This report also assesses the land dedicated to the production of feed for a range of commodities. The estimates, resulting from the combination of various databases, will be useful in validation efforts of GGELS’ subsequent quantification tasks. The resulting picture also constitutes valuable information on the EU livestock sector’s “footprint” in its own right: We estimate that about 60% of the EU’s UAA is dedicated to the production of feed, corresponding to about 50% of the EU arable land. Land used for EU feed outside the EU, 90% of which concerns land for soya bean cultivation, corresponds to some 10% of the EU arable land.

A last point addressed is the brief characterization of the production systems providing the main animal product imports to the EU. These characteristics will be used in subsequent work to assess greenhouse gas emissions from a food chain perspective induced by animal product imports by the EU.

Acronyms

AA	Administrative Arrangement
AFOLU	Agriculture, Forestry and Land Use action of the Climate Change unit, Institute of environment and sustainability, JRC
AGRI-ENV	Agriculture and Environment action of the Rural, Water and Ecosystem Resources unit, Institute of environment and sustainability, JRC
AGRITRADE	Support to Agricultural Trade and Market Policies action of the Agriculture and Life Sciences in the Economy unit, Institute for Prospective Technological Studies, JRC
CAPRI	Common Agricultural Policy Regionalized Impact model
COPA-COGECA	Union of European farmers and agri-cooperatives
EAA	Economic Accounts on Agriculture: Eurostat database
EDGAR	Emission Database for Global Atmospheric Research
EU	European Union, 27 member states
FADN	Farm Accountancy Data Network
FAO	Food and Agricultural Organization of the United Nations
GeoCAP	Geo-information for the Common Agricultural Policy action of the Agriculture unit, Institute for the Protection and Security of the Citizen, JRC
GGELS	Project acronym "Greenhouse Gas from the European Livestock Sector" of the JRC project "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions"
GHG	Greenhouse Gas
ICPA	Integrated Climate Policy Assessment action of the Climate Change unit, Institute of environment and sustainability, JRC
IE	Institut de l'Élevage: French livestock board
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center
LPS	European Livestock Production System
NUTS	Nomenclature of Territorial Units for Statistics; harmonized EU administrative region denomination
UNFCCC	United Nations Framework Convention on Climate Change

Member State acronyms:

at Austria	ee Estonia	it Italy	pt Portugal

be Belgium	es Spain	lt Lithuania	ro Romania
bg Bulgaria	fi Finland	lu Luxembourg	se Sweden
cy Cyprus	fr France	lv Latvia	si Slovenia
cz Czech Republic	gr Greece	mt Malta	sk Slovakia
de Germany	hu Hungary	nl Netherlands	uk United Kingdom
dk Denmark	ie Ireland	pl Poland	

1. Introduction

This report constitutes the second deliverable of the study "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)", in accordance with the terms of reference of the Administrative Arrangement (AA) No. AGRI-2008-0245.

This report aims to provide insight into the European livestock sector at a broad level, describing its importance from various perspectives at EU and member state (MS) level. Many recent reports and articles, particularly those addressing environmental impacts, refer to the abstract notion of "the livestock sector", and GGELS is not an exception. Readers' interpretation of these works is often influenced by the subjective image one attaches to this abstract notion. A European citizen is for example likely to think of a Holstein dairy cow reared on lush pasture without knowing the representativeness of this image. Regarding the sensitivity of politics and the public opinion at large to livestock-environment issues, it is important to promote objectivity by informing about the wide range of species and production systems that make up this complex sector, and their relative importance. GGELS dedicates considerable attention to providing such information, not because of the absence per se of a consistent and sufficiently detailed description of today's EU livestock sector, but in order to provide results per species and production system. This is considered a requirement for results able to support policy making. An additional requirement is that results are localized with sufficient detail. In this perspective this document provides a first level of information which will be elaborated by the project tasks that concern the typology and zoning work.

2. The importance of livestock production in the EU and its MS

2.1. Economic importance

In 2007 livestock production accounted for 41% of agricultural output in value terms, representing 1.2% of the European Union's GDP. Highest GDP shares are found in "new" member states (with Bulgaria, 4,4%, and Romania, 3,8%, standing out), while lowest shares are found in Luxemburg (0,5%), United Kingdom (0,6%) and Sweden (0,7%). This does not reflect the dynamics of the relative importance of livestock production in agricultural output: Ranging from 28% of agricultural output in the case of Greece to 69% in the case of Ireland these extremes seem to be substantially influenced by bio-physical conditions.

In addition to the overall economic importance per country, table 1 also shows the relative contribution of the main subsector. At EU level the spread over the different output categories illustrates the diversified nature of the EU livestock sector. Still the dairy sector comes out as a relative heavyweight in economic terms: milk output is highest, to which has to be added the fact that about 60% of beef also originates from the dairy sector (CEAS 2000; Ernst&Young 2007), resulting in a total of some 45% of the livestock sector's output.

Output levels of milk, a fundamental while bulky and perishable food element, are understandably substantial in all MS (ranging from about 1/5 to well over half of livestock output). Output levels of other "farm gate" commodities vary more strongly, leading in a number of MS to a clearly specialized livestock economy at national level. These are readily identified in table 1: "dairy-beef" in France and Ireland; "pig" in Spain and Denmark; "sheep and goat" in Greece and "pig-poultry" in Hungary.

Member state	Livestock Production			Share (%) of livestock production (value terms)						
	Million euro	Agricultural output share	GDP share	Milk	Egg	Beef	Pig meat	Sheep and goat	Poultry meat	Other animal produce
FR	23542	36,4%	1,2%	31	4	34	12	3	13	3
DE	20400	45,1%	0,8%	47	3	15	25	0	8	2
IT	14441	33,5%	0,9%	30	7	23	16	2	15	8
ES	14296	36,6%	1,4%	19	6	15	33	11	13	2
UK	12301	56,8%	0,6%	33	5	26	9	9	14	3
NL	9140	39,9%	1,6%	43	5	18	22	1	8	3
PL	8994	45,5%	2,9%	35	8	10	28	0	17	2
DK	5449	60,2%	2,4%	27	2	6	44	0	3	18
RO	4584	34,7%	3,8%	30	15	11	21	4	10	9
IE	4092	68,5%	2,1%	40	1	37	7	4	4	7
BE	3799	52,0%	1,1%	25	3	27	34	0	9	1
AT	2883	48,0%	1,1%	33	6	29	23	1	5	4
GR	2881	27,9%	1,3%	37	5	8	9	27	5	9
PT	2499	37,9%	1,5%	30	4	20	19	5	16	7
HU	2296	35,4%	2,3%	22	9	5	28	2	27	7
FI	2259	55,2%	1,3%	46	2	15	15	0	6	15
SE	2225	47,7%	0,7%	44	5	18	16	1	5	10
CZ	1763	41,6%	1,4%	43	4	16	23	0	13	0
BG	1259	41,4%	4,4%	39	9	9	13	13	14	4
SK	941	48,9%	1,7%	31	10	13	21	1	13	12
LT	892	45,7%	3,1%	51	6	16	16	0	9	1
SI	572	50,6%	1,7%	32	4	29	18	2	14	3
LV	411	43,4%	2,1%	49	8	11	15	1	9	7
CY	305	50,9%	2,0%	28	4	4	28	11	21	4
EE	303	48,2%	2,0%	55	3	8	22	1	6	6
LU	165	60,7%	0,5%	57	2	30	10	0	0	0
MT	71	59,5%	1,3%	24	11	6	22	1	10	26
EU27	142190	41,4%	1,2%	34	5	20	21	4	11	5

Table 1 EU livestock sector's 2007 economic output (Eurostat 2008).

2.2. Production volumes

Even before the 2004 enlargement the EU was already the world's largest dairy producer (120 million tons per year, 24% of which from Germany, 20% from France, 13% from the UK and 10% from the Netherlands). With the 2004 and 2007 enlargements the EU dairy cow herd rose from about 18 million heads to over 24 million heads.

The European Union is the world's second largest producer of beef after the United States, with Brazil trailing only slightly in third place. The EU produces around 8 million tonnes of beef a year, predominantly in the 15 "older" countries of the bloc.

France has by far the EU's largest cattle herd, with 19 million animals, followed by Germany and then Britain. Italy, Ireland and Spain are each home to around 6 million cattle.

For pork, the EU is the world's second largest producer after China and turns out about 22 million tonnes annually. Again, the bulk comes from the 15 longer-standing members.

Germany is the EU's largest pig rearer, with almost 25 million animals, followed by Spain, with 23 million.

The EU produces around 11 million tonnes of poultry meat and 1 million tonnes of mutton and goat meat a year.

Britain leads in sheep with 24 million animals, closely followed by Spain. Greece has by far the most goats, with more than 40 percent of the EU total, again followed by Spain.

Britain also has the most hatching chicks, followed by France. Germany, Spain and Poland are also big producers.

Pork accounts for 45 percent of the meat consumed in the EU, followed by poultry, at 25 percent, and beef/veal at 19 percent. Europeans consume around 43 kg (95 lb) a year of pork, 23 kg of poultry meat, 18 kg of beef and veal and only 3 kg of mutton and goat meat. Self-sufficiency ranges from 80 percent in mutton and goat meat to about 96 percent in beef (Reuters 2007).

These meat consumption percentages roughly reflect the sectoral split of output in volume terms, but constitutes a marked contrast with the production output split in value terms presented in the preceding paragraph. Beef production is of much lesser importance in satisfying meat demand than its value suggests. The EU can in fact be roughly characterized as a “white” meat consuming continent.

As demonstrated by the production figures in weight terms presented in Annex 1.1, production levels vary strongly among member states, a fact that is doubtlessly going to affect relative livestock greenhouse gas emissions levels among MS. Differences in production levels are partly explained by differences in national consumption, influenced by population size and per capita consumption, the latter varying substantially in the case of meat. At least as important for explaining production level differences is the interdependence among MS as evidenced by the varying self sufficiency levels: a limited number of MS are important production centres that supply a large number of other MS with a share of their produce. Production exhibits substantial and similar concentration at EU level for all main commodities, with Germany, Spain, France and Italy standing out, followed by the UK, Poland and the Netherlands.

Annex 1.2 presents indicators of productivity. Again one observes very important differences among member states, reflecting differences in production systems. Average dairy cow productivity in the most productive MS is 3,5 times that of the least productive MS. In 2006 Jongeneel (Jongeneel and Ponsioen 2006) indeed noted that eight out of the ten then new MS are Central and Eastern European Countries (CEECs), jointly producing about 20 per cent of total EU-15 milk production and that large differences exist between the eight new MS and the EU-15 in terms of prices, production methods, milk yields, product quality, farm structures, farmers’ and consumers’ income, etc. Among them Poland is the largest producer but has a low milk yield, while Hungary and the Czech Republic are smaller producers but with milk yields comparable to those in the EU-15. Beef production is closely linked to dairying, with specialized beef production hardly playing any role. Dairy productivity in the two most recent MS, Bulgaria and Roumania, is still well below that of all other MS. The three Scandinavian MS clearly have highest dairy productivity, indicating the presence of modest size, but very intensive dairy sector.

Apart from some exceptions, animal productivity of beef and pig meat is of a similar order of magnitude, which regarding the very different maintenance/feeding costs of the respective animals clearly indicates the structurally higher productivity of pigs.

2.3. Imports and Exports

While gross trade flows between the EU and the rest of the world (taken from FAO trade statistics) often represent a substantial share of the EU production, net flows are generally low. Total meat exports from the EU represent over ¼ of EU meat production, but the net export flow is currently only just over 1%. The individual situation for beef, pork and chicken is similar: over ¼ of production exported, but a net import flow representing 3 to 4% of production for beef, a net export flow of 4 to 5% for pork and a net export of less than 2% for chicken. Small ruminant meat represents a more substantial net import, representing 16% of EU production.

Net trade of egg products is not significant, while that of milk products was not assessed since it takes to a large extent place in the form of transformed (milk powder) and second order products, mainly cheese. According to Chatellier (Chatellier and Jacquerie 2004), the EU15 (representing the vast majority of milk production as seen above, and a still higher share of international trade) exports some 10% of its dairy produce. Since the EU also imports a lower, but significant amount of dairy products (mainly swiss cheese), the net export is again not a very important driver for the sector. Although the cited 10% would represent nearly 35% of international dairy product trade, this share decreases at the benefit of Oceania (Chatellier and Jacquerie 2004).

2.4. Trends

EU dairy production is very stable, largely as an effect of the quota system, but this hides important trends. In general, dairying in the EU continues to intensify and specialize (see figure 1, which illustrates recent declines in cow numbers and increases in average yield per cow). Farm herd sizes increase. Together this means that production continues to concentrate on fewer, larger farms (eg, 40% of EU dairy cows are in herds of at least 50 head) resulting in a corresponding decrease of dairy farming on many holdings and in some cases abandonment of holdings. This is true for virtually all dairy farms irrespective of system or bio-geographical region; noting that 85% of EU milk production is derived from one high input/output (see (CEAS 2000)) economic/technical class of dairy farming, except where national authorities actively seek to help maintain small producers or promote organic production (eg, Austria), such as some in mountain areas.

This ongoing restructuring started well over two decades ago. Large decreases in numbers of dairy cows occurred between 1984 and 1997 in Belgium (40%), France (35%), the Netherlands (35%), Spain (32%) and Italy (29%). Dairy cow numbers in the EU as a whole declined by 26% for the EU-12 between 1984 and 1997 from 27.524 million head to 21.760 million head and by 7% between 1992 and 1997 for the EU-15. At the same time the average herd size in the EU increased by 74% between 1984 and 1997 and milk yields per cow have increased steadily in every Member State between 1985 and 1997.

The primary factors of influence originally driving these trends were probably the nature of the support regime (largely price support) and the associated economic and technical implications for production systems. For all producers this effectively focuses attention on producing a clearly defined maximum output level (quota determined) at the lowest possible cost. For the producers that account for the majority of EU production this has resulted in maximising production output per cow via intensification and the use of high input: high output systems.

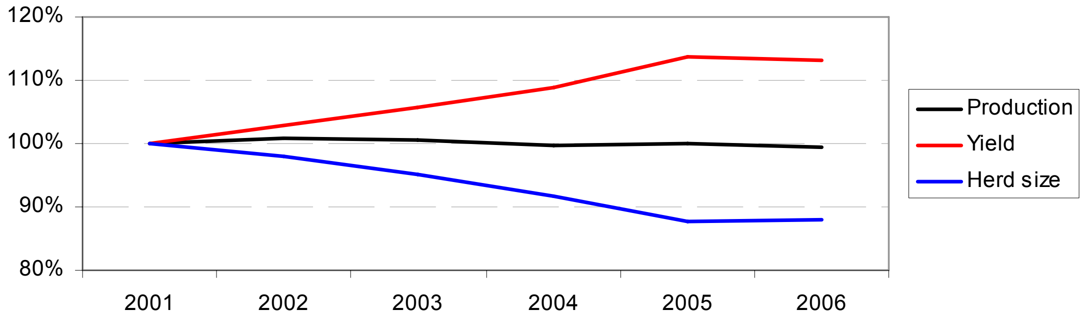

Figure 1

During that same period, the 1980s and 1990s, meat consumption of most MS was characterized by a decreasing per capita beef and veal consumption, while the consumption of pig and poultry meat increased. EU15 general meat consumption changed little over the 1995 – 2004 period, with an overall annual growth rate of about 1%. Consumption of chicken meat rose with about 20% and that of pork with some 10%, while bovine meat consumption returned close to its initial level.

In the future the competition between species remains important and will probably increase, particularly in price terms. The hypothesis of a stagnating consumption level, consequence of a high consumption level, an ageing population and changing nutritional habits (new generations consume less meat), is generally admitted[1].

The EU's share in world meat trade is expected to decline over the coming decade, while stable consumption should then also lead to declining exports, resulting in a still stronger focus on the domestic market. The latest EU Commission forecasts for the beef sector indicate that EU-27 beef production will fall six per cent to 7.6 million tonnes between 2007 and 2014[2]. The major factors influencing the medium to longer term projections for the beef sector are the gradual decrease in the EU dairy herd (the origin for two thirds of EU beef) and the continued impact of decoupling. These factors combined with rising cereal prices are forecast to reduce the incentives for intensive beef production systems. They will also reduce production from unprofitable production and hence overall output.

As regards the trends in the EU-12 MS which acceded the EU after 2004, the transition from central planning to a free market brought severe shocks to the livestock sectors of the transition economies. Demand-side shocks included rising consumer prices and falling real income that came with price and trade liberalization. On the supply side, producers faced falling output prices and

[1] See also the FAO-OECD 2008 – 2017 projections OECD-FAO (2008). Agricultural Outlook 2008-2017 - Highlights, OECD**:** 73.

[2] http://www.lmcni.com/filestore/bulletin/11_APR_2010.pdf

sharply rising prices for feed and other inputs. Producers also had to adapt to fundamental changes in the markets for land, labor, and capital that came about with the transition (Bjornlund, Cochrane et al. 2002). From 1989 to 2000 stocks declined with often more than 50%. Monogastrics and milk are on the rise in Poland and Hungary since the mid-1990s, while Romania stable in milk and egg since then. In Poland, Hungary, and Romania, cattle numbers stabilized after 1994 or 1995, once the transfer of animals into the private sector was complete. Poultry fared better in Poland and Hungary than in the other countries. The declines were much less, and, after 1993, poultry output began to grow in both countries, particularly in Poland. Several factors account for the growth of poultry output in Poland and Hungary. Consumers began to substitute lower priced poultry meat for beef, and producers were able to respond quickly to that shift in demand. In addition, a large share of poultry production was private in both countries before the transition.

Afore mentioned structural change in the dairy herds is very marked in the transition economy MS: while the number of cows was expected to decrease by 13 % between 2004 and 2008, the yield per cow is estimated to increase by 11 % (EC 2004). Consequently, the milk production decreases only by about 4 %, in some countries, like Latvia, it is expected to even increase or be at least stable. This implies that overall fodder demand will decrease but also the quality structure will change, as roughage and pasture will be substituted or at least supplemented by protein and starch containing feedstuffs.

The increase in poultry production will result in higher feed use of cereals, especially of wheat. Wheat use for feed purposes in transition economy MS was expected to increase by 23 % from 2000 to 2008 (absolute figures are 9.5 mio tons in 2000 and 11.7 mio tons in 2008), a rate that outperforms the growth of total internal use which is about 9 % for the same period (from 25.7 to 28 mio tons) (EC 2004). The feed use of coarse grains will also increase by the high rate of 22.7 %. Oilseeds are also expected to experience a growth in feed use.

3. Farming methods and farm structure across the EU

3.1. Beef and dairy production

The situation in the EU-15

Dairy farming systems remain characterized by an important diversity, despite the strong afore mentioned restructuring (the number of dairy holdings in the EU15 is now well below the one observed in France in the beginning of the 1970s), technical modernization and the wide adoption of the Holstein race[3]. Most salient aspect of this heterogeneity is the substantial variation in size (surface, herd and quota), making it hard to compare small units from the southern EU (but also Austria) with large units dominant in the UK, Denmark and the Netherlands. The heterogeneity also expresses itself through the natural production conditions, labor conditions, the (feed) resource base and the intensification level. The level of specialization also varies markedly between regions. The application of milk quotas and the development of different business forms constituted an

[3] This section largely draws on Chatellier, V. and V. Jacquerie (2004). "La diversité des exploitations laitières européennes et les effets différenciés de la réforme de la PAC de juin 2003." INRA Production Animale **17** (4): 315-333.

incentive for diversification towards annual crops, landless animal production or beef production (Chatellier and Jacquerie 2004).

The average milk quota per farm also varies strongly between dairy regions. Under 160.000 kg in Austria, Spain, Italy, Finland, Portugal and south Germany (Bayern), farm quotas exceed 400.000 kg in the UK, Denmark, the Netherlands and East-Germany. Dairy farms in the latter region are a rather special case for the EU: while of a very large size (664 ha and 1,3 million kg quota) and an important paid labor force, productivity is low and dependence on direct public aid is high (Chatellier and Jacquerie 2004). While representing only 11% of EU15 dairy farms in 2004, these over 400.000 kg quota farms produce 39% of milk supply. Still the number of under 100.000 kg quota farms remains important at EU level (38% of EU15 dairy farms in 2004, representing 10% of production). They are predominantly encountered in the southern dairy regions of the EU and in Austria. The number of registered dairy cow holdings with relatively low levels of cow numbers substantially increased since the EU enlargements. This highlights a 'long tail' in the structure of production whereby a majority of total dairy holdings are relatively small in terms of cow numbers and contribution to total EU production. These farms are probably less specialised than those accounting for the majority of production with dairying being one of a number of enterprises (mainly other livestock enterprises) undertaken. However, to these farms dairying as an activity remains an important part of total economic activity.

The beef and dairy economics in the EU-12

Without contradicting the above statement on the long tail due to enlargement, the situation of dairying in the Central and Eastern European (CEE) countries that entered the EU in 2004 and 2007 should not be seen as uniformly dominated by small holdings.

Among the countries of the 2004 enlargement, Poland is by far the largest country in terms of population, area and milk production. However, the average milk yield in Poland (4.0 ton/cow in 2002) is about 500 kg below the average in the eight CEE MS, and about 65 per cent of the average yield in the EU-15 (6.1 ton/cow in 2003). This relatively low milk yield is indeed the result of the large number of very small non-specialised farms in Poland, producing partly for own consumption and using mainly grasslands for feed (Jongeneel and Ponsioen 2006). But the two countries among the eight CEE MS with the highest average yields, Czech Republic and Hungary (about the EU-15 average), are the second and third largest milk producers, respectively, in the group. In these countries there are many large collective and cooperative farms, which use more modern technologies and concentrated feedstuffs as an important part of the feed ration. 95 per cent of Hungary's milk production meets EU hygiene standards, and similar high levels are reached in the Czech Republic (Jongeneel and Ponsioen 2006).

The differences in average yields between most of the EU-12 and the EU-15 remain large, which suggests that a large increase in yield is still possible and expected. A significant part of the milk production in the eight main MS is not processed in the dairy industry but either directly marketed or consumed by the farm family. In Latvia, Lithuania and Poland, only about 45 to 65 per cent of the milk production goes to dairies. Reasons for this include low quality of the raw material and high milk collecting costs. In Romania, most livestock is held on peasant farms averaging half a hectare in size. Production is primarily for subsistence purposes, and very little is marketed. Upon the transition to a free market, farmers, no longer able to afford a balanced feed mix for animals, sharply reduced the use of costly mixed feeds, switching to less expensive feeds that are poorly balanced with proteins and other supplements. Cattle producers turned away from relatively expensive concentrated feed in favour of forage crops and pasture grazing (Bjornlund, Cochrane et al. 2002).

In contrast with these subsistence situations, the share of deliveries to the dairy industry in the Czech Republic and in Slovakia is almost the same as that in the EU-15, around 95 per cent of milk production. In these countries, the dairy processing industry is relatively well developed and modernised (Jongeneel and Ponsioen 2006).

Main characteristics of EU dairy systems

Box 1 provides a description of the functioning of an average dairy system in the UK, extracted from (Garnett 2007), illustrating the complexity of dairy farming as practised on EU market oriented holdings throughout the EU.

Box 1 – The beef and dairy system in the UK

On average, dairy cows calve once every 385 days, and give birth to either a pure dairy or a 'beef cross' calf. In the latter case the father will be chosen from a beef breed. Dairy herds need to be restocked at the rate of roughly 20% a year to replace cows that no longer produce milk (as a result of old age, ill health, or poor yield). In order to achieve this 20% replacement rate, roughly half the best yielding dairy cows are impregnated with the semen from a dairy bull, although the proportion varies by system and year. Dairy cows that have reached the end of their productive lives are slaughtered and enter the meat chain. However their bodies yield very little meat as they have been bred in such a way that all their energy is directed into milk production.

The remaining milk cows are crossed with beef bulls, such as Charolais, Hereford and Aberdeen Angus breeds and their offspring reared for human consumption. In addition to these cross-breeds the pure dairy bred bull calves, born as a by-product of dairy heifer breeding, are also generally fattened as beef bulls or steers (neutered males).

Suckler beef on the other hand is obtained from cattle bred specifically for their meat yielding properties. These properties include the quality and quantity of muscle they put on (conformation) and the efficiency and rapidity with which they grow. A suckler calf is the offspring of a pure bred male (sire) and either a pure bred beef female (dam) or a beef-dairy cross. In other words they are of between 75-100% pure beef pedigree. The calf is fed on mother's milk until it is weaned at about 6 months. It can grow rapidly (up to 1.5 kg/day), and produces a high quality carcass. The weaned calf is referred to as a store animal and is either finished by the breeder or is sold on to another farm.

Some of the male beef cattle are castrated, partly to avoid unwanted breeding where cattle are raised in mixed sex groups and partly because steers are less aggressive, easier to manage and can be reared outside with less difficulty – bulls charging around the countryside tend to be fairly unwelcome. On the downside steers have a slower growth rate than their uncastrated counterparts. Bulls are generally kept inside and slaughtered by the age of 12-15 months whereas steers and heifers take around 18-24 months to reach slaughter weight.

Feeding the dairy herd:

A dairy cow will consume an average of about 20-22 kg dry matter a day, although in some high-yielding systems she can eat up to 28 kg. While grass is the best way, economically speaking, of feeding an animal it cannot provide the most concentrated nutrition, hence the use of other bought-in feed. In particular, a high yielding dairy cow cannot satisfy her metabolic requirements from a forage-based diet alone and as the proportion of high-genetic merit cows (cows with high milk yield potential) has increased (as cow numbers have fallen) so has the reliance on dietary supplementation.

Other sources estimate that, for dairy cows, between March and September about 50% of their diets (dry weight matter) consists of fresh forage and the remainder of prepared feeds. In the winter, 50% of their feed is silage and 50% concentrates. Expressed in terms of energy, the grass/silage element makes up roughly 40-45% of the diet; in terms of energy protein the grass:concentrates ratio would be 30:70. Another source estimated that, averaged over all the feeding systems, around 75% of the diet of ruminants is supplied by forage (including silage). A later paper by the same author, however, gives a lower figure of 60%. The reason for this discrepancy is that the use of compound feed for ruminants increased over this time, and continues to increase. Clearly the variation in estimates reflects the range of different systems and different farmer preferences.

Feeding the beef herd:

As noted, pure dairy-bred calves also enter the meat chain; indeed, these calves account for 65% of all meat output. They will be reared for the first 12 weeks of their life on formula milk and concentrates. Some will then go onto store producers (kept on silage and grass for 3-9 months before being sold on to finishers). Others will go directly to semi-intensive finishers and will be fed grass during the summer, and silage and concentrates during the winter. Others will go to intensive finishers where they will consume a mixture of oilseed cake, straights and straw. 45% of dairy calves are ready for slaughter by 20 months, 25% within 2 years and only 15% will be reared for a longer period than this.

Source: (Garnett 2007)

This general scheme illustrates that variation in dairy systems is strongly related to feeding strategies and thus influenced by bio-physical conditions. Bos et al. (Bos, Pflimlin et al. 2003) distinguish two general types of dairy farming with regard to climatic conditions. In Northern Germany, Denmark and Sweden the predominant strategy is to increase milk yields per cow. A high level of concentrate feeding strongly contributes to high milk yields. This strategy is mainly due to the relatively short growing season (5-7 months) which limits the grazing period. Furthermore, rainfall is not always sufficient for high grassland yields. Where climate is characterized by mild winters and high amounts of precipitation (Ireland, Western England, Brittany), milk production is based on a long grazing period on permanent grassland. Also the alpine regions are characterized by permanent grassland, but this is because arable farming is not possible in mountainous areas. In these grassland based dairy farming systems, the achievement of high milk yields per cow by means of concentrate feeding and breeding for high milk yield is generally a less important objective than maximizing milk yields from grassland.

Many other factors influence the strategy followed by the dairy farming system of a particular country or region. Bos et al. (Bos, Pflimlin et al. 2003) provide a synthetic description of the resulting strategy for a selection of countries and regions which have been annexed to this report (Annex 2).

The two general types described by Bos et al. also constitute a first order discrimination in the typology proposed by the Centre for European Agricultural Studies (CEAS) (CEAS 2000) for the EU15, distinguishing high input/output from low input/output systems (boxes 2 and 3).

Box 2 - High input/output systems

a) **Locations**. The Netherlands, England, SW Scotland, La Mayenne region of France, Western and SW France, Northern Italy, Sweden, Finland, Northern Spain, Denmark, Germany.

b) **Production**. These systems account for 83% of total EU dairy cow numbers (about 18.5 million head) and approximately 85% of total EU milk production (about 96 million tonnes).

c) **Structure**. They are characterised by having relatively large average herd sizes (eg, over 70 cows in the UK, but within a range that falls to about 44 cows (the Netherlands). These systems are also where most specialist dairy farms are found (data deficiencies preclude the provision of supporting data).

d) **Intensity**. Stocking rates tend to be high (eg, over 2.0 LU/ha/year but can be as low as 1.4 LU/ha/year), supported by relatively intense fertilisation (150kg N/ha to 300kg N/ha), use of buffer feeds (zero grazed grass (eg, former East Germany), maize silage and brewers grains are commonly used: eg, maize silage accounting for over 25% of the main fodder area) and use of concentrates which are usually fed to yield in the milking parlour (especially in the 'industrial' production systems of East Germany). Winter feed tends to consist predominantly of maize silage, although grass silage is used in regions such as Finland and Sweden where the climate is not suited to growing maize. Winter feed is supplemented with products such as cereals, brewers grain and wet beet pulp fed as straights or via concentrates.

e) **Calving**. Tends be all year round with a slight bias towards spring in certain countries, such as the Netherlands, in order to maximise the use of peak grass growth in spring and to match peak milk production to the perception that prices are usually higher in the summer and have traditionally been so. More northerly Member States such as Finland and Sweden have a slight bias towards autumn calving (August to October). Variability in calving by location is significant even within zones, regions or countries.

f) **Housing**. Cows are housed in the winter months (up to 8 months of the year in the more northerly parts of the EU) and in certain cases may be housed overnight in autumn and spring. The harsher the conditions, the longer the winter housing period becomes. In Finland and Sweden the period spent housed is even higher (between eight and ten months (depending on latitude)), but is constrained beyond this by animal welfare legislation which stipulates a minimum outdoor grazing period. The extreme form of housing can be found in the 'industrial' units in parts of the former East Germany (the new Länder) where cows are sometimes permanently housed.

g) **Replacement/age of herd**. Average herd age tends to be young which implies a relatively high replacement rate.

h) **Breed**. Specialist dairy breeds of which Friesian/Holstein dominates (ie, variants of which eg, British Friesian, Holstein (Prim'Holstein in France), Dutch Holstein). These account for almost all of herds (over 95%).

Box 3 - Low input/output systems

a) **Locations**. This type of system is essentially associated with the main form of dairy production in Ireland, although variations to this exist in some other regions such as the northern and western extremities of the UK, parts of northern and eastern France, some of the Azores and throughout the Atlantic and Continental zones (see section 3) where producers have taken up 'organic' production systems.

b) **Production**. These systems probably account for 6-8% of total EU dairy cow numbers (about 1.3- 1.75 million head) and about 4-5% of total EU milk production (about 4.8-6 million tonnes).

c) **Structure**. Farm sizes can fall within a broad range of 20 to 80 ha. Accordingly average herd size also falls within a fairly broad range (25-70 cows, with an average of about 30 in Ireland (the main location)). These systems include some specialist dairy farms and organic producers but mainly comprise mixed farms in which other livestock enterprises are practised (data deficiencies preclude the provision of supporting data).

d) **Intensity**. Stocking rates tend to be in the range of 1.0-1.4 LU/ha (1.9 LU/ha in Ireland). Where organic systems are practised stocking rates fall to about 0.8 LU/ha. Less than 30% of farmed land tends to be used for forage (mix of cereals and brassicas), with the rest being permanent grassland. Forage areas are supported by fertilisation levels of about 50-100kg N/ha (zero use in organic systems). Grazing is an important part of the feeding regime with use of concentrates not usually higher than 500kgs/cow. Winter diets tend to comprise a mix of grass and maize silage and hay and the summer diet is dominated by grazing. In organic systems areas of fodder beet and arable crop silage may be only half the corresponding area under conventional systems with greater use of clover and lucerne based silage.

Contrary to Bos et al., who claim a strong link between these two main strategies and climatic conditions, CEAS (CEAS 2000) claim that "systems are more influenced by market constraints than physical constraints. As a result, farms of different dairy systems frequently occur contiguous with each other." But as figure 2 shows they do discriminate at a second hierarchical level different high and low I/O systems for three main biogeographical areas.

Table 4.1: EU dairy systems

See Table 4.2 for typical threshold values for indicators of each system

CATEGORIES OF PRODUCTION AND REGIONS		FODDER AND FORAGE RESOURCES (LAND USE CATEGORIES)				
		SEMI-NATURAL PASTURES	***GRASSLANDS***	***CROPS & GRAIN MIXED***	***CROPS & GRAIN MAIZE***	***LIMITED GRAZING***
CONTINENTAL ATLANTIC BOREAL MACARONESIAN	*HIGH INPUT/OUTPUT*		G1 INTENSIVE GRASSLAND SYSTEMS (LEYS) GRASS 60% + CROPS	CG1 CONVENTIONAL MIXED SYSTEMS CROPS 50%+	M1 INTENSIVE MAIZE SILAGE SYSTEMS MFA = Maize 25%-60% CROPS 50%+	L1 INDUSTRIAL
	LOW INPUT/OUTPUT		G2 PERMANENT GRASSLAND SYSTEMS (Lowland) GRASS 80%-100%	CG2 LOW-INPUT AND ORGANIC MIXED SYSTEMS		
ALPINE AND BOREAL	*LOW INPUT/OUTPUT*	P1 TRANSHUMANT SYSTEMS	G3 PERMANENT GRASSLAND SYSTEMS (Mountain) GRASS 80-100%			
MEDITERRANEAN	*HIGH INPUT/OUTPUT*					L2 MEDITERRANEAN COMMERCIAL SYSTEMS
	LOW INPUT/OUTPUT			CG3 MEDITERRANEAN MIXED SYSTEMS (SMALL SCALE)		

Figure 2

Some characteristics of the Mediterranean high and low I/O systems represents differences with respect to the dominant "Atlantic" characteristics of boxes 2 and 3 which are important in the environmental context of out study. Mediterranean systems probably account for only 7% of total EU15 dairy cow numbers and about 5% of total EU15 milk production. The commercial specialist systems (the high I/O system), where 50-60 head herds are common, tend to keep cows indoors all year round with zero grazing. On mixed farms (the low I/O system), where herd size can be as low as 10 head, stocking rates tend to be low (under 1.0 LU/ha). Feed in the commercial farms comprises a mix of farm grown roughage (a mix of maize and ryegrass silage and alfalfa hay). On the mixed farms grazing is used for 3-4 months per year in the spring with feed for the non grazing seasons derived from traditional polyculture systems (mix of tree crops, vegetables and cereals). The latter system makes very little use of mineral fertilisers (slurry and manure are however widely used in the forage cultivation system). On the commercial dairy farms there is widespread use of irrigated maize silage and dry-land ryegrass growing which is cut 2-3 times per year.

3.2. Sheep and goat farming

The number of sheep and/or goat holdings is important and exceeds the number of dairy or even cattle farms in general in the Mediterranean MS (incl. Portugal, but excl. Slovenia), as well as in Bulgaria, Romania, Hungary, Czech Republic and even in the UK. But farm herd sizes are generally small, output levels low. Statistics and studies describing EU small ruminant production systems are very scarce. They play an important role in the subsistence mixed farming systems of the EU-12 MS, but here information is very limited and often unreliable. Many breeds are adapted to living in harsh conditions and to feeding on coarser grasses, so they can often be found in poorer and more rural parts of the EU. Most of the remaining herd is primarily dedicated to milk production, but again because of the small holding size, as well as the frequent on farm or otherwise local transformation (milk is nearly exclusively used for cheese), production data are scarce. Much of the cheese production takes place under certified and controlled labels, generally limiting the scope for very intensive systems. Grazing is generally important, with farm grown roughage supplementing in the too cold or too hot and dry periods. A variable level of complementary concentrate feeding is common in milk production oriented small ruminant systems.

3.3. Pig production

EU pig production is generally an intensive, indoor , large scale business which combined with the much weaker dependence on the local resource base and bio-physical conditions leads to a relatively low level of variability in production systems. Both pig and poultry play an important role in mixed livestock small holdings throughout the EU, particularly in the CEE MS, but this system represents little in terms of overall herd size and still much less in terms of contribution to overall production (which strongly contrast with e.g. the situation in the world's largest pig producer China where still well over half the production originates from such small holder systems.

Pigs are raised to produce piglets or to produce meat. Sows raised for breeding are housed in different systems from pigs raised for meat -- fattening pigs. Weaning usually takes place at four weeks, after which piglets are mixed with other litters in special housing systems for weaners. The average EU litter size is roughly 11. When the piglets have reached approximately 30 kg in weight, they are often moved to other accommodation to finish their growth before slaughter takes place at 5.5 to 6.5 months of age. In most EU countries, the live weight at slaughter is between 105 and 115 kg (Reuters 2007). In contrast with poultry production, pig farming is a far less integrated industry. In the UK only about 5% of breeding pigs and 28% of rearing and finishing pigs are grown on farms under the direct control of processors; the majority are reared on independent farms. Many of these are, however, contracted to a processor, some directly but the majority through producer groups (Garnett 2007).

Pigs consume both prepared compound feed and by-products from other parts of the agricultural and food industries. Drawing again from Garnett' description of the UK situation, valid for a very large part of EU production (Garnett 2007) pig compound feed is largely made up of cereals (60%) and oilseeds and pulses (29%). The remaining 11% is comprised of oils, vitamins, minerals and amino acids. Co and by-products will vary according to availability and include biscuit fragments,whey, yoghurt tank washings and brewing by-products. Approximately 30% of pig producers currently use liquid feeds as opposed to dry compound feed or home-mixed rations. Liquid feeding is not new to the industry, but UK producers have been slow to take advantage of it, mainly because of the high capital cost of conversion. Liquid feed is made of whey or potato starch with cereals, oilmeals and various vitamins added. There are three main stages in pig rearing. The first encompasses activities to do with breeding, gestation and farrowing. The pigs are then weaned, at which point they move onto the second or nursery stage. After this they enter the final or 'finishing stage'. Each stage in a pig's life requires a different diet. While some farms will undertake all stages in the pig rearing process, others may focus on just one or two of the stages.

One of the few pig farm system characteristics that varies considerably throughout the EU is farm size. Monteny et al. (Monteny, Witzke et al. 2007) provide size distribution information for each MS. While the majority of farms, also in the most important producing countries Spain and Denmark, generally have a few hundred fattening pigs, there is generally a small fraction exceeding the IPPC threshold (>2,000 fattening pigs; >750 sows), contributing very significantly to overall production. While representing only 0,3% of EU fattening pig farms, they contain 16% of the population. 41% of the population is contained in holdings with over 1000 heads, representing 1,0% of the number of holdings. Sow farm figures are rather similar. Virtually all MS have a substantial portion (>>10%) of their pig population in such large farms, a notable exception being

Poland with only 4% of fattening pigs and 5% of sows in IPPC farms, and more surprisingly also France (7% of each) and Belgium (7 and 3% resp.). In the CEE MS some extremely large holdings can be found. In Romania for example, following the transition from a centrally planned to a free market economy, large cooperatives were liquidated early and land restituted to its former owners. However, most state owned farms continued to exist and to benefit from subsidies not available to private farms. As of 1997, 34 percent of the hogs and 19 percent of poultry numbers were still raised on these state farms. The state livestock complexes were huge, vertically integrated enterprises. Some of them had as many as 800.000 hogs (i.e. some 12% of the national pig population on one single "farm"!). They typically engage in every stage of the production chain: farrow to finish, slaughtering, processing, and even retailing. Many of these farms are located in the prime grain-growing regions and produce their own feed as well (Bjornlund, Cochrane et al. 2002).

3.4. Poultry production

The main characteristics described for EU pig production in the preceding section largely apply to poultry production: Poultry meat tends to be produced in barns or other enclosed shelters, although outdoor husbandry is increasing gradually. Feeds are made up from locally grown or purchased ingredients, often grain-based, or bought in as prepared "compound" feedstuffs (Reuters 2007). Most of the chickens we eat are raised in intensive systems in large purpose-built houses, on deep litter of chopped straw or wood shavings. Chickens are kept for about 6 weeks, until they reach a weight of around 2.2 kg. Turkeys are slaughtered at around 20 weeks when they weigh 13 kg. The main contrast with the pig sector, as also stated above, being its higher level of integration. The mainstream broiler industry is highly integrated and concentrated. The processor companies often own or control all stages of production, from the supply of day-old chicks (they also usually own at least some of the breeder capacity and hatchery facilities) through feedstuff manufacture and supply to delivery of the poultry meat to the retailer. 60% of broiler chickens today are grown on farms owned directly by processors; the rest are grown by independent farmers, almost all of whom are contracted to a processor (Garnett 2007). Of the raw material input to the chicken feed milling sector, about 89% consists of cereals, soy, oilseeds and pulses.

Concerning layers, the majority of the eggs produced in the EU come from caged systems. In already standing conventional caged systems, a minimum of 550 cm^2 per bird is required. However systems built since 2003 must allow 750 cm^2 per bird and the cages be 'enriched,' as it is called, with a nest, perching space and a scratching area. Food is supplied in troughs fitted to the cage fronts and an automatic water supply is provided. The units are kept at an even temperature and are well ventilated. Electric lighting provides an optimum day length throughout the year. In the UK barn systems produce around 7% of eggs (Garnett 2007). Here the hen house has a series of perches and feeders at different levels and the stocking density must be no greater than 9 hens per square metre of useable floor space. The free range system is the third alternative; this produces around 27% of eggs produced in the UK.

Regarding farm size the situation is rather similar to that of pig holdings (see above). The situation is still more extreme though. In the EU, IPPC poultry farms (>40.000 head) represent only 0,1% of laying hen farms, but contain 59% of the laying hen population (Monteny, Witzke et al. 2007)! For broiler farms these figures are resp. 0,5% and 64%. In Greece, Ireland, Austria and Finland the laying hen population in IPPC farms represent less than 30%, while this is more than 70% in Spain Italy, Czech Republic and Slovakia: the absence of a spatial pattern hints at the "landless" character of production. Moreover for broiler the situation is similar, but high and low share MS are not the same.

During transition poultry fared better in Poland and Hungary than in the other CEE countries. The declines were much less, and, after 1993, poultry output began to grow in both countries, particularly in Poland. Several factors account for the growth of poultry output in Poland and Hungary. Consumers began to substitute lower priced poultry meat for beef, and producers were able to respond quickly to that shift in demand. In addition, a large share of poultry production was private in both countries before the transition (Bjornlund, Cochrane et al. 2002).

4. Land use related to livestock in the EU and abroad

4.1. Methodology for estimating the feed origin for different species

Information on feed is an important component of a study assessing livestock induced emissions. Not only because feeding ratios determine to an important extent the inefficiency of feed conversion, and thus manure production and related emissions, as well as enteric fermentation of ruminants. Feed also represents livestock's link to land use. The livestock sector is by far the largest anthropogenic land user in the world, just as it is known that this land use on average also induces important gaseous emissions (Steinfeld, Gerber et al. 2006).

Identifying the amount and the location of land dedicated to feed production is required before one can estimate gaseous emissions on the basis of information concerning agricultural practices and land use competition induced land use change specific to these locations. This in turn requires identifying the raw materials mobilized to produce the feed fed to each of the animal species in each of the life stages in each of the production systems. This is a highly complex task, as the information on feed provided in the preceding section also indicates. Additional factors make this task difficult:

1. information on feed composition in literature is scarce and non-exhaustive, whereas as it is well known that raw material composition can vary between regions as a function of differences in comparative advantages;
2. none of the existing statistical databases allow to derive detailed feed information, but only for animal production in general, and not consistently. Also, statistics on commodity flows like trade data are not differentiated according to their use;
3. feed can be produced on-farm, but important quantities are also purchased as compound feed on the market, while feed manufacturers do not easily disclose information on raw material composition not only because of confidentiality concerns, but also because of the strong temporal variability of this composition, strongly influenced by fluctuations on the commodity markets;
4. "by-products", i.e. leftovers from the processing of agricultural produce for another production purpose, constitute a significant part of livestock feed in many production systems (with the exception of poultry systems). This adds another step in retracing the raw materials at the origin of feed where not only the by-product fraction is not well known, but nor is the original raw material. For instance, there is uncertainty about whether molasses cake originate from cane or from beet, as well as about the cereals at the origin of brewers grains residues and about the fruit at the origin of "citrus pulp".

In this context our study proceeds on the basis of the agro-economic model CAPRI (see 1st interim report), where nutritional models are used to estimate the broad feed formulation needed to match regional animal population figures with regional production data. Raw materials are then allocated to the broad categories of this feed formulation on the basis of regional and national production data, economic information and international trade data. This allows obtaining a "consistent" estimate, but whose link with reality remains to be verified. Expert validation is needed, but the general feed use information provided by the supply utilization accounts of statistical databases mentioned at bullet number 2 above also constitutes a valuable source for validation.

The below sections present the general (i.e. not species specific) feed use information of a range of commodities and the estimates of the corresponding land use. The estimates result from the combination of various Eurostat databases (2005 – 2007 average figures), supplemented with information from FAOSTAT and UN ComTrade databases. While useful in validation efforts of GGELS' subsequent quantification tasks, the resulting picture also constitutes valuable information on the EU livestock sector's "footprint" in its own right.

4.2. Total land use requirements for animal feed – estimation method

This section assesses the total required land by livestock in every member state. The starting point are the official statistics on animal feed demand as given by the supply balance sheets of the Eurostat database. One implication of this is that most by-product feed use is not accounted for. It is important that within the CAPRI model a realistic share of feed is put on the account of by-products, in order to avoid over-estimation of other commodities' use. In the top-down land use accounting of this section though, omission of by-products does not have a strong impact because by-products like molasses, cereal brans and, to a lesser extent, citrus pulp represent a small fraction (in weight terms) of the original product, while its per unit value is well below that of the "main" product: their combination results in a very low value fraction of the original agricultural produce and it is on the basis of this value fraction that a portion of land would be assigned to feed use. It is important to note that in our study protein-rich feed components[4] like oil crop cakes (from soja bean and rape) are not considered by-products, because these cakes represent a considerable part of the original raw product's value thus constituting an important driver of production (see also Box 4).

There are **three main groups of animal feed components** which require a different accounting procedure:

1. grass and fodder;
2. directly fed food crops;
3. the feed part of "food-feed" crop, i.e. the oil cakes.

Concerning the first category, all permanent grassland and land under temporary grass and other green fodder land (mainly fodder maize) as well as fodder beets (all taken directly from Eurostat's agriculture land use database) is fully put on the account of each MS' livestock sector, the bulky material implicitly being supposed to remain within the domestic market.

[4] An important protein rich feed component not considered by this report is fishmeal, since there is no implication for land use (and thus land use related emissions). It needs to be assessed though whether GHG emissions related to fishing, fish processing and fish meal transport can be ignored: The EU currently typically imports some 550 thousand tons of fishmeal for animal feed, mainly from Peru and Chile.

Food crop land used for animal feeding is assessed starting from the aforementioned supply balance sheets. The following crops with a significant feed use share have been considered:

- cereals: common wheat, durum wheat, barley, grain maize, oats, triticale, rye and meslin;
- root crops: potatoes, sugar beets;
- oilseeds: soya beans, sunflower, rape and turnip rape;
- pulses, in grain.

An important hypothesis that underlies the accounting here is that feed supplies originate preferentially from the domestic market. This is justified by the following reasoning: if the agricultural sector of a country cannot meet or chooses not to meet the domestic demand for one of these commodities itself, this means that another country disposes of a comparative advantage in producing that commodity, generally inducing a higher quality compared to the domestic produce. And even if of the same quality, transport costs of these still rather bulky products will lead to a higher unit price for the imported produce, and it is supposed that the more expensive produce is preferentially destined to food use.

As a consequence of this hypothesis, feed is only considered as imported whether domestic production is insufficient. For feed supplied by the domestic market the corresponding land use is estimated on the basis of the average national yield (crop area and harvested production taken from Eurostat's "farm to fork" database). For imported feed area estimates are based on the average national yield of the most common country supplier (generally a higher yield than that encountered in the importing country), even if some produce may originate from outside the EU.

For oil cake demand, first the national supply potential is considered, which covers domestic production of oil seeds reduced by the share already fed as straights, plus oil seed imports: all this produce can safely be assumed to be crushed for oil extraction and cake production. If this supply potential meets demand, the oil cake value fraction of the corresponding land use (estimated as above) is put on the account of feed. Value fractions were taken from Chapagain & Hoekstra[5] and are 2/3 for soya cake, 1/3 for rape cake and 1/5 for sunflower cake. For the share of demand not met by domestic cake supply calculations are run backwards, "transforming" cake into beans/seeds by division with the product fraction, then dividing with yields of the important producer MS (or from Latin American suppliers in the case of soya bean), again multiplying the resulting required area with the corresponding value fraction.

Box 4 - The importance of soy for the EU livestock

Soya bean is a very important element in the diet of livestock since soybeans have several practical and nutritional advantages over other oilseeds. Compared with rape seed (which can be and is grown in the EU) soy has a higher protein and lower fibre content. Soy is also less oily and more protein rich than other seeds and so the extraction process produces a relatively greater proportion of cake to oil.

In particular, soy is the preferred ingredient for pig and poultry diets as it contains a better mix of the essential amino acids needed by animals (mainly higher lysine) which makes it more digestible – an important consideration for monogastrics. In ruminant diets, rapeseed is more commonly substituted because it is cheaper and achieving a specific amino acid mix is less of an issue. Ruminants can also cope with certain anti-nutritional properties in rapeseed

Measured by weight, every 100 kg of soybean yields 20 kg of oil and 80 kg of cake or meal (Chapagain and Hoekstra 2004). We have already observed that soy produces a lower yield of oil but a relatively higher quantity of high quality protein than other oilseeds. While on a weight basis the oil is more valuable than the cake, in absolute terms the reverse is true, since the absolute amount of cake produced is so much greater than the oil. The relative economic balance

[5] Chapagain and Hoekstra 2004

between soya cake and soy oil fluctuates, but as a general rule the cake and oil account for two thirds and one third of the crop's economic value respectively (Chapagain and Hoekstra 2004). And while soy oil ranks in value as one of the less valuable vegetable oils (peanut, cottonseed, corn and rapeseed oils attract higher market prices), soymeal cake carries the highest value of the oilseed cakes. Economically, therefore, soycake should by no means be classed as a by-product since it has very considerable economic value in its own right. So does demand for the soycake as a feedstuff actually drive growth in soybean production? In short – yes.

Four countries – USA, Brazil, Argentina and China – account for almost 90% of world output. Asia (excluding China) and Africa, the two regions where most of the food insecure countries are located (and where small-scale soy production is most likely to be found), together account for only 5% of production. Growth in US soy production is now slowing due to limits on the amount of land available. The major areas of soy expansion, therefore, are in South America, China and India. Of these, South America is by far the most significant and it is here that soy production's environmental – and more specifically greenhouse gas – impacts loom largest.

Source: (Garnett 2007)

Box 4

The total figures that result from this accounting have a supposed link with real feed land use in a country only in cases where this country does not exchange any significant amount of feed or related raw materials with any other country. The figures represent an estimation of the feed land use "footprint" of every MS' livestock sector, which over estimates its national feed produce use in MS with significant imports (e.g. cereal feed use in the Netherlands and Belgium, see below). At the same time some MS are important feed suppliers to other MS, their own livestock sector's feed land use representing only part of the total national area dedicated to feed production (e.g. France).

Table 2 summarizes the results per member state and at EU level. The main result is that if the EU would produce by itself all feed its livestock sector requires (supposing biophysical conditions allow), nearly 2/3 of the entire Utilizable Agricultural Area (UAA) would be needed to be dedicated to this.

For some small MS with a substantial size livestock sector this figure approaches or even surpasses a 100% of the UAA (e.g. resp. Slovenia, Denmark and the Netherlands, Belgium). For 25 out of the 27 MS this figure exceeds ½ the UAA, while for 18 MS this share is 2/3 or more. It appears that there are only a few MS (particularly Bulgaria, Ireland) where permanent pasture makes up a very large share of the feed area. Except for Hungary and Bulgaria, all MS need to dedicate over 40% of their arable land to feed production. Some MS that are either small with respect to their livestock sector's size (NL, BE) or that dispose of relatively little arable land (PT, MT) more arable land than the total those MS dispose of is required to feed their livestock herds. For the EU as a whole this figure approaches 60%. A large part of this land is dedicated to fodder production, but food crops play an important role too. Would cereal feed indeed preferentially be sourced from domestic production, 53% of the EU's cereal production area would be dedicated to this. Even for an emblematic food crop like wheat this share represents 37% at EU level. Even large MS like Spain would dedicate a large majority of their wheat production area to their domestic livestock sector (64% in this case).

The share of animal products in agricultural output (section 2.1) does thus not reflect its economic importance in the food sector: much of the other agricultural output is for feed, not food, increasing the importance of animal food products in relative terms.

4.3. Estimation of land use of imported animal feed

Since feed imports from outside the EU are significant, the total feed land use figures do not correspond to actual feed land use in the EU. For some of the feed products (e.g. root and fodder crops) we can though safely suppose that the total land use is actually close to reality at EU level, since imports are insignificant and their bulkiness prevents from long range transport. The same accounts for cereal crops like grain maize, barley and oats largely cultivated for feed use.

The single most important feed import into the EU consist of soya bean and its cake. Since soya bean cultivation in the EU is only of some significance in Italy and Rumania, excluding the entire soya area from the EU land use balance should get us close to the actual EU feed land use. This results in an estimate corresponding to 60% of the UAA (only 5% down) and exactly 50% of the EU arable land. Still five MS would need to dedicate over 85% of their arable land to feed, which points at the importance of transfers between MS.

The EU imports of soya bean and cake comes largely from South America, mainly Argentina and Brazil. The arable land the EU "virtually imports" from these countries would correspond to about 9% of EU arable land. This may be a slight under estimation since according to the Eurostat feed demand data just over 30 million tons of soya bean cake would be consumed annually, while according to the UN trade data base Comtrade the EU imported an equivalent of about 35 million tons in 2007, which confirms the magnitude of the figure. The over 10 million ha of soya land the EU “imports” would represents about 26% and 34% of the total 2007 soya export value of respectively Argentina and Brazil.

To have a more in depth analysis of land use outside the EU, all MS that have to import (according to the above scheme) substantial quantities of a given feed commodity (only those fed as straights) were selected. The share of imports from outside the EU was assessed and a corresponding share of the virtual land imports of the commodity attributed to outside EU land use. Adding up land of all commodities considered per MS except for oil cake, shows that Spain and Portugal stand out as the main extra-EU straight feed importers. Some seven MS import significant quantities of soya bean for straight feeding. Spain and Portugal particularly stand out by the importance of their extra-EU grain maize feed imports, again mainly from Argentina but also from Ukraine, while Spain also imports a substantial amount of dried pulses for feed from a range of countries (Canada, USA, Ukraine, Argentina). At EU level grain maize land use outside the EU would be the most important (some 224 thousand ha), after soya bean and its cake, followed by dried pulses (204 thousand ha) and sunflower cake (176 thousand ha). The new total of a over 11 million ha would then correspond to about 10% of the EU arable land, i.e. considering also the non-soya feed land use outside the EU only adds about 1%.

5. Conclusions

The overview provided by this report, largely restricted to characteristics at national level, provides a broad but good understanding of the EU livestock sector’s complexity. Throughout the EU the livestock sector is a major player of the agricultural economy and its land use is massive. The relative importance of different sub sectors varies enormously among MS, influenced at the same time by cultural values and bio-physical conditions (pork in Spain and beef in Ireland), while economic conditions also interfere (small ruminants often playing a larger role in more subsistence production oriented economies). Then within each sub sector a range of production systems occurs. While this reported describes these in broad terms, a spatially and thematically more detailed analysis is currently ongoing which will result in a zoning at NUTS 2 level of dominant production systems for a range of six species.

This report assesses the land dedicated to the production of feed for a range of commodities. The estimates, resulting from the combination of various databases, will be useful in validation efforts of GGELS' subsequent quantification tasks. The resulting picture also constitutes valuable information on the EU livestock sector's "footprint" in its own right.

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Annex 1.1 Meat production (2007 data, where absent completed with most recent data over the 2003-2006 period)

Member state	All Meat			Production per category (1000 t)						
	1000 t	Self sufficiency (%)	Consumption per capita (kg/head)	Milk	Egg	Beef	Pig meat	Sheep and goat	Poultry meat	Other animal produce
BE	1879	165	100	2943	174	271	1018	4	454	36
BG	236	63	49	801	99	22	76	21	116	0
CZ	663	na	na	2899	140	80	359	2	222	0
DK	2133	394	107	4619	78	129	1749	2	171	3
DE	7802	101	90	28403	778	1186	4985	26	1142	90
EE	68	77	71	692	10	15	38	1	12	0
IE	1085	272	105	5268	46	540	231	67	123	4
GR	101	90	10	774	113	39	55	7	29	1
ES	5924	115	123	6335	924	682	3191	233	1308	170
FR	6527	106	102	24374	952	1532	2281	126	1810	315
IT	4280	74	91	11062	743	1110	1559	61	984	290
CY	102	90	144	135	8	4	55	7	30	1
LV	84	55	65	838	42	21	40	0	21	1
LT	174	95	52	1931	59	38	99	1	68	0
LU	21	61	93	274	1	9	10	0	0	0
HU	946	113	82	1842	167	35	489	1	376	10
MT	22	59	93	41	7	1	10	0	7	2
NL	2257	188	83	11128	615	365	1253	16	534	2
AT	948	108	100	3130	95	218	536	6	124	7
PL	3636	na	na	12096	556	355	2093	2	1143	54
PT	904	73	109	1969	122	92	386	26	316	24
RO	1183	79	72	4997	338	231	491	73	305	5
SI	139	na	na	666	23	38	34	0	67	0
SK	235	70	65	1302	73	23	114	1	84	4
FI	407	107	73	2356	58	87	204	1	87	15
SE	579	82	79	2986	108	142	289	4	106	18
UK	3680	73	82	14073	634	882	739	325	1452	12
EU27	46013	na	na	147933	6963	8146	22384	1014	11091	1063

Annex 1.2 Animal Productivity across the EU (2007 data, where absent completed with most recent data over the 2003-2006 period)

Member state			**Meat Productivity per category (kg/head/y)**[6]			
	Cow milk (kg/head)	Egg[7]	Beef[8]	Pig meat	Sheep and goat[9]	Poultry meat[10]
BE	5613	20,9	143	164	21	1,54
BG	2384	25,8	79	86	8	1,88
CZ	7116	14,6	83	135	10	1,04
DK	8382	28,6	130	133	20	1,42
DE	6949	18,3	139	170	13	2,58
EE	6646	1,4	115	104	8	na
IE	4844	27,7	112	147	19	1,58
GR	5160	21,1	74	53	1	0,25
ES	7013	30,4	120	122	9	2,20
FR	6485	19,3	114	152	14	2,35
IT	6015	17,2	178	164	4	2,56
CY	5696	18,1	109	117	11	1,97
LV	4647	31,5	97	89	7	1,47
LT	4774	na	98	107	11	1,84
LU	6822	na	80	151	5	na
HU	6926	25,6	92	119	5	2,49
MT	5413	18,6	118	127	0	1,09
NL	7469	14,6	157	107	8	1,10
AT	5968	15,5	148	148	15	2,16
PL	4518	21,5	130	119	4	1,91
PT	6440	78,3	81	163	7	1,43
RO	3177	188,0	192	73	10	3,01
SI	5726	25,1	105	63	0	2,32
SK	7225		91	123	3	1,35
FI	7955	13,5	143	143	6	1,50
SE	8165	18,7	123	167	8	
UK	7115	20,2	109	151	14	1,71
EU27	6119		126	140	9	1,94

[6] "Usable" production distributed over the standing population, the latter corrected for net flows of live animals (i.e. exported produce not accounted for in the national production figure)

[7] Kg per hatched layer

[8] Productivity per "non-dairy" cattle, i.e. a commission by including dairy heifers compensated by omission related to excluding culled dairy cows entering the meat chain

[9] Low productivities largely due to the impossibility to differentiate small ruminants mainly kept for milk production. Production statistics seem unreliable as well

[10] Kg per hatched broiler, i.e. an imperfect productivity measure not accounting for life time differences

Annex 2 Selected dairy farming system description (Bos, Pflimlin et al. 2003)

Denmark

In Denmark, forage production is typically part of a crop rotation scheme. This system is frequently addressed as 'ley farming'. Some of the reasons that explain the preference of crop rotation systems at the expense of permanent grassland are:

• Grassland yields are limited by a short growing season and water shortage in summer (sometimes drought periods)

• Water shortage is reinforced by sandy soils upon which most dairy farms are located; under these circumstances permanent grassland would have to be renewed regularly due to sward deterioration, yield decline and increase of weeds

• Cultivation is always possible on sandy soils

• As a consequence, it is a short way from regular grassland renewal to a ley system; newly established grassland provides a higher yield level and higher forage quality than permanent grassland

• N transfer from the ley phase to subsequent crops (cereals) is another advantage

Typical crop rotations consist of spring barley for whole-crop silage with undersown grass/clover, 1-2 years grass/clover for conservation and/or grazing, and two years of cereals. Cultivation of maize is restricted by the short growing season and cool summers. Silage maize is grown nly in the southern parts of Jutland where it replaces whole-crop silage of cereals. White clover has successfully been re-introduced in Denmark, which was facilitated by the crop rotation system with short-lasting leys and, on many farms, irrigation facilities. Furthermore, Danish regulations strictly limit the use of mineral N fertilizer by a 'nitrogen quota'. Farms without irrigation facilities sometimes rely on red clover/grass because red clover is less susceptible to water shortage. Leys are predominantly used by mixed cutting and grazing. On average, two-thirds of the grass/clover area are grazed. However, with increasing farm and herd size there is a tendency towards year-round indoor feeding.

The Netherlands

The Netherlands have the highest population density within the European Union. More than in any other country there is an intense pressure on land due to the requirements of industry, infrastructure, housing, agriculture and nature reserves. Consequently, land and quota prices are higher than in other European countries. This structural framework explains why Dutch agriculture is characterized by an exceptionally high intensity with regard to the use of external inputs such as mineral fertilizer and concentrates. High N emissions per unit land and high levels of P accumulation in agricultural soils are the consequential drawbacks. Climatic conditions favour grass growth, which is the dominant forage crop on Dutch dairy farms. Silage maize is grown particularly on sandy soils in the southern and eastern parts of the country. Grassland is predominantly used as permanent grassland dominated by Lolium perenne L., temporary grassland is of minor importance. Grassland utilization gives priority to grazing as this is the cheapest way to convert grass into milk. On the major part of the grassland area, rotational grazing at the stage of maximum herbage digestibility is integrated with cutting of the surpluses for silage. Especially in the Southeast, where dairy farming is most intensive, restricted or zero-grazing systems are becoming more important.

Ireland

Dairy farming in Ireland is characterized by N-intensive but capital-extensive grassland-based production systems. Climatic and soil conditions (750-1500 mm rainfall per annum, long grass growing season of 250-330 days per year, heavy and poorly drained soils especially in the North and West of Ireland) largely dictate the reliance on permanent grassland. Consequently, dairy farming in Ireland aims at a maximum milk production from grazed grass. This is facilitated by relatively cool summers which help to maintain highly digestible swards throughout the grazing season. The Irish system is based on compact spring-calving between February and April. Grass silage is fed in the winter period between October and March, of which a considerable part falls within the dry period. Concentrates are supplemented only in the early lactation (February-May). Milk production is thus highly seasonal with most of the milk produced between March and November. The most commercial, economically viable dairy farming enterprises are located in the South-West of Ireland. These farms also have the highest input of organic N to agricultural soils. On most Irish dairy farms beef production is a major second enterprise. Grassland management gives priority to grazing. Depending on the intensity of a farm, one or two silage cuts are included in spring or summer. The Irish low-cost system, aiming at minimum winter feeding, concentrate supplementation and replacement, depends strongly on seasonal calving in spring. This, in turn, requires a calving interval of around 365 days, which can be achieved only with milking cows of high fertility and body condition. As a consequence, the genetic merit of the Irish dairy herd (mostly British Friesian) is relatively low for milk production. Milk output per cow remained almost constant since 1997 apart from a slight but progressive increase on farms at the upper end of the range. The highly seasonal scheme of milk production, which limits the development of value-added consumer-orientated products for EU markets, is surely an important reason for the lack of capital in the Irish dairy sector. It is, however, expected that dairying will concentrate in the South-East of Ireland at the expense of smaller non-viable farms in other parts of the country.

The alpine regions

In the alpine regions of Austria, Switzerland, Southern Germany and parts of France and Italy, agriculture can be characterized as dairy farming on permanent grassland in the mountainous areas, with arable farming on the less sloped soils in the valleys. On most of the sloped fields tilling is either not possible or not recommendable due to the risk of soil erosion. Permanent grassland is thus the only possible crop. Generally, dairy farms are relatively small compared to other European regions. Average farm sizes are in the range of 15 ha, with a considerable proportion of part-time farms. Conservation of landscape elements and tourism are important in the alpine regions and often provide a considerable part of the farmer's income. Similar to grassland-based systems in other European regions such as Ireland, maximizing milk production from permanent grassland is a major objective. However, the growing season is relatively short, which implies a higher amount of winter feeding than in other permanent grassland regions. Usually, 2-3 cuts are included in a rotational grazing system. Since cheese production is an important enterprise of the alpine dairy sector, hay is fed instead of grass silage on many farms in order to meet the requirements for cheese production. At higher altitudes permanent grazing during the summer months (‘alp grazing’) is still a common feature.

Italy

The production of beef meat and cow milk is by far the most important husbandry activity in Italy. Pig production comes second. There are 1.7 million dairy cows (45% of the total of cattle LU in Italy) and nearly 80 000 dairy farms. Dairy production is therefore very important in Italy, especially in the North. In the last ten years, the number of stocked animals has strongly decreased in the cattle sector (-21%). This is the result of a sharp decrease in the number of farms (-46% over 10 years) and the concentration of animal husbandry in larger farms. The total number of pigs and poultry has been rather stable over the last ten years, even though they are also concentrating in larger farm units.

In Italy, cattle, pig and poultry livestock production is traditionally concentrated in the northern regions (particularly in the Po plain) where soil, climatic and infrastructural conditions are the most favourable. More than 68% of cattle, 77% of dairy cows, 83% of pigs and 74% of poultry are concentrated in these regions. Sheep and goat production occurs mainly in central and southern regions.

The distribution of crops shows that maize is traditionally the reference crop for dairy farming. This cereal is both grown for the production of grain (26% of the farm surface) and for silage (20%). Maize silage is directly used on the farm. Maize grain (dried and stocked inside or outside the farm) contributes also directly to the feeding of farm animals. More traditional forages are represented by rotational and permanent meadows (appr. 19% of the farm area). Meadows normally produce hay, however the first and the last cuts are less frequently used for silage production. Grazing is very rare. White clover is the dominant legume during summer in most permanent and in some rotational meadows. Lucerne is frequently cultivated in pure stands in rotational meadows. Other, less frequently cultivated forage crops are winter Italian ryegrass (often in combination with maize) and winter barley or triticale harvested for silage making. Winter wheat and a few other arable crops complete the list of cultivated crops. If Italian dairy production is compared with that of other European countries it should be noted that the main difference is the lack of grazing, as animals are normally housed indoors year-round.

France

Herbivores occupy about 60% of the Useable Agricultural Area (AA) whilst about 30% of the AA is valorised for dairy production. Cereal crops cover about 45% of the total AA of the country and forage areas therefore represent 55% of AA. Within this forage area, the area always under grass, consisting of both permanent grassland and summer pastures, covers 10 million hectares or about 70% of the forage area (FA). However, this area has declined by 30% in 30 years. Temporary grassland covers 2.6 million hectares and is to be found essentially on dairy farms. Grass/legume mixtures now represent more than two thirds of sown grassland. Finally, maize silage, intended mainly for dairy production, covers 1.4 million hectares. This forage crop has developed alongside the intensification of dairy farming in France, as its area has multiplied fourfold in 30 years. The number of dairy farms was 128,000 in 2000 and has diminished by 70% since 1984, when quotas were introduced at EU level. Remaining farms have 4.2 million cows, i.e. an average of 33 cows per farm. The dairy herd outnumbered the suckling herd in France for a very long time (7 cows out of 10 were dairy cows in the early 1980s), but there are now more suckling cows than dairy cows. This reduction in the dairy cow population can be explained by the increase in production per cow. The average yield was 5 600 kg milk per cow in 2000, whilst it was about 4 000 kg in 1984.

The West of France and the foothills.

About a third of French dairy production comes from these regions, characterised by plains and low hills. The soil and climate conditions, with a marked oceanic influence, are by and large favourable to dairy production and explain its development over the past 40 years. The soils, on schist or granite, enable both temporary grassland and maize to be cultivated. Taking the rural density into account, dairy farms are relatively average, which has led to specialisation, intensification and sometimes to an association with pigs and poultry (in the West of France: 25% of dairy farms in Brittany). The dairy farming systems are rather intensive (1.6 to 1.8 LSU.ha-1 FA) and include forage maize, which accounts for between 30 and 50% of the forage area. Temporary grassland (from 3 to 6 years) is included in the rotations with maize and cereals (from which the straw provides manure). About half of this sown grassland is an association of grass and white clover. Under these conditions, milk production is between 6,000 and 7,500 kg per cow

Flanders

After WW II clover and fodder beet cultivation declined to a negligible level; maize cultivation increased in a spectacular way. About 56% of the Flemish agricultural area is under grassland (2/3) and forage crops: maize (1/3) Twenty-seven percent (2 762 farms) of the dairy farms account for more than 50% of the milk production. There are only 200 farms with more than 100 cows and a lot of small farms: 21% of the farms have only 5% of the dairy cows. The average farm on sandy soils is larger than that on loamy soils. A large proportion of the small dairy farms also has beef cattle.

Germany

As in other countries, both the number of dairy farms and the number of cows is consistently declining. For instance, in Schleswig-Holstein the number of dairy farms is declining by 3-4% per year, while the number of dairy cows has been reduced by 35% since the introduction of milk quota due to increased milk yields per cow. Since milk quota trading has been liberalized in the early 1990s there is a continuous concentration of quota and cows in bigger, intensive enterprises. This development is accompanied by an increasing specialization of farms, i.e. from mixed farming systems towards specialized farming enterprises. two categories of dairy farming systems can be distinguished. Main dairy farming areas are located in the coastal regions of Northwest Germany and at the foothills of the Alps in South Germany. Differences in soil, climatic and topographic conditions consequently do not allow a 'general' characterization of dairy farming in Germany. Dairy farming systems in South Germany are comparable to those in alpine regions as present in Austria or Switzerland, while dairy farming in Northwest Germany shows some similarities with Dutch or Danish dairy farming systems. Dairy herds are much larger in former East Germany. The collectivized large farming enterprises have been set up as commercial farms in the early 1990s by private investors. Dairy farming is, however, of minor importance in eastern Germany.

Northern Germany (Schleswig-Holstein)

Forage production is carried out on 56% of the total agricultural area in Schleswig-Holstein. 470 000 ha is permanent grassland, of which roughly 40 000 ha is located on low moor sites. These sites can be characterized as 'obligatory' grassland since they are not suitable for arable crop production. **Most of the remainder can be addressed as 'facultative' grassland,** which is also suitable for arable crops. Currently, 68 000 ha are cultivated for silage maize production, while leys account for only 40 000 ha. These figures suggest that permanent grassland is the dominating forage crop in Schleswig-Holstein. 72% of all dairy farms rely on both grass silage and maize silage, with roughly similar proportions of the two silage types in the basic ration. In the marshes close to the North Sea, less maize is used due to climatic conditions. This is often compensated for by cereal whole-crop silage. Few farms rely on grass silage as the only roughage component. Permanent grassland is used mainly as pasture (40% of the total permanent grassland area) or as mixed system with 2-3 silage cuts (40%). Only 10% of the permanent grassland area is used exclusively for cutting (Wachendorf & Taube, 2001).

Grazing is allowed to lactating cows on more than 90% of all dairy farms. Rotational grazing is still dominating, but half-day grazing (‘siesta grazing’) and also zero-grazing becomes more important, especially on farms that have above-average milk yields. With increasing herd sizes and increasing milk yields, grazing becomes less important because grazing management is more difficult with a large herd, and nutrient supply is not sufficiently constant on pasture to obtain maximum milk yields. On those farms at the upper end of the range, high-quality grass silage is made from the first cut in spring. The grazing period thus begins later, and supplementation is more important during the grazing period in order to obtain maximum milk yields in the early lactation.

South Germany

Generally, dairy farms in South Germany are much smaller compared to the rest of the country with a considerable proportion (in some regions more than 40%) of the farms being managed as part-time farms.

Management intensity is almost similar to that in North and Northwest Germany. In mountainous regions, however, dairy farming is far less intensive. Mountain slopes and high amounts of rainfall (1,000-2,400 mm per year) do not allow arable cropping and hamper cutting of grassland. Thus, more than two thirds of the agricultural area in the 'Allgäu' region is used as pasture. Conservation of landscape elements is of major importance in the mountainous regions, not at least because of tourism, which provides a considerable part of the farm income. Much of the milk is sold to cheese factories. In order to meet the requirements for cheese making, these farmers are not allowed to feed silage. Thus, hay is an important component in the diet of dairy cows

Annex 3 Land use of member state and EU livestock sectors

Member state[11]	**Total Feed Area**		Fodder area	Wheat feed area		Other cereal feed area		Root feed area	Oilseed feed area	**Non-pasture**[12] **feed area**	
	1000 ha	Share of UAA (%)	1000 ha	1000 ha	Share of wheat area (%)	1000 ha	Share of cereal area (%)	1000 ha	1000 ha	1000 ha	Share of arable land (%)
BE	1741	**126**	769	202	96	175	115	8	587	1227	**146**
BG	2669	**52**	1984	307	29	281	37	3	94	802	**26**
CZ	2031	**53**	1337	303	38	369	43	4	17	1139	**43**
DK	2676	**99**	829	543	79	608	78	6	690	2449	**99**
DE	12118	**71**	6565	1295	42	2326	54	18	1914	7223	**61**
EE	616	**76**	403	58	63	122	63	2	31	403	**69**
IE	3603	**84**	3163	100	112	170	96	6	164	459	**41**
GR	1236	**31**	581	39	5	441	43	0	174	958	**42**
ES	16585	**66**	8333	1283	64	4311	88	5	2653	9292	**73**
FR	19912	**65**	14771	1425	27	1527	32	25	2163	9986	**52**
IT	9384	**67**	5949	231	11	1677	49	6	1521	5500	**73**
LV	1282	**71**	1054	54	26	160	43	14	0	647	**56**
LT	1828	**66**	1329	83	23	318	41	23	74	963	**51**
LU	108	**83**	91	5	41	11	57	0	0	40	**66**
HU	2570	**44**	1330	253	23	751	35	2	235	1541	**34**
MT	32	**308**	5	2	100	15	566	0	10	32	**384**
NL	3077	**162**	1221	373	268	403	351	2	1078	2289	**215**
AT	2698	**83**	2041	83	29	347	54	1	227	902	**65**
PL	8676	**54**	4152	875	40	2656	42	177	815	5384	**45**
PT	2964	**79**	2267	146	155	348	138	0	202	1216	**101**
RO	8722	**62**	5419	425	20	2473	54	86	318	4118	**46**
SI	454	**91**	348	11	34	91	105	2	3	159	**90**
SK	1105	**57**	771	110	30	137	32	2	86	576	**43**
FI	1521	**67**	662	74	36	586	56	0	199	1487	**66**
SE	2167	**69**	1567	144	40	348	50	2	106	1668	**63**
UK	9709	**58**	7042	844	46	615	51	9	1197	3997	**73**
EU27	**119522**	**65**	**74014**	**9275**	**37**	**21269**	**53**	**404**	**14560**	**64490**	**59**

[11] Cyprus was excluded because of structurally missing statistics on nearly all information categories

[12] All feed producing land, except permanent pasture

Annex 2

Tasks 2.1 and 2.2 output
Preliminary Livestock Production System zoning report

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GeoCAP, Agriculture, IPSC

(document embedded as pdf on the following page: double click to open)

Evaluation of the EU livestock sectors' contribution to the greenhouse gas emission – Phase 1 (GGELS)

Administrative Arrangement (AA) No. AGRI-2008-0245

GGELS

European Greenhouse Gases Emissions from Livestock Production Systems

LPS Regional zoning for the survey of the related manure management practices

Contents

1. Introduction

According to the Administrative Arrangement (AA) No. AGRI-2008-0245[1] signed between DG AGRI and DG JRC, Work Package 2 (WP2) of the GGELS project has to focus on the "Conceptualisation and Build up of Livestock Typology"[2]. The main task of WP2 is the establishment of a LPS typology at NUTS2 level covering all EU27. This LPS typology should allow European regions to be differentiated according to the diversity of LPS farming such as herds' assemblage, feeding strategies or again manures management practices which condition GreenHouse Gazes emissions (GHG) from livestock sectors. Concerning manures management practices, since no specific information exists at region level, while JRC expertise on this issue is insufficient, it has been decided to launch a call for tender[3] to select academic parties for a specific study on this issue following a questionnaire approach. The results of this survey should improve NUTS II LPS description with manure management information for each such region-LPS combination and improve efficiency of the final LPS typology to be produced.

As indicated inside the related technical specifications, study on "Regional manure management practices in EU27" should target European regions according to their LPS characteristics such as, first, animal species. For that, LPS characteristics should be identified previously to the survey by JRC and provided to the contractor to perform GHG EF and manure management sampling and assure relevance of the results obtained from the questionnaires to be addressed to national experts. Annex 1 of the study listed a number of dimensions to be considered to represent regional diversity of LPS; these main dimensions have been carefully considered to represent European LPS diversity:

- subnational regions concerned i.e. LPS characteristics should be detailed at subnational scale
- climatic zone i.e. agroecologic zoning of the main climates met in Europe should be provided
- average farm size i.e. description of the farm types and level of specialisation
- productivity i.e. elements describing production strategies to productivity should be considered.

From that, JRC has decided to build its regional zoning of LPS diversity from one major complete and consistent database grouping national economic accountancy of agriculture and regional characteristics of livestock production activities in Europe i.e. the CAPRI[4] Coco database (Britz & Witzke, 2008). Further, CAPRI being the system from which European GHG emissions would be modelled and political scenarios tested, it appeared pertinent to have recourse to its datasets.

Consequently, this document is describing the methodology and the results of the subnational zoning of European LPS as expected to be provided to the contractor in charge of the "EU27 regional survey of the manure management practices" study.

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[1] Administrative Arrangement (AA) JRC Contract n° 30944-2008-04 NFP ISP N° AGRI-2008-0245 between DG Agriculture and Rural Development (DG AGRI) and the Joint Research Centre (JRC)
[2] AA n° 30944-2008-04 NFP ISP N° AGRI-2008-0245: WP2: Typology and characterization of the EU livestock sector – Task 2.1: Conceptualisation – point N°4: Manure management
[3] Tender specifications: Qualitative assessment of manure management in main livestock production systems and a review of gaseous emissions factors of manure throughout EU27 (specs_16884.doc)
4 CAPRI: Common Agricultural Policy Regional Impact Analysis (see http://www.ilr1.uni-bonn.de/agpo/rsrch/capri/capri_e.htm)

In the first part, the necessary aspects of LPS to be taken into account for zoning European LPS diversity would be largely pointed out. In a second part, by considering information availability inside CAPRI databases, a restricted list of regional LPS characteristics would be proposed. Then, the methodologies used to produce LPS indicators and to perform European regions classification are described in the third part. The fourth part is dedicated to the presentation of the zoning results obtained for each one of the LPS components retained; this asking for a large mapping effort through Geographic Information System (GIS) environment. Finally, in the last part, lists of European regions to be sampled when addressing region-LPS combination are proposed and discussed.

2. LPS characteristics towards manure management strategies

The aim of the European LPS zoning being to facilitate the setting up of a survey to elicit "Manure management practices in Europe", a primary description of manure production and management is to be undertaken.

As pointed out by Burton & Turner (2003), animal production in Europe has considerably changes in the last decades with e trend towards more specialized and intensive production systems. The increase of the size of the holding is generally accompanied by a reduction of the labour forces per hectare of crop or per livestock head, leading to the increased use of machinery, plant production products and processed animal feedstuffs and to a higher specialization of the LPS. In the same time, the increase of the meat demand (+ 4% between 1996 and 1999 – Aumaître, 2001) and the reduction of the purchasing capacities of consumers ask for the intensification of the livestock production practices and the reduction of the associated costs.

If intensification and specialization of the LPS is the trend in Europe, not all the holdings have followed or have had the possibility to follow it. Livestock farming systems are varying from one country to another, or even, from one region to another in the same country depending on intrinsic climatic, land use or cultural characteristics of the regions. To date, this is conducing to a large range of LPS in Europe.

LPS diversity is described by a range of farming characteristics among them (i) animal species and numbers, (ii) targeted production sector i.e. specialisation, (iii) intensification of livestock production and (iv) manure management strategy coupled to cropping system are perceived as priorities when classifying LPS (Burton & Turner, 2003).

2.1. Animal species and numbers

When considering livestock production, animal numbers can be easily undertaken at any level of the work. Regional production of bovine meat or milk in a region is for instance a good indicator of the number of respectively cattle for milk and cattle for meat which can be found in a region. Simultaneously, manure production is also strongly correlated to the herd size in a region. Consequently, there are different possibilities to address animal numbers. However, the sole consideration of the herd size is not informative enough; it just allow regions to be classed by considering abundance of animal heads (per animal species) or of livestock units[5] (when no distinction is made between animal species) and for depicting of regional livestock production concentration. At the opposite, animal species asks for the stratification of total regional herd in

[5] Where one livestock unit – LU – is defined as the environmental impact of a 500 kg dairy cow

species-related herds. Then, absolute abundance[6] or relative abundance[7] can be used to describe the herd size of one given animal species.

Whatever the choice made to express animal number in absolute or relative values, and to consider total or species herd size, the result is just a density of production by animal species at regional level.

To obtain a higher level of pertinence, livestock number is often used together with cropping system information, or with feeding strategies to provide more precise information onto the level of intensification and specialization of the LPS. For instance, intensification can be expressed as the number of grazing livestock units per hectare of fodder area i.e. the stocking density. By representing the capacities of a local cropping system to absorb nitrogen (phosphorus and potassium as well) from manures, high stocking densities[8] give then a precise idea of the potential environmental risk that livestock production is exerting over biodiversity (Mayer et al., 2005), nitrate pollution of water resources (Ridley et al., 1999; de Klein & Ledgart, 2001; Anger et al., 2002) and GHG emission (Soussana, 2004). If too small[9], stocking density also describes situation where under utilisation of pastures could conduct to woody encroachments and a sharp decrease of the potential of biomass production (Zarovali et al., 2007). On the other hand, crops or pasture production can be divided by the number of animals to express the potential energy and protein autonomy of a LPS or a specific holding (Kainea & Tozer, 2005).

On the other hand, distinction between animal species is very important to be considered when addressing manure production and management. In effect, nature of manure to be managed is partly dependent of the animal species present in a region. Three broad categories of manure are generally considered (Burton & Turner, 2003):

- Liquid manure or slurry are produced by animals generally raise indoor on solid floors regularly swept clear of any excreta by using wash water – it represents an important proportion of holding producing pig meat. In 1996, slatted floors represented 75 and 78% of floors used in buildings for finishing pigs respectively for Denmark and France (Aumaître, 1996).
- Solid manure from animals kept on bedding material which is collected together with all excreta as farm yard manure (FAM) – many dairy cattle in France, Scandinavian and Eastern Europe countries have recourse to bedding material and are collecting solid.
- Mixed manure when animals kept on bedding material but liquids are drained from the bedding and collected elsewhere.

However, animal species is not enough alone to decide of the nature of manure produced in a region and of the manure management strategies. Other information such as the proportion of time a year spent indoor (from 100% for housed raising cattle fed with fodders and import of feedstuffs on farm to few percent in case of sufficient grazing pastures available on farm) or the pasture management (grazing or haymaking pasture) are necessary.

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[6] Absolute abundance (n) as the exact number of individuals in a given herd

[7] Relative abundance (n/N in %) as the proportion of individuals in a herd (n, cattle milk for instance) over the total number of bovine individuals in a region (N, cattle milk + cattle meat)

[8] Rule of thumb is to consider stocking density > 1.4 LU/ha of fodder area as intensive and at risk for water nitrate pollution (Ernst and Young, 2007)

[9] Rule of thumb is to consider stocking density < 0.8 LU/ha of fodder area as very extensive and at risk for woody encroachments

2.2. Specialization

Considering animals or livestock unit numbers also allows for depicting the concentration of certain livestock production in definite regions. Regional specialization is generally due to the concentration of all livestock sector facilities such as feedstuffs manufacturing, slaughtering plants, processing plants and marketing industries in one or few single regions a country. This could have been encouraged by local authorities and/or governments as a way to accelerate and make perennial a certain livestock sector. However, other reasons can explain the development of such regions of concentrated activity: the geographical (proximity to transport networks and market places), environmental (climatic, crop potential) or cultural advantages can separately or all together decide of the concentration of livestock production and of the specialization of a region. Reciprocally, specialization also concerns every one of the producers present in the region. When he's not a pioneer but only a follower, the farmer would largely benefit from the local sector advantages if he decides to adapt his farming to the regional specialized production and to adopt the related practices. It provides him a more constant market opportunity over time. On the other hand, specialization conducts to high investment efforts for adapted machinery and buildings and selective cropping system; this reduces the flexibility and the capacity of the holding to adapt its production in case of agricultural sector crisis.

Specialization is generally determined from the proportion of the revenues/incomes coming from each one of the production activities present in the holding; the larger source(s) of income is (are) then describing of the specialization adopted by the holding. Based on the standard growth margin (SGM), European statistical surveys such as FADN[10] is attributing type to the holdings according to the first or the two-first main sources of revenues met. Specialized "granivores (type 50)" in FADN are presenting a higher income share from pigs and/or poultry production and are dispatched into three different second order types (501- specialist pigs, 502 - specialist poultry and 503 – various granivores); once again, each one can be dispatched into several third-order types (5011 – specialist pig rearing, 5012 – specialist pig fattening…).

If specialization in a region generally matches the farms specialization (Jutland in Denmark, Brittany in France or again Catalunya in Spain are presenting very specialized farms matching the regional specialization), this trend is not always valid. Relationship between regional specialization and farms specialization has to be considered carefully. Attention must be paid to not consider the sole regional output to determine specialization. If only few specialized holdings are concentrating a very large proportion of the regional herd size, the rest of the holdings, whatever the specialization, would have limited influence onto the output-based regional specialization. This, even if they are counting for the larger used arable area and are essential to be considered when addressing landscape management and biodiversity conservation.

Consequently, attribution of a level of specialization to a region should focus onto major sources of incomes as well as to farm types' assemblages in a region. This is especially true when considering indoor livestock productions (granivores, very intensive dairy cattle…) which require very little dedicated land area, ask for large and efficient manure management systems and involve supplementary agricultural areas to land-spread manures.

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[10] FADN: The Farm Accountancy Data Network from DG AGRI is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy http://ec.europa.eu/agriculture/rica/index_en.cfm

2.3. Livestock production intensification

Intensification can be expressed in different manners. Intensification is for instance expressed as the quantity of product obtain from one animal i.e. the yield or as the total output in Euro per ha (Andersen et al., 2006). It can be also expressed as the number of grazing animal per ha of fodder area (see § 2.1.) and very often as the level of inputs (standardized economic valuation) used per animal (or livestock unit) or per unit of product.

In the same time, independently of the animal species/race considered, manure composition is strongly dependent of livestock production techniques such as feeding strategy, animal housing or again storage and land-spreading systems used. Feeding strategy impacts on manure production has been largely described (Driedger & Loerch, 1999; Kerr et al., 2006; Hoffman et al., 2007). Limit-fed diets tend to significantly reduce the quantity of manure produced (bulk density and dry matter) or the composition of excreta (NH4 in slurry and headspace N2O). At the opposite, rich protein diets have for consequences a high concentration of nitrogen and phosphorus in excreta corresponding in such situations to protein feed luxury consumption (Tomlinson et al., 1996; Portejoie et al., 2004; Philippe et al., 2006). Trends from dairy cattle are also observed for finishing pigs when considering the sole lysine in the crude protein fraction of feedstuffs (Salter et al., 1990).

Thus, the later paragraph highlights the fact that feeding strategy has to be considered when determining the level of intensification of livestock production in a region. But the fact that farmers are using merchantable concentrated feedstuffs together with homemade feedstuffs makes the determination of the intensification level difficult. Information concerning the share of auto-consumed and purchases feedstuffs is often too limited or even unavailable. The precise determination of the level of intensification from the feeding strategy is then rough. However, together with the proportion of the investments dedicated to the animal diet and/or the veterinary protection, potential autonomy to feed (energy, protein, lysine…) animals could allow the regional level of intensification for a given production to be estimated.

2.4. Manure management strategy

If land application is the most widespread disposal technique for manures, many different manure storages are used in Europe. Vessel storage for liquid manure and slurry, concrete pads for solid manure from which effluent draining out are collecting separately or again weeping wall stores for wetter manure, and deep-litter storage in animal house before spreading are examples of provisions for storage. Storage is generally decided according to the type of manure, the storage capacity needed and the regulatory restrictions in vigour. As mentioned previously, to date, no complete and precise information concerning manure management strategies adopted over Europe is available. If MATRESA[11] project and RAMIRAN[12] survey described general trend and techniques, the information was often incomplete to provide a clear description of the manure management solutions in use in every one of the EU27 regions together with local livestock production specificities and agro-ecological conditions. Then, a complete and relevant typology of the LPS not including the manure management strategies in use was out of order. Consequently, in the frame of the GGELS project, it has been decided to obtain the missing information by surveying every one of the regions in Europe (EU27) which present particular but representative LPS characteristics.

This task being outsourced, it was important to provide to the contractor, a clear and as complete as possible description of the LPS existing in Europe. In accordance with the previous paragraphs, regional animals assemblages, livestock production specialization and intensification have been

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[11] MATRESA: MAnure TREatment Strategies for Sustainable Agriculture (see Burton & Turner, 2003)
[12] RAMIRAN: Research Network on Recycling of Agricultural and Industrial Residues in Agriculture (http://www.ramiran.net/)

taken into consideration. We also described related cropping systems in use in a region. To date, no well organised manures market exists; and manures transportation was considered as very limited: as in CAPRI Modelling System, we assumed that manures are used locally to fertilize crops present on-farm or in the neighbouring (in the region). This allowed us to consider each one of the European region independently and to calculate individual nitrogen-N balance (the same for phosphorus-P and potassium-K) and potential N-surplus as an indication of the environmental risk LPS is exerting over a region (for details, see Peres-Dominges, 2005).

3. CAPRI Modelling System and data availability

Regarding the range of modelling systems available to date, and considering that the central expectation of the GGELS project is the GHG emissions quantification of LPS activities in Europe, we decided to adopt the CAPRI (Common Agricultural Policy Regional Impact analysis) modelling system as main instrument of analysis[13]. CAPRI is connecting GHG emissions calculation from robust European statistical data; and it gives the possibility to simulate GHG emissions of Agriculture (or one given agricultural activity) according to CAP scenarios to be tested.

CAPRI system was designed from the beginning as a complex projection and simulation tool for the agricultural sector based on (Perez Dominguez, 2005):

- an activity breakdown of regional agricultural production (about 50 activities) and farm and market balances (60 products, 30 inputs);
- a physical consistency framework covering balances for agricultural area, animals, animal feedstuffs and crops nutrients requirements (as constraints in the regional supply model);
- economic accounting principles (from EAA) from which all inputs and outputs declared inside national agricultural accounting systems are considered and revenues and costs are broken down by region and production activity;
- a detailed policy description for which all relevant agriculture payment schemes are integrated inside the regional supply models together with non-EU policy and word market components;
- behavioural functions and allocation mechanisms in line with micro-economy theory.

From this, general CAPRI structure is organized around two main model components: the market and the supply modules (Figure 1 - to be updated to EU27).

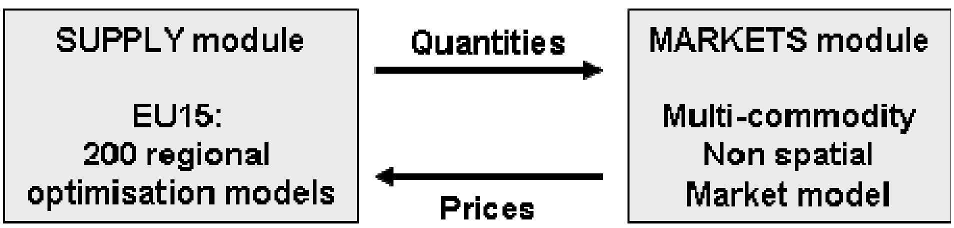

Figure 1: General CAPRI model layout

Basically, CAPRI modules are informed with a set of European statistics datasets such as NewChronos, SPEL, etc. which provide information at national level and are made consistent inside CAPRI CoCo database; statistical data are then regionalized when confronted under constraints to the REGIO database (Figure 2).

[13] http://en.wikipedia.org/wiki/CAPRI_model

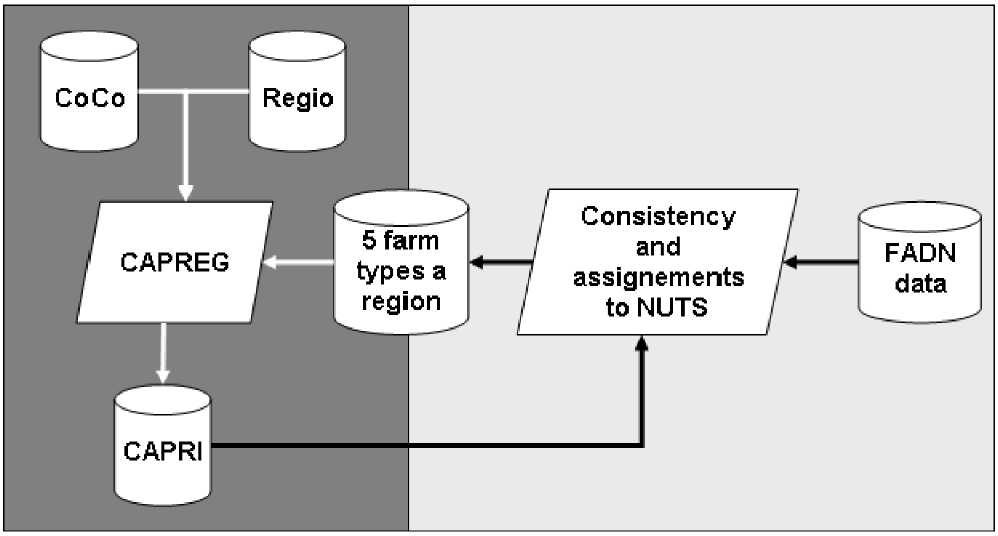

Figure 2: General interconnection between CAPRI databases and FADN based-on farm typology in the frame of the SEAMLESS project

Amongst the different modules, some are more linked with the problematic addressed in GGELS project – the FEEDING and FERTILIZING modules in which all input/output livestock-related activities and practices are considered and GHG emissions quantified – the FARM TYPE module which is mainly dedicated to interpretation and communication by connecting results from simulation to main agricultural activities identified in a region – the DNDC module generating environmental indicators of sustainability for the different agricultural activities identified in a region and finally the DAOUT module for mapping/zoning and communication purposes (Britz and Witzke, 2008). Concerning the FARM TYPE module, farm types as defined in FADN are not conserved inside CAPRI. In fact, in CAPRI, farms are classified according to 50 possible agricultural activities. Later, only the five main representative activities in a region are considered; remaining farms not distributed in the formers are summed inside a sixth activity group so called "rest". This allows for lightening simulation time costs and to not provide overloaded and difficult to interpret results.

Unfortunately, databases used within CAPRI (national databases = Eurostat - area statistics, farm and market balances, Economic Accounts for Agriculture, agricultural prices … regional databases = REGIO and data on Common Agriculture Policy from DG-AGRI - engineering information as animal requirements, regionalised data including fertilizer and feed distribution …) and compiled inside CAPRI CAPREG database do not provide all the information necessary to describe precisely the manures management strategies in vigour at regional level. However, from this, it's possible to depict main regional characteristics and trends of LPS. We used 2002 CAPRI baseline as source of data to describe LPS. All the variables grabbed or calculated from 2002 CAPRI baseline have been grouped inside *"GGELS_final_table.xls"* to further uses; details concerning the variables are given in annex 1. All these explicative variables have been used to process stratification-classification of the European regions according to the LPS descriptors retained.

4. LPS descriptors

The descriptors used to class the regional LPS are obtained or calculated from 2002 CAPRI baseline dataset. It concerns every one of the 243 regions (see annex 2) that CAPRI is considering in EU27 + Norway. These descriptors concern the six different livestock production sectors retained in this study:

- BOMILK as dairy cattle for milk production
- BOMEAT as meat production from bovine livestock
- POUFAT as the meat production from poultry (broilers…)
- LAHENS as the eggs production from hens
- SHGOAT as the meat and milk production from sheep's and goats (ewes…)
- PORCIN as the pig activity concerning the meat and the rearing (sows) activities.

The different descriptors retained can be grouped into 10 different categories:

- Identifiers (to identify regional and/or national level – used in GIS to communicate mapped results)
- Animal assemblages and livestock herd diversity to characterize regions according to the assemblages observed of the six different livestock sectors considered in this study (BOMILK, BOMEAT, POUFAT, LAHENS, SHGOAT, PORCIN)
- Climate data allowing regional agro-ecological situation to be described
- Intensification has been expressed in different ways: (i) as the total costs (€) and the proportion (%) over the total cost of production of money dedicated to feedstuffs and veterinary products and (ii) as the stocking density (for grazing livestock)
- Production being largely available from CAPRI we used total revenue per livestock sector in a region, revenue per head or per livestock unit, or again percentage of the total livestock revenue coming from one specific livestock sector (revenues from crops were also used)
- Farm types: to verify classification of regions from animals assemblages we decided to confront our results to the Eurostat data at regional level. Farm types which have been considered were those addressing fully or partly livestock production.
- Cropping system is described as the true area or the proportion of the total regional agricultural area used to grow one specific crop (sunflower for instance) or a family of crops (cereals for instance)
- Manure production: no information concerning the storage and spreading systems in use in region, we focused onto the quantity of manures (total or N, P, K) produced by livestock sector.
- Feeding strategy: apart from the money spent for feedstuffs purchasing which is available in CAPRI, feeding strategy cannot be directly calculated because of the lack of knowledge considering on-farm auto-consumption of crop's products. In this special case, we calculated the proportion of grazing animal energy and protein annual requirements which could be covered by the use of the sole fodder crops – it conducted to the obtaining of a fodders-energy and -protein autonomy of the regions. For granivores (PORCIN, LAHENS and POUFAT) the regional lysine autosufficiency was calculated as the balance between the "rich protein crops (rape, soybean, sunflower) + wheat and barley" supplies and the annual granivores lysine requirements. It was expressed as a percentage of the total requirements.
- Environmental impact: as an output of the CAPRI-dynaspat simulation platform, total N-P-K from manures was confronted to total N-P-K plants' requirements to determine the potential utilization which could be done of the manure to fulfil plants requirements (N-P-

K) i.e. regional N-P-K autonomy and the risk of N-P-K surplus in a region; the latter being considered as an indicator of the risk of ground- and surface-water pollution by nitrate and phosphate from livestock activities.

Among all the dimensions presented below, specialization is not clearly visible. In fact, we considered specialization as the result of considering both the cropping and the livestock production systems. Indeed, according to us, only cross-comparison of information describing the cropping system and information eliciting animals assemblage should allow us to define the nature and the level of specialization of a given region. This step is discussed within the sixth paragraph of this document.

4.1. LPS descriptors directly extracted from 2002 CAPRI baseline

To data traditionally available inside CAPRI, simple calculation of secondary variables have been undertaken to limit the effect of correlation between raw data. For instance, production expressed as a total quantity of product or as a total amount of money was very strongly correlated with the size of the herds within a region. By calculating relative values (%), particularities of each region were safeguarded and correlation avoided; this allowed the simultaneous use of information of the same nature without risk of overweighting of these variables.

However, in certain circumstances, information provided by CAPRI was not sufficient and additional estimation was necessary.

4.2. Additional and calculated descriptors

Complementary data concerning climate – feeding strategy – and farm type have been obtained from JRC Agri4cast action, INRAtion © and Eurostat respectively. Diversity of the animals assemblages in EU27 + Norway was also processed by having recourse to ecological methodologies. The methods used are briefly presented hereinafter.

4.2.1. Climate

Climatic data were extracted and processed from the current Crop Growth Monitoring System (CGMS) version 2.3 managed by JRC Agri4cast action. Complete description of the CMGS is use in JRC can be found in “The MARS Crop Yield Forecasting System” (Micale & Genovese, 2005).

Climatic data are provided through a network of 6000 meteorological stations in Europe and neighbouring countries (Figure 3). These data are generally used as input for crop growth model and as weather indicators for a direct evaluation of alarming climatic situations. The data are collected from various sources including METAR[14]. Observations of maximum and minimum temperatures, precipitation and sunshine duration are daily processed; METAR also provides temperature, dew point, visibility and cloud amount. Other meteorological information are provided such as potential evapotranspiration, climatic water balance, global radiation or again snow depth.

[14] METAR: METeorological Airport Report

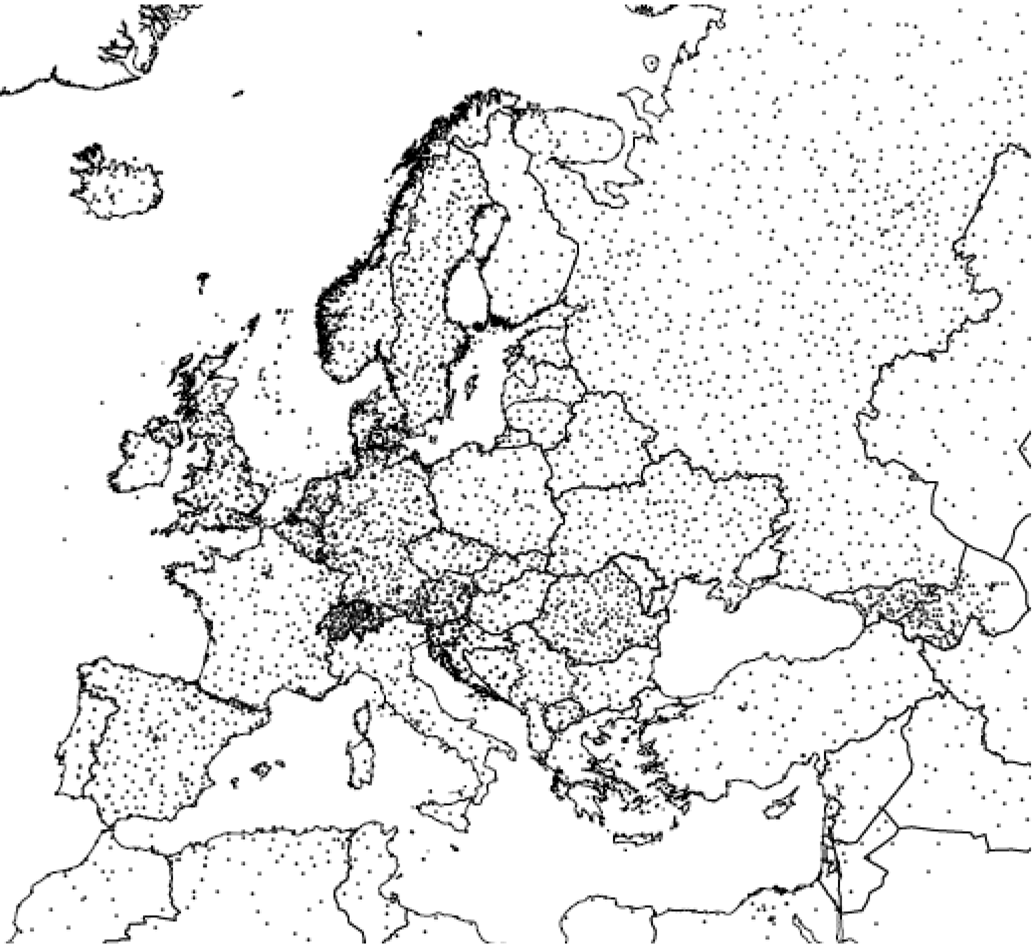

Figure 3: Network of meteorological stations for which data is available for (part of) the period from 1975 until the current day (Micale & Genovese, 2005)

After data quality check, daily meteorological data are interpolating onto a regular climatic grid of 50 by 50 kilometres. From this grid, averaged values of climatic data are obtained by aggregating cells of the grid linked to a given region; aggregation is made by weighting each cell used according to the proportion of the cell area contained within the region.

For the purpose of the GGELS project, a limited list of meteorological variables has been decided. These variables have been chosen to point out the climatic potential of a region for crop growth and animal welfare: cumulative sum of temperature (°C.day^{-1}, base temperature of 0°C), temperature (°C), precipitation (mm), photosynthetic active radiation (MJ.m^{-2}.day^{-1}) and number of rainy, snowy, frozen days. Some of them have been calculated as cumulative sum for the first 3, 6 and 12 months of the year (to proximate growing period duration and/or to match cropping system calendar).

For each one of the region, elevation characteristics were obtained from SRTM 90v4 (void filled) by joining elevation data with regional NUTS2 delineation inside GIS. Average and standard deviation were obtained for each one of the 243 regions considered inside CAPRI. Dispersion index calculated as the variance-to-mean ratio was used as complementary information describing the level of uniformity of the elevation within a region. Equation is presented below.

$$D_I = \frac{\sigma^2}{\mu} \qquad \text{(equation 1)}$$

4.2.2. Animals assemblages

To describe the animals assemblages and in the same time to point out of the specialization over Europe, we had recourse to an ecological method based on the calculation of the index of similarity between two herds situated in two distinct European regions. Similarity index was calculated for each one of the possible pairs of regions. Data used should allow us to weight each one of the six livestock sectors considered according to its participation to GHG emission; consequently, we used "abundance" expressed as the number of livestock units (LU) in a region. Because statistical processes request non zero and missing values, raw abundance *Ai,r* for a livestock sector *i* in a region *j* was square rooted after addition of 1 LU. This also allowed us to not overweight highly represented livestock sectors against rare/absent livestock sectors in a region and to process multivariate methods related to population similarity estimation (Cheng, 2004).

There are numerous measurements of similarity (Legendre and Legendre, 1983), and confusion exists about which similarity measurement to use. Two broad classes of similarity coefficient exist: (i) binary coefficients using presence/absence (1/0) data, such as Jaccard's coefficient (Chao, 2005) or Sorensen's coefficient (Sorensen, 1948); these coefficients are generally used when only the lists of species are available and comparisons are possible at this lower level of resolution, weighting rare species the same as common species; (ii) quantitative coefficients for which supplementary information such as species abundance in an assemblage is required; among these, Morisita's index of similarity (Morisita, 1959) is considered the best overall measurement of similarity for ecological use (Wolda, 1981), almost independent of sample size (unlike Sorensen's index).

Morisita's similarity coefficient for each pair of regional animals assemblages (transformed data) was calculated as follows:

$$C_\lambda = \frac{2\sum(X_{ij}X_{ik})}{\left((\lambda_1+\lambda_2)n_j n_k\right)} \quad \text{(equation 2)}$$

where:

$$\lambda_1 = \frac{\sum(X_{ij}(X_{ij}-1))}{\left(n_j(n_j-1)\right)} \quad \text{(equation 3)}$$

$$\lambda_2 = \frac{\sum(X_{ik}(X_{ik}-1))}{\left(n_k(n_k-1)\right)} \quad \text{(equation 4)}$$

where C_λ = Morisita's index of similarity between regions j and k,

X_{ij}, X_{ik} = the number of livestock units of the livestock sector i in regions j and k,

n_i, n_k = the total numbers of livestock units in regions j and k.

The principal advantage of this similarity index is that it considers together the number of species present in an assemblage and the magnitude of the total and species-related abundances.

Method used when estimating similarity between species' assemblages (here, livestock sectors or animals assemblages) is ordination. Ordination entails multivariate methods; different multivariate methods exist, such as hierarchical clustering (Johnson and Wichern, 1992), non-metric multidimensional scaling (NMDS) (Kruskal, 1964), correspondence analysis (CA) (Jongmann et al., 1995) or principal component analysis (PCA). They start from a triangular matrix of similarity indices between every pair of animals assemblages (of regions). All the methods are applied to reduce the complexity of multivariate information in the original matrices to a low-dimensional picture.

We chose to apply two multivariate methods: (i) PCA processed into JMP-V6.0 platform (The SAS Institute)[15] after obtaining of the double matrix of Morisita's index of similarity from EstimateS V8.0[16] (Colwell, 2004) and (ii) NMDS processed directly with transformed value of abundance through PAST software[17]. The coordinates of every one of the regions on the significant (>80%) PCA principal components and NMDS axis were added to the GGELS_final_table.xls.

4.2.3. Feeding strategy

Despite the fact that data concerning animal energy, protein and lysine (for granivores only) requirements per animal are directly available inside 2002 CAPRI baseline database, the lack of explanation concerning the units used and the necessity to update feeding factors asked for a complete recalculation of the animals requirements. This was undertaken for each one of the eighteen livestock production activities considered inside CAPRI (DCOH, DCOL… see annex 1); then requirements were calculated per herd and grouped to obtain total energy/protein/lysine requirements for each one of the six livestock sectors considered in GGELS.

The method and main characteristics describing animal production and growth considered within CAPRI (Nasuelli et al., 1997) was respected. However, certain values were extracted from current literature (mainly for granivores) and from "Alimentation des bovines, ovins et caprins" (INRA, 2007) for grazing livestock. The approach being relatively similar between livestock activities considered inside CAPRI, we briefly detailed hereinafter the method used for two categories: dairy cow (CAMILK) and poultry for fattening (POUFAT).

- Dairy cow (CAMILK):

  The requirements (energy as well as protein) for a dairy cow correspond to the sum of the requirements for (i) the maintenance, (ii) the milk production and (iii) the gestation.

  Accordingly to INRA procedure (INRA, 2007), a dairy cow was assumed to be 40 months old – of medium corporal status – with a live weight of 650 kg – inseminated at 13th week. Simulation of milk production corresponded to the 25th week (mid-term). Complementary information such as regional CAMILK production of milk ($l.head^{-1}.year^{-1}$) was extracted from CAPRI database. Milk production duration was considered as equal to 305 days. 2002 values of the protein and fat content of milk were extracted from Eurostat database.

  - Maintenance (M) requirements:

$$R_M = \left[\left(0.041 * LW^{0.75}\right) * I_{act}\right] \qquad \text{(equation 5)}$$

  Where

  R_M, the maintenance energy requirements per day

  LW, the live weight (650kg)

  I_{act}, the index of activity of the animal corresponding to a supplementary maintenance requirements for animal reared indoor (I_{act}=1), outdoor (I_{act} = 1.2) or mixed (I_{act}= 1.1). I_{act} was regionally determined according to the assumption that

[15] http://www.jmp.com/software/

[16] http://viceroy.eeb.uconn.edu/EstimateSPages/AboutEstimateS.htm

[17] http://folk.uio.no/ohammer/past/index.html

regional stocking density of grazing animals >2 conducts to indoor rearing, <2 but ≥1 conducts to mixed rearing, and <1 to outdoor rearing.

- Milk Production (MP) requirements:

$$R_{MP} = \left[MP_{avg} * \left[0.44 + \left(0.0055 * \left(C_F - 40 \right) \right) + \left(0.0033 * \left(C_P - 31 \right) \right) \right] \right] \quad \text{(equation 6)}$$

Where

R_{MP}, the milk production energy requirements per day

C_F, the regional fat content of milk

C_P, the regional protein content of milk

MP_{avg}, the daily milk production per dairy cow calculated from the annual milk production per dairy cow given in CAPRI ($MP_{CAPRI/year}$) divided by 305 days of production a year

$MP_{CAPRI/year}$ corresponds to the annual production of a dairy cow in a given region

- Gestation (G) requirements:

$$R_G = \left[0.00072 * \left(VW_{birth} * e^{(0.116 * IW)} \right) \right] \quad \text{(equation 7)}$$

Where

R_G, the gestation energy requirements per day

VW_{birth}, the veal weight at birth, considered as equal to 45 kg

IW, the insemination week, considered as equal to the mean value observed, 13th week

Then over the year, the total energy requirements for dairy cow is equal to the daily requirements for maintenance, milk production and gestation multiplied respectively by the number of days for each activity: 365 days of maintenance, 305 days of milk production and 270 days of gestation (CAPRI values). Values obtained are expressed in French UFL (Unité fourrage vache laitière) and were converted into MJ/head^{-1}.year^{-1} (by multiplying by 1700 to obtained Kcal then by 4.185 to obtain kJ).

In the same manner, protein requirements per dairy cow a day are calculated by summing maintenance, milk production and gestation protein requirements weighted by the specific number of days of each one of these the three activities:

$$R_{Prot} = \left[\left(3.25 * LW^{0.75} \right) + \left(1.56 * LW * CP \right) + \left(0.07 * VW_{birth} * e^{0.111 * IW} \right) \right] \quad \text{(equation 8)}$$

- Poultry for fattening (POUFAT):

Concerning granivores activities, it has been initially decided to class European regions according to the level of digestible lysine autosufficiency of the regions defined as the percentage of the digestible lysine requirements covered by the lysine coming from rich protein crops + wheat and barley production a region. Thus, digestible lysine requirements for each one of the three granivores sectors (LAHENS, POUFAT and PORCIN) have been calculated. Example of poultry for fattening (POUFAT) is provided below.

From total production of carcass from poultry (in tons) and number of heads provided by CAPRI, we calculated the mean carcass weight of broilers (kg) in a region from which a mean live weight (LW_f) per individual was obtained by divided the carcass weight by 0.75 (Brake et al., 1995). From this, maintenance and growth energy requirements were calculated for the birth-to-8 weeks old period of growth of broilers following Leclercq & Beaumont (2000):

Then the mean metabolic size of the broiler (T) was calculating as follows:

$$T = \left[LW^{0.75}\right] \quad \text{(equation 9)}$$

The averaged weight (LW_{avg}) of a broiler over the growth period (60 days, default value) is calculated from the initial weight (LW_i= 30g) to which is added half of the final live weight (LW_f)

$$LW_{avg} = LW_i + \left(\frac{LW_f - LW_i}{2}\right) \quad \text{(equation 10)}$$

The lipid content of meat (C_{Lip}) is considered as equal to 0.17 g/g from which protein content of meat (C_P) is calculated as follows:

$$C_P = 0.225 - (0.27 * C_{Lip}) \quad \text{(equation 11)}$$

Maintenance (R_M) and growth (R_G) energy requirements are given by the following formula:

$$R_M = 130 * T * EE * 20 \quad \text{(equation 12)}$$

$$R_G = \left(LW_f - LW_i\right) * \left[\left(9.47 * C_P\right) + \left(10.47 * C_{Lip}\right)\right] \quad \text{(equation 13)}$$

Where

EE, the energy efficiency being considered as equal to 1 (0.9 for laying hens)

From this, quantity of aliment to be consumed during the life of one broiler (C, kg) is calculated as follows:

$$C = \left(R_M + R_G\right)/3200 \quad \text{(equation 14)}$$

And finally, the quantity of digestible lysine necessary per broiler along life being equal to 8.56 g per kilogram of aliment consumed (Leclercq & Beaumont, 2000), total amount of digestible lysine needed a year was calculated by multiplying the individual broiler requirement by the number of heads produced in one given region.

- Grazing livestock energy & protein autonomy and granivores digestible lysine autosufficiency:

To obtain regional energy/protein autonomy and digestible lysine autosufficiency indicators, requirements calculated as shown above, were directly compared to the regional energy/protein supplies from fodder activities (for grazing livestock) and lysine supplies from rich protein crops + main cereals directly usable for granivores (wheat, barley, grain maize). Proportion (%) of local requirements covered by local supplies inside a region corresponded to expected autonomy and autosufficiency proxies. For that, land use share (hectare) and production share in a region are necessary.

Inside CAPRI, the EUROSTAT's REGIO data on regionalized agricultural data in the EU is used; then, data available inside REGIO are made consistent with the sectoral SPEL-EU data base as a frame for any regionalization. The SPEL-EU data base is an official data base of EUROSTAT available for external users. It combines physical and valued data of several domains of EUROSTAT's agricultural statistics into a frame work consistent to the EAA, covering the EU member states in time series starting from 1973. The internal consistency and the activity based approach of the data base provide a natural starting point for any regionalization (Wolf, 1995). In other words, an aggregation of the main data items inside REGIO (areas, herd sizes, gross production and intermediate use, unit value prices and EAA-positions) over the regionalized data must recover the sectoral values of SPEL (Britz, 1997). As an example, the approach is explained for cereals:

The SPEL activities BARL (barley), MAIZ (grain maize) and PARI (paddy rice) match directly the information in REGIO, hence the regionalized data are set to the values in REGIO. The difference between the sum of these areas and the aggregate cereals in REGIO must be equal to the sum of the remaining activities in cereals as shown in SPEL, namely RYE (rye and meslin), OATS (oats) and OCER (other cereals). As long as no other regional information is available, the difference from REGIO is broken down applying sectoral shares.

The approach is shown for OATS in the following equations, where the suffix *r* stands for regional data:

$$LEVL_{OATS,r} = \left(CEREAL_r - WHEAT_r - BARLEY_r - MAIZEGR_r - RICE_r\right)$$
$$LEVL_{OATS,SPEL} \Big/ \left(LEVL_{OATS,SPEL} + LEVL_{RYE,SPEL} + LEVL_{OCER,SPEL}\right)$$

Similar equations are used to break down other aggregates and residual areas in REGIO.

From the obtained area and production by crop activity, quantity of energy and protein for grazing livestock and digestible lysine have been calculated and used to estimate the regional level of autonomy to fulfil livestock requirements.

4.2.4. Farm type

As explained in the introduction of the paragraph 4 (page 10), total number of farms in a region and number of farms per farm types concerned by livestock production in regional Eurostat database (2002) were extracted. The list of the farm types of interest is available inside Annex 1. Because the abundance of farms per farm type of interest is provided at NUTS1 or NUTS0 level for certain countries (BE, NL, DE, AU), we have calculated the proportion (% of the total number of farm in a region) of the farms included in each farm types from NUTS0 or NUTS1 data and applied these percentages to each corresponding NUTS2 region.

The value obtained should be used to verify that classification of the regions obtained from the profile of the animals assemblages is coherent with the regional statistics available.

5. General methodology of the regional zoning

Whatever the regional descriptor considered (climate, feeding strategy, cropping systems…), the same classification methodology has been applied. It corresponds to a pure statistical approach of clustering of the regions regarding the descriptors retained. The method is briefly described hereinafter.

For one given animal sector considered (CAMILK for instance) or all sectors in the case of the regional clustering of the animals assemblage, different dimensions have been considered (see § 4 – LPS descriptors, p 10). It concerned eight dimensions:

- the animals assemblages
- the climates
- the cropping systems
- the feeding strategies
- the manures production
- the level of intensification
- the level of production

- the environmental impact

Raw data were directly extracted from CAPRI and expressed as absolute (n) and relative (%) quantities. When needed, they were processed to obtain intensification, autonomies or again autosufficiency proxies and introduced inside six different tables addressing one specific livestock sector each inside JMP 6.0 (SAS Institute). Then, four successive steps of the classification methodology were applied:

- Step 1: Multivariate platform was used first to decide of the descriptors to retain: scatterplot matrix on correlations was used to point out correlations between pair of variables – correlations between two variables higher than 0.90 asked for the withdrawal of one of the two variables considered, generally the less informative or the one expressing absolute value. By this, relative variables are often conserved: it allowed cross comparison between regions or classes of regions independently of the magnitude of the remaining variable in the regions. For correlation higher than 0.8 (up to 0.9), subjective decision based on expert knowledge to withdraw or not a variable was decided according to the loss of information it induced.
- Step 2: Principal components analysis (PCA) on correlations was then processed onto the remaining variables. Varimax rotation of the first significant principal components (cumulative percentage ≥ 0.75) was done and the rotated coordinates of the regions (row labels) on the remaining components were saved into the table of variables.
- Step 3: Two-way hierarchical ascendant classification (HAC) – standardized Ward method was then processed on remaining variables from PCA. The HAC was ordered according to the first component obtained from PCA: it eased for the visualisation of the results of the clustering. When using the first principal component as the column by which to sort regions, the data is ordered by generally small values to generally large values simultaneously across all variables used. It also gave a colour map on the dendrogram that is sorted across all variables in overall descending order.
- Step 4: To determine the relevant number of clusters to be processed, the approach was to perform in parallel of the HAC in JMP, a Ward two-way HAC into Xlstat v8.0. This platform, at the opposite of JMP, proposes an automatic (statistic) determination of the number of cluster (N_C). Then, in JMP, HAC was repeated on the same variables for a number of clusters between N_C-3 and N_C+3. The final number of clusters to be kept was decided by exploring the interpretability of the results of analyses of variance (ANOVA – Student t-test when normal distribution and Kruskal-Wallis test when non-normal distribution) obtained onto the variables by cluster when number of clusters varied from N_C-3 to N_C+3.

6. European LPS particularities in regions

Before to discuss classifications describing each one of the livestock sector, a certain number of maps have been produced from the available data to illustrate the European particularities of the livestock production (all sectors confounded) at regional level; these results are briefly presented and discussed in this part.

6.1. General overview of the Livestock Production in Europe

Europe is leading world agriculture production: in 2002, the EU15 participation to the shares in world trade in agricultural products was more than 40% either for exportation and importation; agricultural products traded from/to EU15 represented a share closed to 10% of the total merchandise and primary products traded in the world (WTO, 2003). But agricultural production in Europe is not uniform; agriculture production is differently distributed over Europe from one country to another as well as from one region in a country to another region. The mapping of the agriculture production – expressed as the revenue from crops and livestock production in a region (Figure 4) – shows that the main countries participating to the annual European agriculture revenue are the Denmark, France, Germany, Ireland, Italy and Spain. However, other countries such as the Greece, Netherlands, Portugal or again the United Kingdom appeared as important as the former; the difference is just that their agricultural production is more concentrated in few regions of production (Portugal, Netherlands) or more uniformly dispatched (and consequently lower) across all the country (United Kingdom). Figure 4 also shows that the total 2002 European revenue was mainly a consequence of the agriculture productions of Western countries located onto the Atlantic and Mediterranean perimeter.

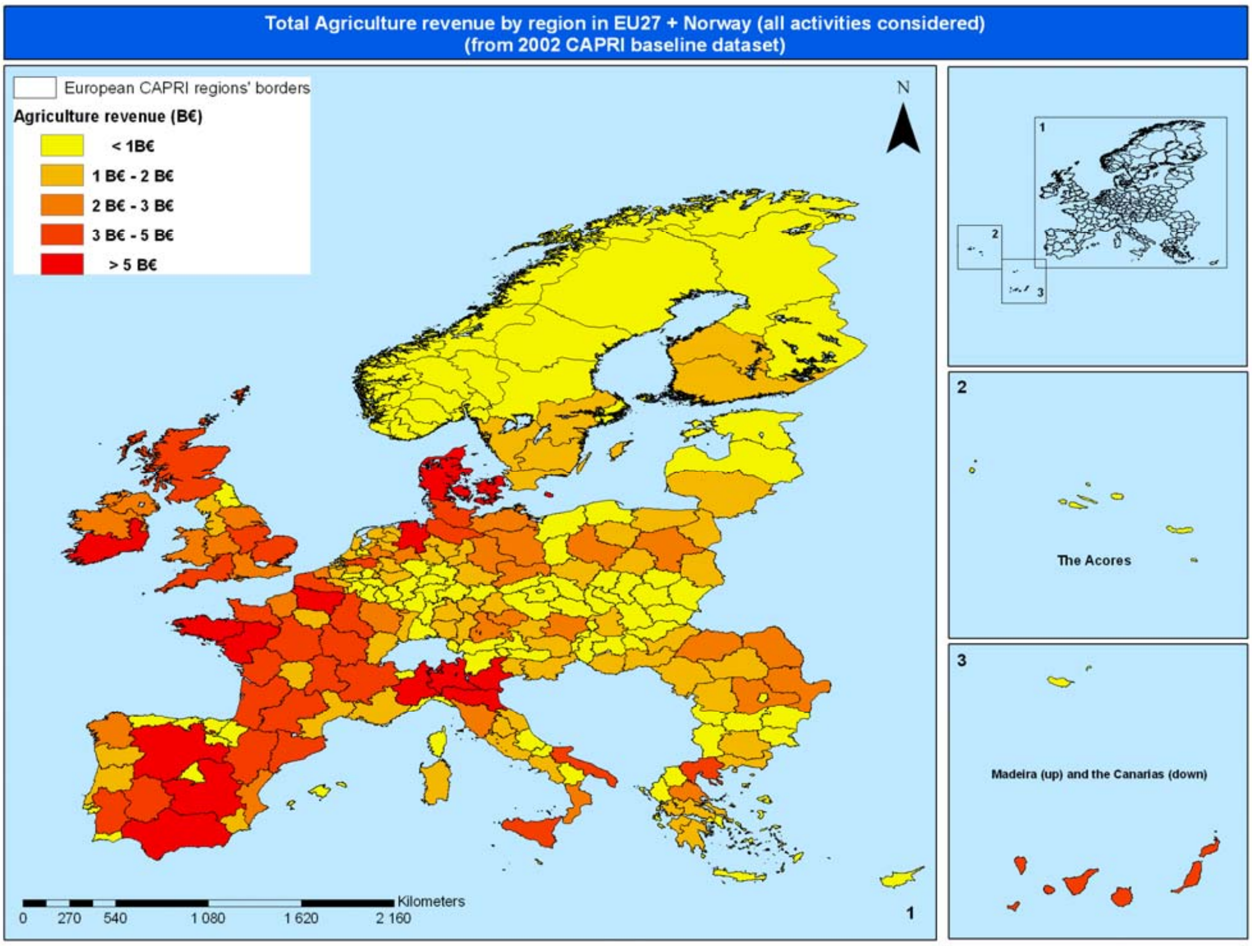

Figure 4: Mapping of the total agriculture revenue (B€) per region in EU27 + Norway

However, this figure tended to disadvantage regions with a limited potential area of agricultural production. This has been corrected by considering agriculture revenue relatively to the total used arable area (UAA) in a region (Figure 5). European regions presenting the higher revenue per hectare of UAA were found in Belgium (BE21[18], BE22 and BE25), in Italy (ITC4, ITD3, ITD5), in France (FR52), in Germany (DE94, DEA3), quite all the regions in the Netherlands and the Rogaland region in Norway. Cyprus, the Canarias (ES70) and Madeira (PT30) were also of interest.

[18] The table of the NUTS0, NUTS2 codes and names of the regions considered inside CAPRI is given in annex 2

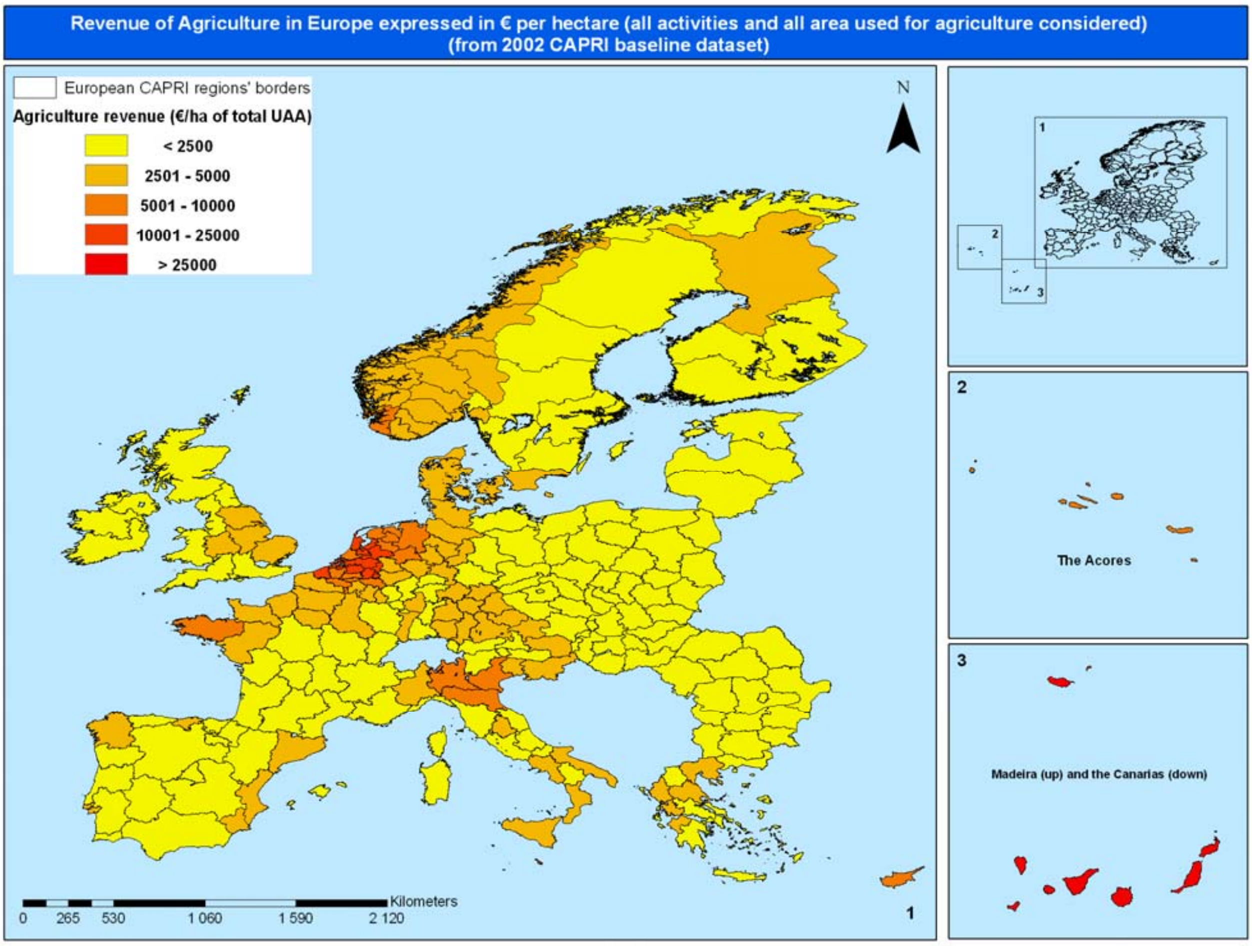

Figure 5: Mapping of the relative regional agriculture revenue (€/ha of total UAA) in EU27 + Norway

For 2002, we have then considered the share (%) of the livestock revenue (all the six livestock sectors together) in the total agriculture revenue (Figure 6). Expressed as a percentage of the total agriculture revenue, it suggested the importance of the livestock production for the regional agriculture economy and allowed the different regions to be compared independently of the absolute livestock revenue observed in a region. On the other hand, it asks from the reader an effort to consider the predominant regions for livestock production (Figure 6) and the total agriculture revenue (Figure 4) together.

The European regions presenting the highest (≥ 80%) share of the livestock production were situated on a SW-NE axis, from northern Portugal to Norway, including Denmark, Ireland, The Netherlands and the United Kingdom. Another predominant zone for livestock production was centred on the Alpine massif and contains French, Italian and Austrian regions. Furthermore, Catalunia in Spain, Auvergne in France and Stredné Slovensko in Slovakia are few isolated regions where the share of the livestock production remained important.

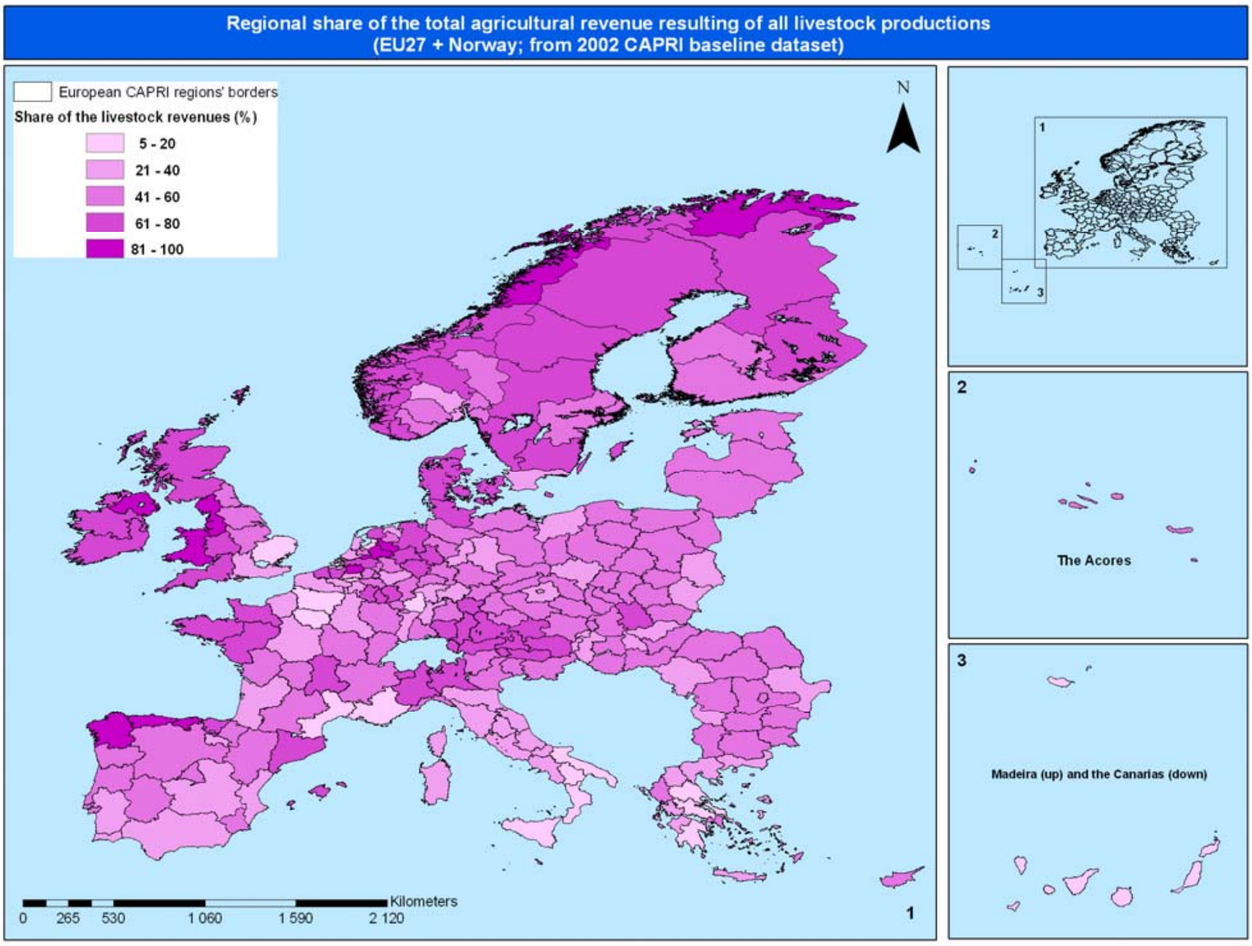

Figure 6: Regional share (%) of the livestock production in the total agriculture revenue in EU27 + Norway

From this, we assumed concentration of the livestock production along the Atlantic border could be climate-dependent. Here, the importance of sufficient precipitation a year for low latitudes or temperate temperature for medium latitude could explain the trend observed: these meteorological conditions could be considered as favourable for the fodder biomass production. In the same time, we could assume that climatic-limited situations such as mountainous or Scandinavian climates (higher latitude), plant production becomes impossible or cost-ineffective and livestock production is the sole farming adapted to the agro-climatic potential.

Inherent to the method of calculation, the share of the plant revenue in the total of the agriculture revenue is the complement to the share of the livestock revenue (Figure 7). The main regions for which plant production is the major source of revenues are logically those presenting a low share of livestock production. It concerned the south of Spain, the south and north of France, the Eastern region in the United Kingdom, and a large part of the Greek regions.

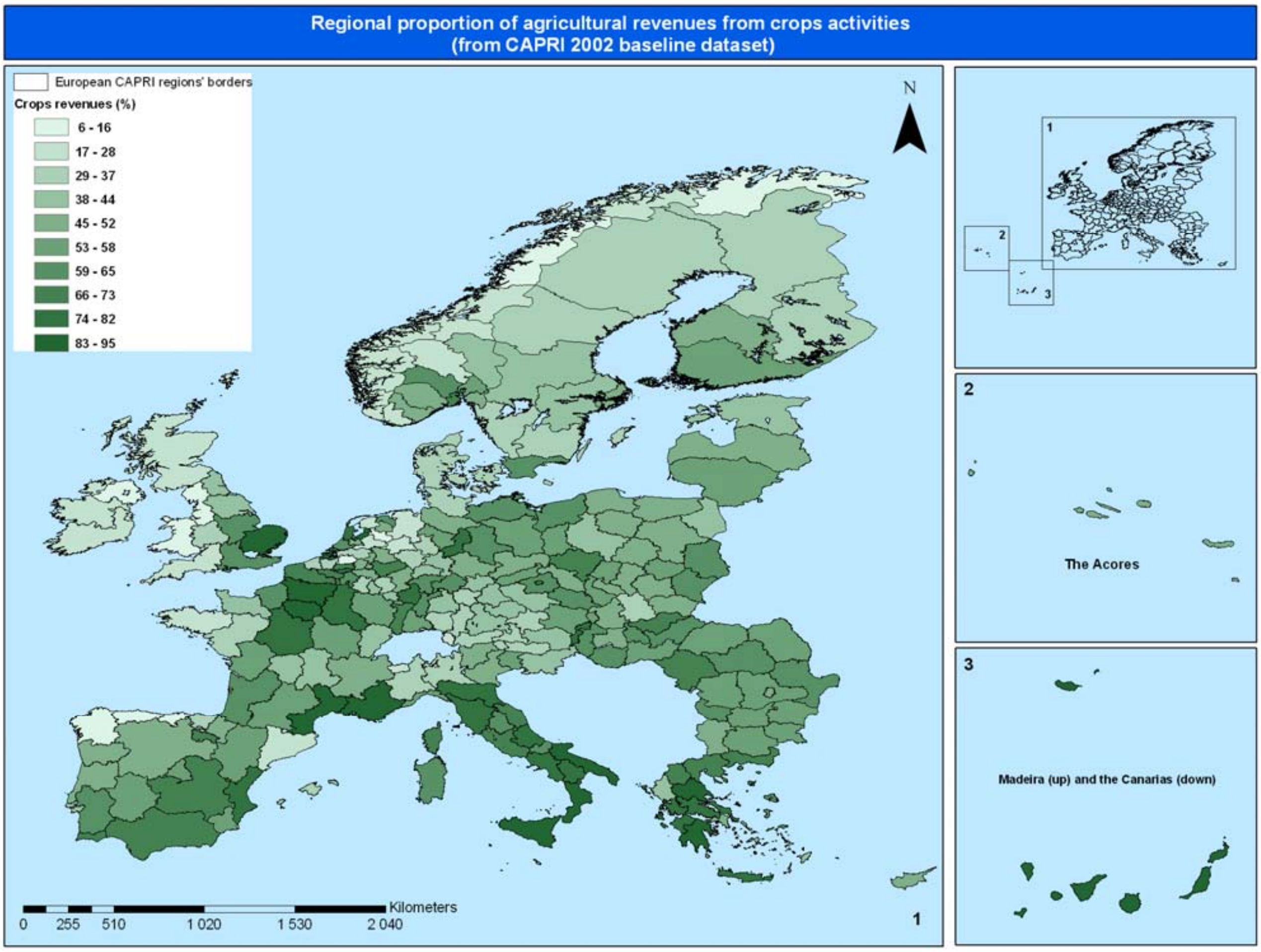

Figure 7: Regional share (%) of the plant production in the total agriculture revenue in EU27 + Norway

From the last two figures, we can remark that the majority of the regions localised in the Eastern Europe present a relatively well balanced share of the total revenue between plant and livestock production. At the opposite of certain western European regions considered as very specialized, eastern European regions appear as less differentiated and less specialized. However this result could be biased due to the fact that all activities have been merged to calculate the agriculture and the plant and livestock revenues. By considering livestock sectors independently, a balanced region for livestock production could become later a very specialized region because of livestock revenue originated from one single livestock sector. This confirms the necessity to conduct further analysis separately for each one of the livestock sectors and to address in depth “regional herd size” and “regional herd composition”.

Herds assemblages would be addressed later in this document (§ - 6.2.1.). Before that, the total number of livestock units (all livestock sectors together) has been calculated and mapped (Figure 8). The denser regions observed for 2002 were situated in a limited number of European countries those already pointed out by Burton & Turner (2003). They were the Weser-Ens region in Germany, all the Denmark, the Castilla-Leon region in Spain, almost all Ireland, the Bretagne and Pays de la Loire regions in France, all the north of Italy from the Piemonte to the Veneto region, the Noord Brabant region in the Netherlands and the South-Eastern region of the United Kingdom plus Scotland. Dense livestock populations were also localised in Eastern Europe regions: the Mezowiecke and Wielkopolskie regions in Poland, Lithuania and the Nord-East region of Romania.

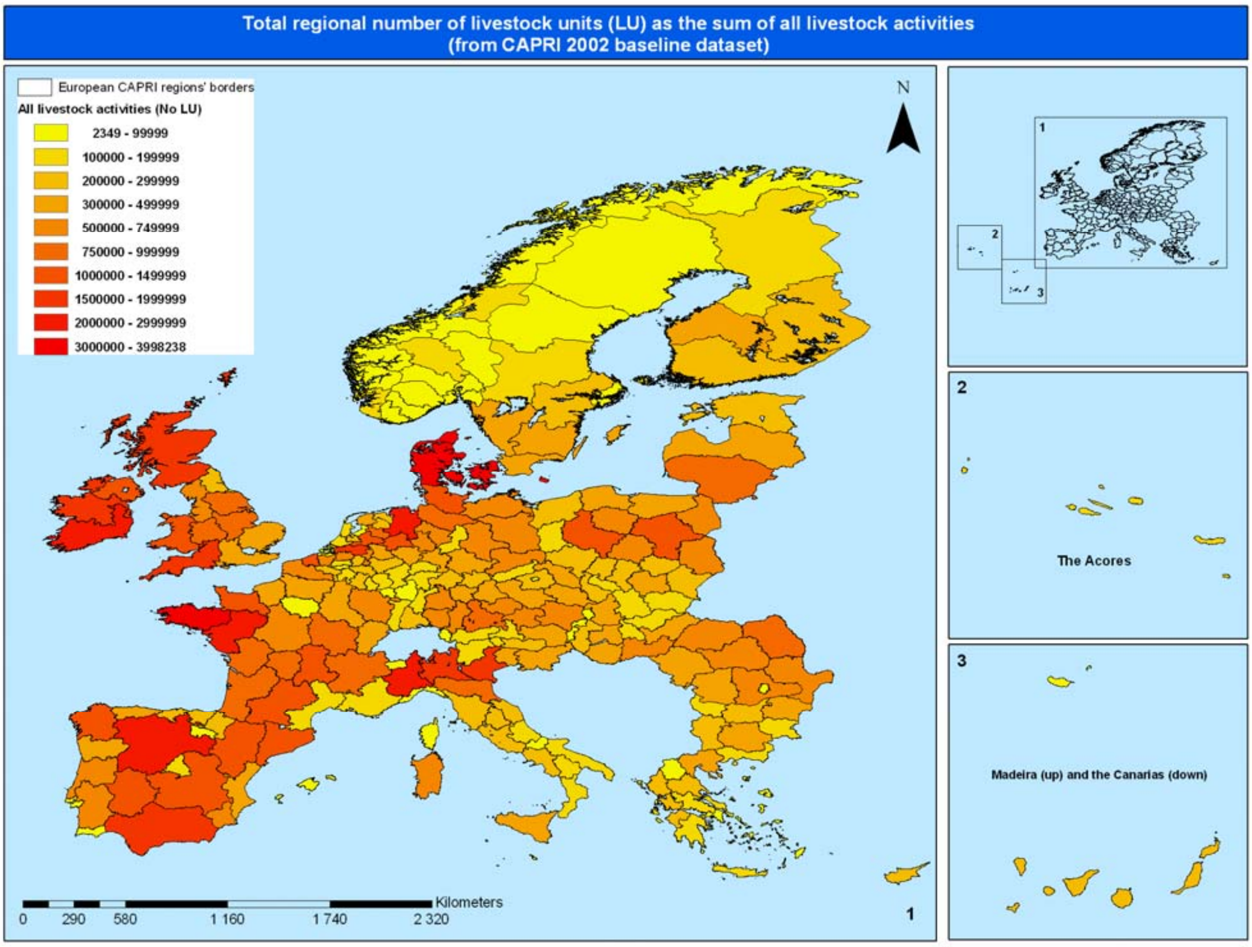

Figure 8: Regional distribution of the total number of livestock units (LU) in EU27 + Norway

When crossed, the share of the livestock revenue and the total number of livestock units coincide well. However, certain regions such as Scandinavian regions are not highlighted in Figure 8; furthermore, some other regions (the Polish ones for instance) appear in figure 8 when they have not been identified as predominant for livestock revenue; this points out the fact that revenue per livestock unit is also important. This confirms that share of the livestock revenue cannot be consider alone; supplementary quantitative information such as the number of livestock units or the produced quantities of livestock products (which are generally very strongly correlated) must be consider when an accurate clustering of the regions is expected.

Logically, when considering the manure production (expressed as the quantity of nitrogen per hectare of arable land) we show that the regions with the highest quantity of nitrogen-from-manures (Figure 9) correspond to almost all the main dense regions. The trend is also valid for phosphorus and potassium. If most of the regions with a dense population of livestock units presented an applicable amount of N-manures inferior or closed to 170 kg per hectare (Reg. EEC No. 676/1991), some of the regions have N-manures availability exceeding this threshold.

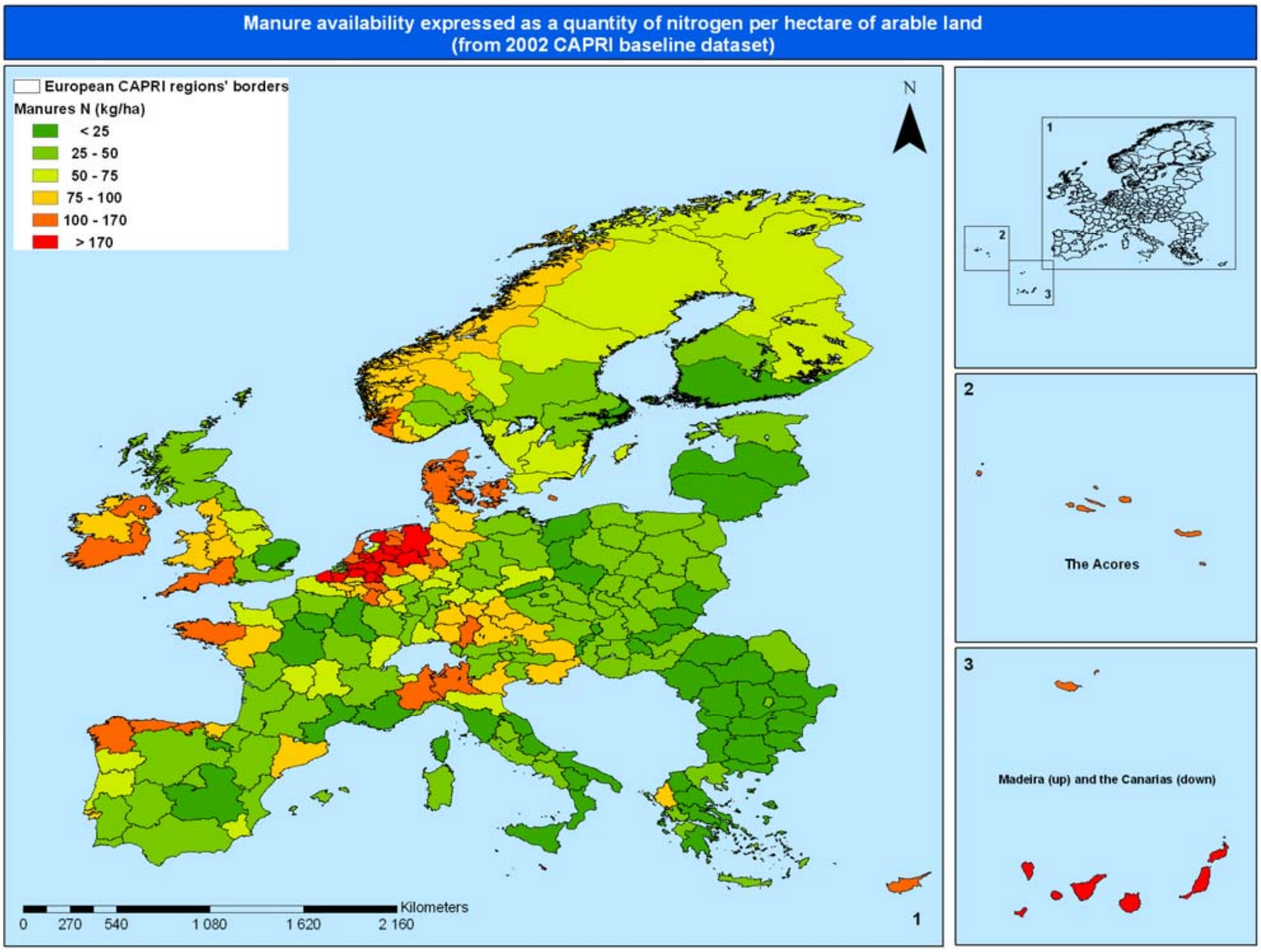

Figure 9: Regional distribution of the nitrogen-from-manures availability per hectare of arable land in EU27 + Norway

It concerned regions concentrated in Belgium (BE21, BE22, BE23, BE25) in the Netherlands (NL12, NL21, NL22, NL31, NL41, NL42), in Germany (DE94, DEA3), The Canarias (ES70) in Spain and Malta (MT). On the other hand, certain regions with a high total number of livestock units (in France, Ireland, Italy or in the United Kingdom) do not show N-manures availability exceeding 170 kgN/ha threshold. However, all these regions are considered as regions in Europe where the pollution of surface and ground waters by nitrate from livestock production is at very high risk. According to the specific climatic conditions met in these regions, decisions concerning the spreading practices are crucial for the protection of the agricultural resources and adapted manures management strategies (storage and spreading facilities) are requested.

Together with the estimated quantities of nitrogen applied from fertilizers and the residual nitrogen from crops, the N-surplus per hectare of arable land has been estimated within CAPRI and mapped (Figure 10). It corresponds to the quantity of nitrogen that cultivated plants on arable land cannot assimilate – crops nitrogen requirements being already fulfilled. Almost all the regions identified as predominant for livestock production (independently of the dominant livestock sector in place) present a very high (>75kgN/ha) N-surplus. It concerned regions located along the Atlantic SW-NE axis, around the Alpine massif and in lesser extent in the north of Finland.

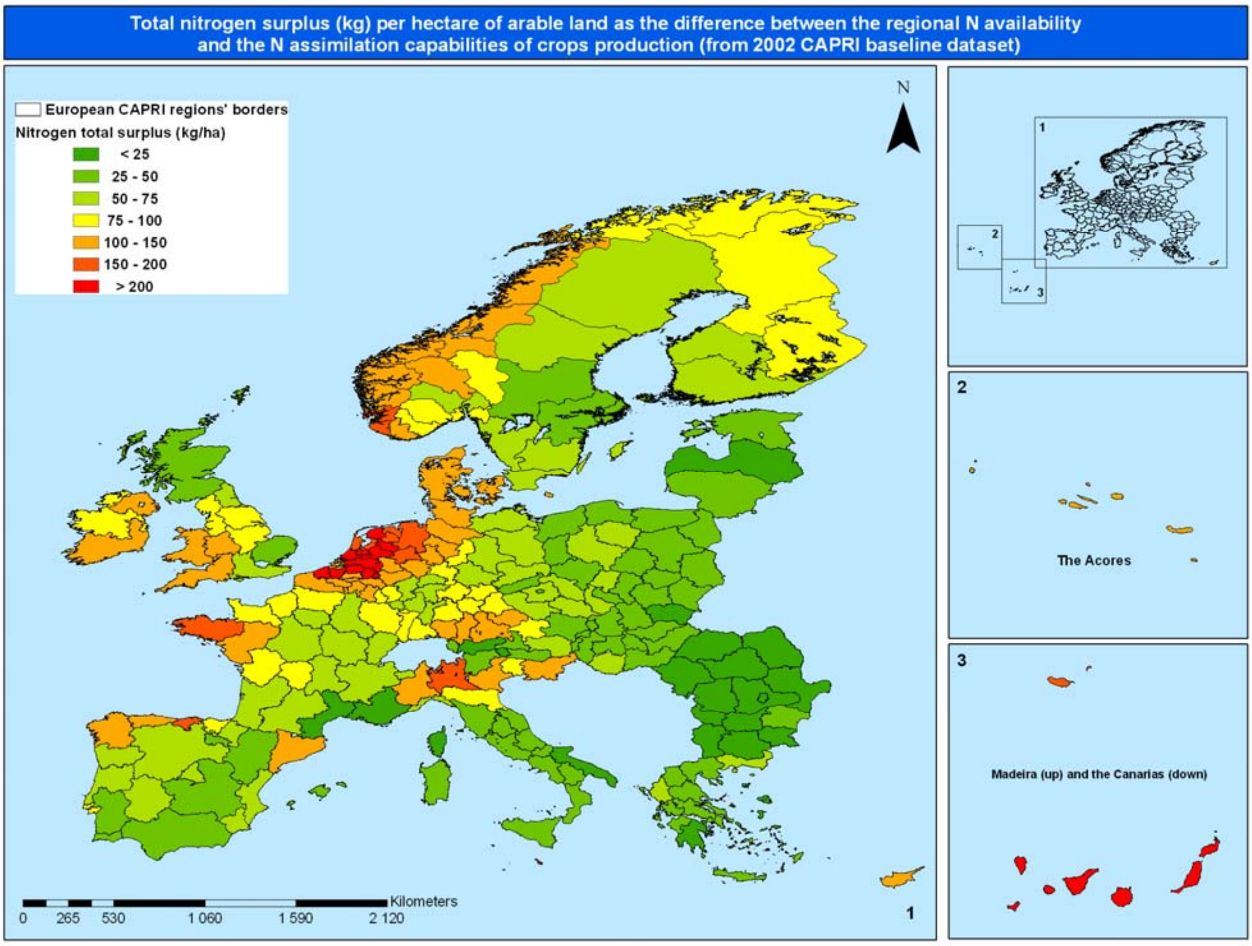

Figure 10: Regional distribution of the total nitrogen surplus (manures + fertilizer + crops residues) per hectare of arable land in EU27 + Norway as an indicator of the water-ground pollution by nitrate risk

Surprisingly, in Eastern Europe, none of the regions with relatively dense livestock population are presenting a high N-surplus. At the opposite regions in Bulgaria and Romania appeared as the less exposed to a water-ground pollution by nitrate (phosphorus and potassium as well). Another remarkable point concerned the Mediterranean regions. Despite the fact that some of the Italian, Spanish and Greek regions were identified as regions with medium livestock population density, they didn't present a high risk for ground-waters pollution by nitrate. Two main reasons could explain this trend: (i) very large cultivated areas proportionally to the livestock herd size (and manures availability) allow farmers to practice an efficient spreading of the manures with a low risk of ground-waters pollution by nitrate; (ii) the nature of the livestock reared in these regions is less manures-productive and limits the risk of pollution; in this case analyse of the animals assemblage and predominant livestock sectors in place should be determinant.

6.2. Climatic, animals assemblages and cropping systems classifications

Prior to the sector-specific classification of the production systems (LPS), stratification of the whole number of regions by a limited number of climatic zones or by the livestock sector predominance or again by the cropping systems in place was possible. It has been considered because stratification generally eases the interpretation of the clusters obtained. Decision was taken to target robustness rather than interpretability of the results and stratification anterior to the classifications was not performed : regarding the limited number of regions (243 in total) stratified population would limit greatly the final number of regions per class of LPS and the rule of thumb was to obtain at least ten regions by cluster. Consequently, classifications dedicated to climatic, cropping systems and animals assemblages were operated separately. This solution asked for a supplementary effort of interpretation to cross by-sector classification results with climatic, cropping system and animals assemblages classification results when deciding of the final regions to be surveyed. But it remained possible.

6.2.1. Climatic classification

The climatic classification was processed following the in-4-steps classification method explained in the paragraph § - 5. From seventeen initial variables and after identification and reduction of the highest correlations, only three variables were retained:

- the cumulative sum of the daily temperature for the 6 first months
- the number of freezing days a year
- the precipitations registered for the year

In the same time, but separately, elevation classification was processed from averaged regional elevation and dispersion index of the elevation (as the elevation uniformity in a region). Concerning meteorological data, the first three components of the PCA absorbed almost 90% of the data variability. Varimax rotation was then executed onto the three first components. The clustering of the 243 regions has been processed over a number of clusters from 5 to 11 for the meteorological variables and from 2 to 8 for elevation variables; the final number was 8 and 5 respectively for climatic and elevation clusters. Distinction and description of the climatic and elevation clusters was made from analyse of variances (normal distribution being verified) performed onto the clustering variables and several other variables. The results of ANOVA are summarized in annex 3 and 4 for the principal descriptive variables. The general rule-of-thumb to obtain at least 10 regions per cluster was not possible; even the reduction of the number of cluster to 5 didn't allow us to obtain clusters with more than 9 regions.

The eight different climates identified can be described as follows (Figure 11):

- Cluster 1 – "Oceanic temperate": situated between the 45°N and 55°N latitudes, it corresponds to a temperate climate (intermediary cumulated daily temperatures with a very low number of freezing days) under oceanic influence (high number of rainy days, but medium to low precipitation abundance per day). These are regions of Western Europe very closed to the Atlantic Ocean and the North Sea: North of France, Belgium, the Luxemburg, the Netherlands, part of the United Kingdom and Ireland and western Germany. These regions correspond generally to sea level regions and in less extent to regions with hilly relief (Figure 12): they are regions with low to very low elevation and a low index of elevation dispersion index describing flat to very flat regions.
- Cluster 2 – "Oceanic cold": this climate is very similar to the previous one with higher quantities of rainfall a year and colder temperature. The radiation is low to very low due to the fact that these regions are situated between 55°N and 65°N latitudes. Under both the polar influence (cold temperature) and the oceanic influence (very wet), these regions have a high number of rainy days and a total precipitation a year the highest in Europe. It concerns only few regions localised on the south Scandinavian peninsula in Norway and the Salzburg and Vorarlberg regions in Austria.
- Cluster 3 – "Mediterranean dry": climate very hot and dry, the regions concerned are under the sub-Sahara influence. Generally situated between the 35°N and the 45°N latitudes, it

corresponds to the southern regions of Spain, Italy and Greece and almost all the Mediterranean archipelagos. Cumulated daily temperature and solar radiation are very high and these regions are benefiting of the larger favourable temperature window for crops growth; however, the lack of precipitation reduces greatly the advantage of the thermal condition by inducing high evapotranspiration and hydric deficit. For annual crops, these regions generally have recourse to irrigation.

- Cluster 4 – "Continental temperate": situated onto an N-SE axis, the regions under the influence to this climate correspond to almost all the central eastern European region, from Denmark to Bulgaria. All the meteorological variables considered depict medium values: with intermediate precipitation, number of freezing and rainy days, a medium cumulated radiation and daily temperature, this climate is more constant one. Because this climate concern regions closed to the ocean as well as regions situated in the Carpathian and Balkan massifs, the corresponding range of elevation fluctuates from low to medium elevation and from low to medium elevation dispersion.
- Cluster 5 – "Continental cold": situated at the interface between the polar and continental influence, the continental cold differs from the previous climate by colder temperatures and higher precipitation. The corresponding regions are situated around the Baltic Sea: Sweden, Finland, Estonia, Latvia, Lithuania and some regions of Norway. They present very low elevation and relatively flat landscape (Elevation – Cluster 2). These conditions are generally considered as favourable to agriculture by facilitating the use of heavy machinery. Despite this, localisation at relatively high latitudes (from 55°N to 70°N) confers to these regions a much more reduced potential for plant cultivation: radiation and cumulated daily temperature are among the lowest in Europe.
- Cluster 6 – "Mediterranean wet": when compared to cluster 3 "Mediterranean dry climate", the conditions met for cluster 6 appear friendlier. Beside high cumulated temperatures and radiation, the corresponding regions benefit of more important and more regular precipitations (724.7mm ± 82.2 against 482.2mm ± 91.4); this counterbalancing the disadvantages observed for cluster 3. Consequently, this cluster can be considered as the best compromise for the cultivation of annual and perennial crops. The regions influenced by this climate are situated between 40°N and 45°N latitudes and are the north of Spain, north of Italy and Greece and the south of France. They correspond to medium mountains' elevation more or less erratic.
- Cluster 7 – "Alpine": almost all these regions concerned are belonging to elevation clusters 3 and 5: they are situated in medium to high mountainous zones. It concerns Austria, extreme north of Italy, Slovenia, The Limousin and Franche Conté regions in France, the Norte region in Portugal, Scotland and Wales in the UK, the extreme south east of Germany and the Vaestsverige region in Sweden. They receive a medium amount of radiation and they present medium temperatures with a medium number of freezing days. However, the precipitations are important as well as the number of rainy days. The number of snowy days (68.48 ± 47.42) is medium when compared to those observed for the Oceanic cold climate (151.68 ± 18.93) and the Arctic climate (212.89 ± 18.17).
- Cluster 8 – "Arctic": finally, the last regions, localised between the 62°N and 72°N latitudes, are concerning the Scandinavian Peninsula. They are under the influence of a very cold and dry climate with a very high number of rainy days. The climatic window can be considered as the worst for agriculture activities: cumulated radiation and temperature are the lowest in Europe; the number of freezing days is 149.6 (± 10.7). Elevation varies from low to medium as well the elevation dispersion.

From this first results, interpretation of the climatic and elevation clusters all together remained an easy thing. However, the elevation classes do not match correctly the climatic clusters obtained: several climatic clusters are presenting a very large range of elevation and uniformity. To go beyond this, a reduced number of elevation classes is conceivable. For instance, socioeconomic models such as AROPAj[19] are considering three elevation classes (≤300m,]300m-600m], >600m) when clustering farm types and/or farming systems. In our case, the reduction to three elevation classes was more convenient for elevation classification interpretation[20] but very limited when related to the climates (for instance, elevation class 2 counted regions with climates 1, 2, 4, 6, and 8). Reduction of the number of elevation classes was then not meaningful and 5 classes of elevation were kept. On the other hand, it validates the method of deciding of the number of classes from a range of clusters centred onto a number automatically determined from statistics.

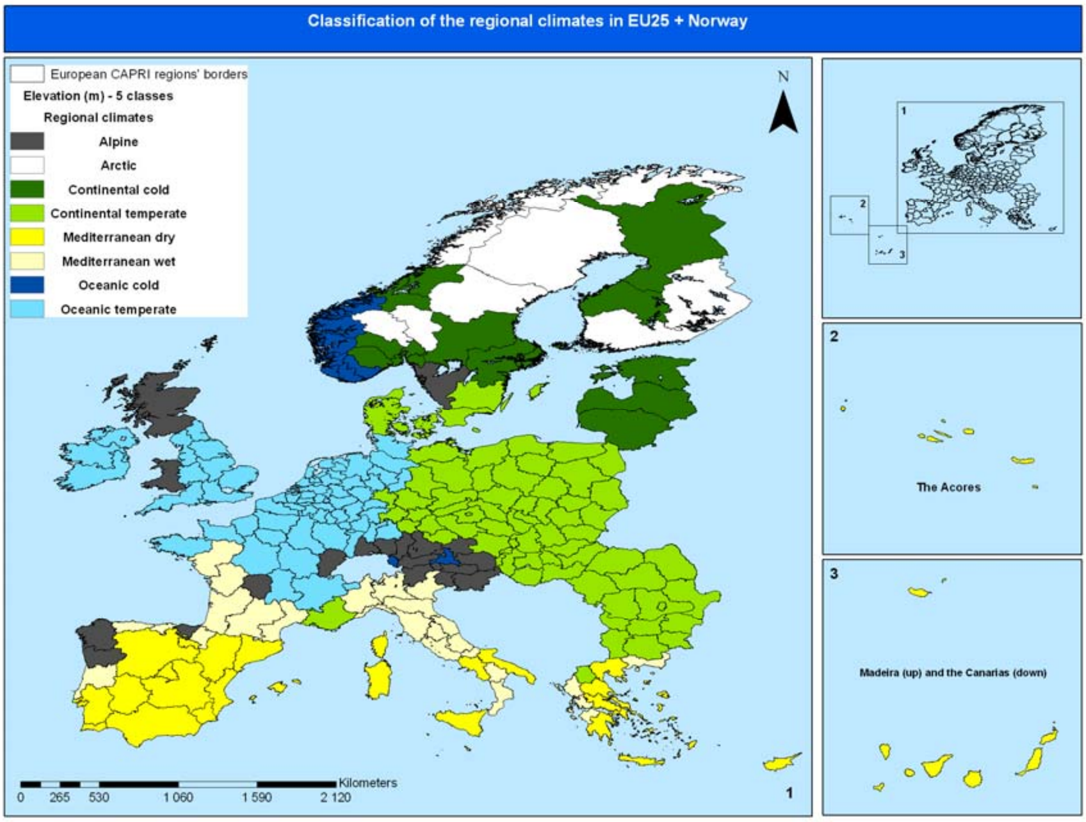

Figure 11: Mapping of the eight main climates identified in EU27 + Norway

[19] http://www.grignon.inra.fr/economie-publique/MIRAjE/model/detail.htm

[20] If three elevation clusters would be decided, averages and standard deviations would be 691.56 (436.79), 101.75 (65.36), 445.32 (11.78) and 424.63 (167.74), 26.66 (23.42), 131.98 (76.34) for elevation and elevation dispersion respectively for clusters 1 (n=38), 2 (n=112) and 3 (n=93)

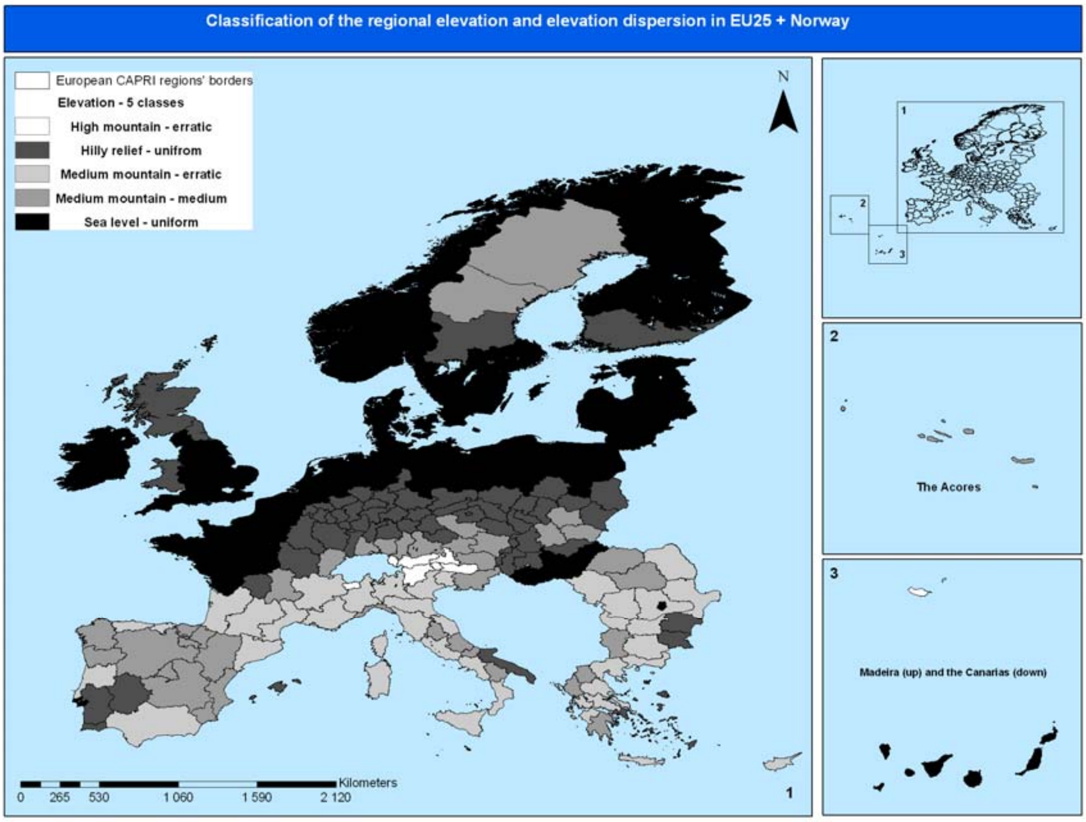

Figure 12: Mapping of the five main elevation classes identified in EU27 + Norway

<u>6.2.1. Animals assemblage classification</u>

The animals assemblage classification was performed following the same method. The data used was the absolute abundance of livestock units per livestock sector from which the by-pairs of region Morisita's index of similarity has been calculated and compiled into a double matrix of similarity (see § - 4.2.2). From the automatic and successive HAC, ten clusters were decided. In parallel, the relative abundance (%) of each livestock sector in the total number of LU was calculated per region. Averages and standard deviations per cluster (as well as ANOVA performance) are shown in annex 5.

Despite cluster 7, all other clusters present at least one livestock sector for which the averaged percentage obtained was higher than the 75th percentile obtained from the analyses of the distribution per sector (n=243). More than half of the clusters show two or three major livestock sectors participating to the animals assemblages. Cluster 7 is the sole cluster for which the percentage obtained is higher than the 50th percentile but smaller than the 75th percentile; no livestock sector is really dominant in cluster 7. From these values, we have proposed a denomination of each one of the clusters by considering the two first livestock sectors participating to the animals assemblages and by respecting the hierarchy of participation. In some cases, because three different livestock sectors participated equally to the animals assemblage, a unique identifier expressing a common aspect to the three sectors was preferred. Regional mapping of the final ten clusters is presenting in figure 12; the different denominations attributed to each one of the clusters are:

- Whatever the number of clusters tested during the HAC (step 3, see § 5.), one of the regions was always identified alone as ovine-dominant. This described a very strong differentiation of the region according to its animals assemblage. This region was the Kriti region in Greece (EL43): more than 85% of the whole regional herd (in LU) in 2002 was composed by SHGOAT. Consequently, EL43 has been considered alone as ”OVINE”.

- Cluster 2 “GRANIVORES / OVINE”: in this cluster, the main productions were the pigs for fattening production and the broilers productions (≥ 75 percentiles); laying hens production was less important but present mean value higher than the 50 percentiles. In the same time, ovine production was also very important (≥ 75 percentiles). This cluster was consequently called “granivores / ovine”, with granivores corresponding to poultry and pigs productions together. The seven regions identified as “granivores / ovine” are eastern Spanish regions and Cyprus. This cluster is describing situations where monogastric livestock production is predominant over other livestock productions under the influence of Mediterranean dry or wet climates (as described in §-6.2.1.). Preference of rearing little grazing animals and monogastric livestock could be partly explained by the limitative climatic conditions and limited pasture production (and share); it should also requires livestock facilities such as cooling systems, automatic feedstuffs distribution to avoid stresses during production and logically involves indoor production systems.
- Cluster 3 “OVINE / BOVINE”: when compared to the two first clusters, the ovine / bovine cluster is differentiated by the fact that bovine livestock for meat are reared together with ovine livestock – ovine staying the dominant production. The regions belonging to this cluster are very dispatched across Europe – from extreme south of Spain to Norway, in Greece and Ireland. In this cluster, sheep’s and goats for meat or milk remains the dominant livestock production (≥ 75 percentiles); and cattle meat production seems to be associated to the latter. This association of grazing livestock is certainly very different fro one region to another, even more from one country to another. One could imagine that feeding corresponds to very intensive indoor production (south of Spain) or to free / rotational grazing of mountainous alpages (in northern Greece, in Provence Cote d’Azur and Corse region sin France or again in Sicilia and Sardegna regions in Italy). On the other hand, “Ovine / bovine” production under higher latitudes such as in Ireland would have recourse to grazing of temporary or permanent pastures at high potential yield and haymaking.
- Cluster 4 “BOVINE / OVINE”: the increase of the bovine livestock share leads to livestock productions targeting bovine production first. Cluster 4 corresponds first to milk and meat cattle production – other livestock productions appear as subsidiary. Regions concerned are situated closed to the Pyrenean chain in France and in Italy benefiting of Mediterranean wet or oceanic conditions in Ireland and Norway.
- Cluster 5 “BOVINE”: together with clusters 7 (n=47) and cluster 8 (n=40), this cluster is one the largest clusters when considering the number of regions it contains (n=46). The bovine cluster presents a large proportion (75% approximately) of livestock destined for milk and meat production from cattle. The corresponding regions are localised in the western Europe at medium latitude and in the northern Europe in Latvia, Lithuania, Estonia and in the Scandinavian peninsula. The presence of bovine productions in these regions could be a consequence of (i) a priority given to grasslands because of too limitative conditions for plants production (high latitudes) or (ii) a locally specialized bovine production due to cultural/historical or sectors facilities at lower latitudes (as in north west of France, south of Germany, Austria).
- Cluster 6 “GRAZING”: Other region specialized in bovine production, especially bovine meat production, are sometimes grouped in less favourable regions as hilly relief or medium mountainous regions (Auvergne and Franche conté regions in France, the Trentino-Alto

Adige region in Italy, the Tyrol region in Austria). In the same cluster, other regions closed to the sea-level (the North-west and south-east regions in the UK) under the influence of oceanic climate or regions under continental cold or even artic climates are presenting animals assemblage classified as bovine (Finnmark and Nordland regions in Norway or Mellersta Noorland in Sweden). If all these regions have a bovine dominant production, they present at less extent a certain SHGOAT share.

- Cluster 7 "MIXED without SHGOAT": In this cluster, none of the six livestock sector is dominant and sheep's and goats production is generally very limited. Bovine for milk as well as pig and in a less extent poultry productions are the major (≥50 percentiles) productions describing this cluster. These regions are clumped in central and eastern parts of Europe, from the Netherlands to Poland. It also concerns north of Italy and some regions in the Scandinavian Peninsula.

For the remaining clusters, regions are more disseminated over EU27+Norway; for them, livestock productions are generally conducted indoor so that climate or relief do not influence so much as assumed for the previous clusters.

- Cluster 8 "GRANIVORES": all the three monogastric categories of livestock appear as preponderant in this cluster. Pigs as well as poultry (LAHENS and POUFAT) productions are the major sources of revenues from livestock in the concerned regions when grazing livestock activities are very weak. A large number of countries are concerned by the granivores production: Belgium, Germany, Portugal, France, Poland, Austria, UK etc. If almost all the countries present one single region specialized in granivores production, Poland, Hungary, south Netherlands and northwest Germany at the opposite seem to have a large part of their territory dedicated to such a production. As expected, the random location of the granivores regions indicates that climate conditions only slightly decide of the organization of the granivores sector. Same trend are observed for the last cluster (cluster N°10).
- Cluster 9 "OVINE / POULTRY": this cluster does not count a high number of regions and appears to a certain extent related to the local farming culture and history. Seven of the eight regions concerned are Greek; the last one is the Spanish Canarias region. The animals assemblage found for these regions excludes cattle breeding and pigs production. Only little grazing (ovine) and monogastric livestock are reared. We assumed that this choice is related to a limited crop production potential which does not allow feedstuffs auto consumption and would require to farmers very high feeding investments in the case where cattle and pigs would be produced.
- Cluster 10 "POULTRY": as stated for cluster 8, only few countries are concerned by a dominant poultry production (POUFAT and LAHENS). Most of them are located in Spain, France, UK, Italy, Romania, Bulgaria and in Norway suggesting that if climate is less influent than for pigs production, the trend is even so to localize poultry production at low latitudes. One could suggest that it may limit heating and cooling costs or corresponds to crops productions dedicated to poultry production (cereals, maize grain…).

From this animals assemblage classification, a large range of regional predominance has been observed. On the one hand, ovine and bovine livestock appeared as organized in regions according to a certain climatic gradient and could be related to the availability and the potential production of fodders. On the other hand, some sector are less climatic-dependent; the "granivores" specialized regions are for instance very dispatched over Europe and do not match any of the agroclimatic gradient. This suggests a less climate-related influence on the monogastric productions: indoor and less land use-dependent, poultry and pig productions can be established everywhere in Europe.

Limitations could be the logistical and sector facilities necessary to collect and transform the production (Burton & Turner, 2003).

This classification also suggests that ovine and poultry productions could be strongly related to cultural and historical practices locally decided along time and that granivores production appear as more specialized in region than other livestock sectors. Once again, without any other meaningful explanation, we assumed that the potential cropping system and the potential of biomass production are the major levers deciding of the size and nature of the livestock to be reared in a region. This should not exclude other possibilities such as cultural or commercial influences.

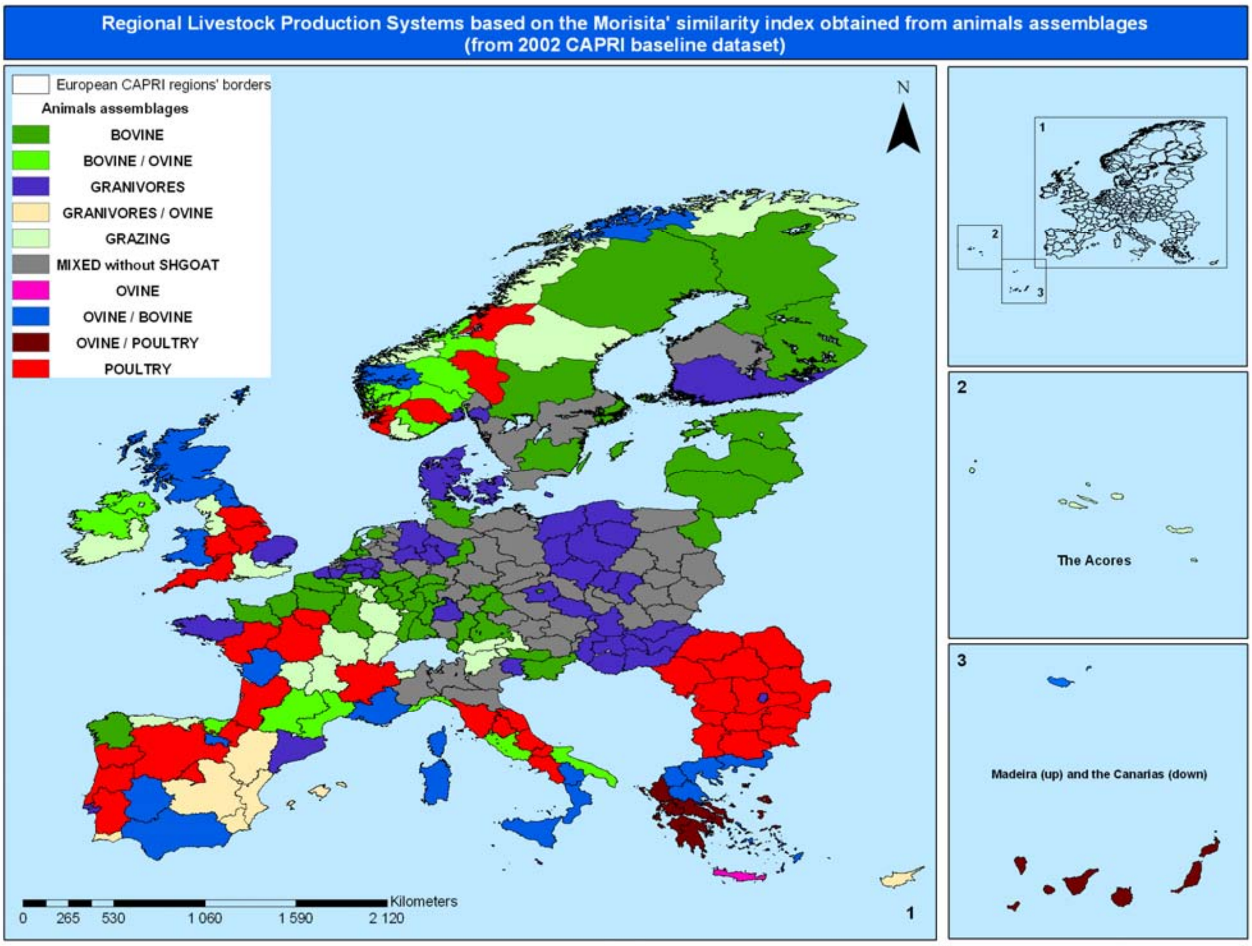

Figure 12: Animals assemblages mapping in EU27 + Norway

The relevance of this classification has been later verified by comparing animals assemblage in a region and European data. From Eurostat, the number of farms per farm types concerned by livestock production has been extracted for 2002. The share (%) of each farm type in the total number of farms was calculated and used to estimate if the animals assemblage classification provides us a valid interpretation of the livestock production in region. Results are shown in annex 6.

Almost all the farm types considered are matching the clusters obtained from classification onto the animals assemblages. Farm types T41, T42 and T43 concerning cattle breeding are well distributed inside the "BOVINE / …" as well as the "… / BOVINE" clusters. Same trend is observed for sheeps' and goats versus "OVINE" and granivores versus "GRANIVORES". However, certain farm types such as T71 and T82 are less well distributed inside the animals assemblage clusters. For instance, T71 – "Mixed grazing" farm type should present a high share for clusters 3, 4, 5, 6 and 7 which are the main clusters where grazing livestock are reared. At the contrary, only clusters 1, 9 and 10 present a high share of T71 – "Mixed grazing" farms. This doesn't signify that our classification is wrong – but it suggests that discrepancy between the two methods exist. Farm type is determined from the economic valuation of each one of the production activities existing on farm (crops as well as livestock production activities are considered for T82 – "crops + livestock" for instance) from surveys. From this, the farm type is decided by considering the first or two first largest activities. To be comparable between European countries or regions, the economic values are expressed in standardized economic size units (ESU) of the farms. However, even if activities are standardized in a second step, initial economic values are different between countries and regions so that activities are not always comparable only from an economic point of view. In our case, the dimensions were the herd size and the herd composition and they have nothing to do with economic valuation. The comparison between our clusters and the Eurostat farm typology is used as a verification of the correctness of our animals assemblages.

6.2.3. Classification of the cropping systems

We saw in the previous paragraph that animals assemblages could be partly related to the cropping system in place in a region and to the corresponding climate. Concerning the differentiation of LPS, the general approach in this document is to consider feeding strategy by comparing the regional livestock feed requirements to the local feedstuffs availability to decide of the level of feedstuff autonomy in a region (i.e. the level of dependence on the market for feedstuffs provision). For that – grazing requirements have been compared to fodders potential in a region and – monogastric requirements for digestible lysine have been compared to the potential lysine production from rich protein, pulses and grain cereals cultivated (see § - 4.2.3.). Independently of the animals requirements, the regional crops' productions (area, yield) available within CAPRI have been used in a first step to determine the major cropping system existing in Europe. From all the 40 plant activities provided by CAPRI, the regional share per crop (soft wheat for instance), per gender (wheat = soft + durum wheat) or per family (cereals) has been calculated for each region. PCA was then performed on all the crops categories. If the main method was to remove crop categories presenting the highest correlations, some of the crop categories were selected (or removed) because of the possibility farmer has to use them directly as feedstuffs for one specific livestock sector. For instance "wheat" (durum + soft), "barley" and "grain maize" were preferred to "all cereals" category because their seeds can be used directly to feed poultry and in less extent porcine livestock.

Finally, eight cropping system descriptors were conserved:

- "Wheat" (durum + soft wheat)
- "Barley"
- "Fodder grasses"
- "Fodder Maize"
- "Rich protein oilseeds" (rape, soybean and sunflower)
- "Pulses"
- "Set-aside and fallow lands"
- Vegetables and permanent crops"

From these values, a range of clusters from 5 up to 11 has been tested and the final number of cropping systems was 8 (Figure 13). Averaged values of the descriptors per cluster are shown in annex 7. From this table and by using other ANOVA results from non retained descriptors, regional land use was described and clusters named. Voluntary, the different cropping systems identified have been sorted according to the presence of permanent crops: from permanent crops to annual crops. This should help the reader to progress inside the resulting classification.

- The "Permanent crops + vegetables" cluster corresponds to regions located on the Mediterranean border; Spanish, Portuguese, Italian and Greek regions are concerned. This trend is certainly closely related to the climate found in these regions: hot and dry, climate would limit the annual crops production to which permanent crops are preferred. When relating to livestock production (see §-6.2.2.), these regions receive OVINE-, GRANIVORES and OVINE/BOVINE-dominant livestock sectors. Pastoralism from one place to another, free-ranging grazing and the grazing of the common/natural grassland areas could be farming practices in vigour in these regions.
- The predominant "Fodder grasses" cluster presents a large share of the UAA occupied by permanent and temporally pastures. Located in Scotland and Ireland, around the Alpine massif in Austria and Italy or again in the Spanish Asturias and Cantabria regions, it corresponds to wet regions favoured by an oceanic or alpine climate. Regions are specialized in the grazing livestock production (figure 12); they are using grasslands as the main source of fibbers and fodder maize areas are very limited.
- The three following clusters "Fodder Grass > Maize", "Fodder Grass = Maize" and "Fodder Grass < Maize" correspond to the progressive increase of the fodder maize share in energy/fibbers supply. The corresponding regions are located around the previous "fodder grasses" regions and are progressively distant from these regions when the fodder maize share is increasing. "Fodder grass > maize" is located in the UK, around the Alpine massif and in medium mountainous regions such as the Corse, the Auvergne and Limousin regions in France or the Sardegna region in Italy. Then, "Fodder grass = maize" is expanded to less elevated regions situated in more diversified climatic zones such as Romanian, Polish, Lithuanian, Latvian or Swedish regions. Finally, when the grass/maize balance is inversed, "Fodder Maize > Grass" is spread over Europe and region such as the Anatoliki and Kentriki Makedonia region sin Greece, Lodzkie, Mazowieckie and Svietokzystie regions in Poland, Alsace, Bretagne and Pays de la Loire in France or others in Italy, the Netherlands, Germany and Belgium are identified as having a fodder maize-based feeding strategy for bovine but also porcine livestock sectors.
- The remaining three clusters are corresponding to cropping systems based on annual crops production plus at a lesser extent other fodders (root fodders), rich protein crops and fodder maize. They are located at medium latitude from northwest of France to eastern Poland, in the eastern part of the UK, In Bulgaria and Romania, in central Spain and in the Scandinavian Peninsula. These regions are not always matching a certain livestock sector (Figure 13). Only the "Mixed without SHGOAT" sector of central Europe seems to be correlated to the "Annuals + …" cropping systems, especially the "Annual crops + rich protein crops". All together, it seems that the diversified annual crops production is meeting the higher livestock sector diversity met in these regions and a general trend can be observed: "Granivores" or "Poultry" animals assemblages seem slightly correlated to the presence of diversified annual crops with protein and/or fodder maize cultivation which should be conceivable according to the importance of proteins into the granivores' ration.

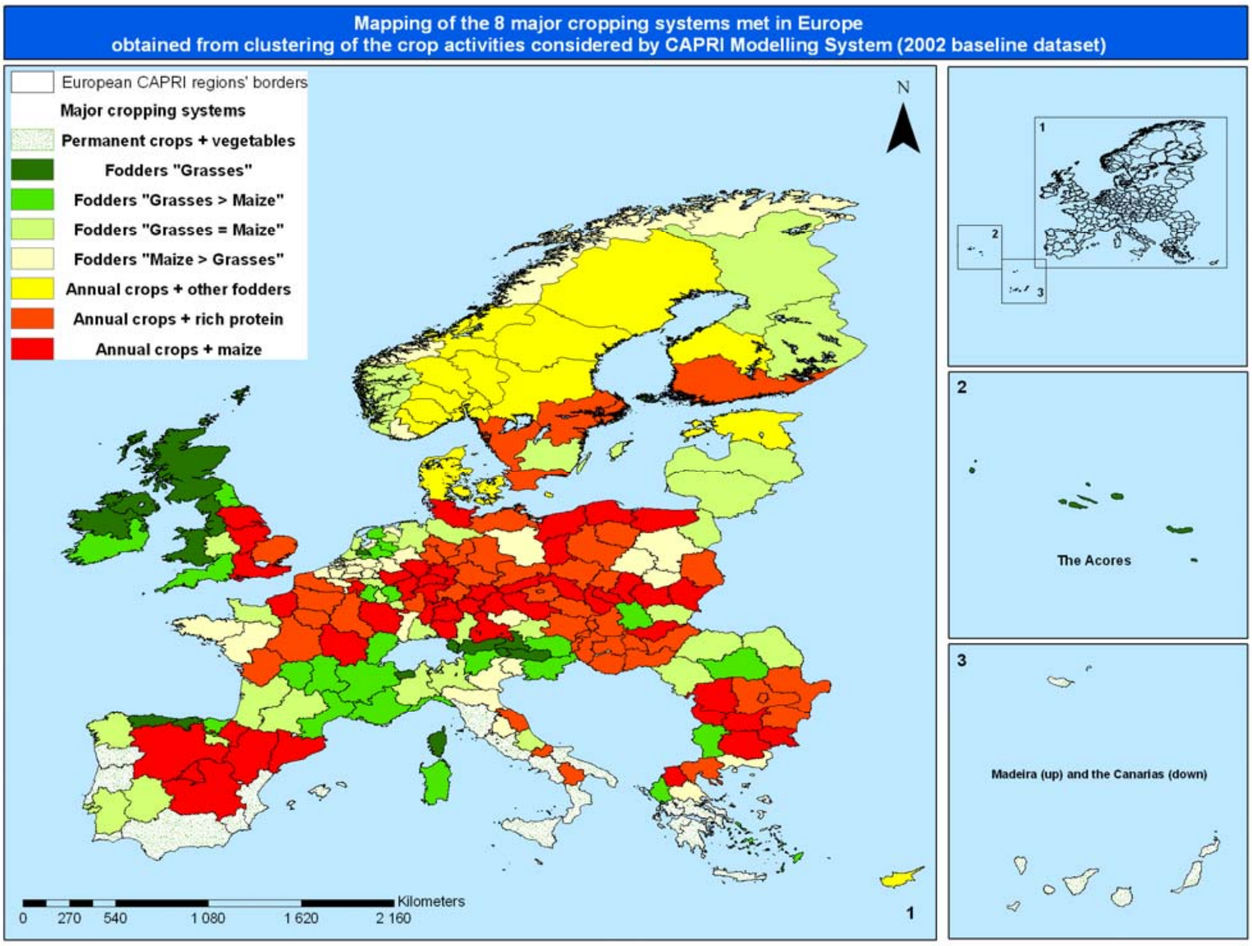

Figure 13: Mapping of the eight cropping systems identified over EU27 + Norway

6.2.4. Intermediary conclusions

Dimensions used until now to describe regions were broad and less informative for somebody who wants to address one particular livestock sector. However, the information obtained allowed us to figure out particularities of the regions and in less extent regional constraints and specificities of livestock production. From results obtained, we showed that decision to produce livestock, as any other agriculture activity, is partly governed by abiotic factors which define locally the potential land use. In most of the cases, for grazing livestock, cropping systems are strongly correlated to the climatic potential for biomass production from fodders itself influencing greatly the composition and the size of the grazing herd to rear in the region. At farm level as well as at larger scale (NUTS2), livestock production systems are partly consequences of the interaction between a local climatic potential – an adapted and effective local cropping system – a possible herd size and composition, the core of this tripartite relationship being the cropping system. It determines the potential of feedstuffs production and the level of autonomy to feed livestock herds. For instance, cattle's breeding is generally located in regions under the influence of oceanic and continental climates where the potential for fodders' biomass production is high to very high; this authorizes cost-effective breeding of large herds on well delimited permanent pasture parcels. At the opposite, limited fodder biomass production under Mediterranean climates requires adapted livestock such as goats and sheep's; in these regions the "cultivated" grassland areas being limited, the feeding strategy is based on grazing under permanent crops (olive trees, …), on common grasslands or on free-ranging grazing in mountainous alpages. However, feeding strategies is not only dependent on the local biomass potential. Part of the livestock requirements can be more or less fulfilled from marketed feedstuffs, especially proteins to feed granivores for which market costs remain very attractive.

Each one of the classifications performed previously gave us initial but insufficient knowledge to describe livestock production systems. If results suggested or even underlined relationships between climatic conditions, cropping system and animals assemblage in a region, integration of these three dimensions with other dimensions of production system must be conducted. It has been done by considering some of the previous descriptors when classifying livestock sectors and by using results of the cropping – animals assemblages to verify of the pertinence of the clusters obtained from the sector-specific classification.

7. Results from classification

This part of the document concerns the main results obtained from classification procedures applied to each one of the six livestock sectors identified within the GGELS project.

7.1. By-sector description of the diversity of the LPS

The 243 regions used by the CAPRI Modelling System have been early classified over (i) 10 animals assemblages and (ii) 8 major cropping systems. The results of these classifications would not be used directly as classifiers to class livestock production systems. On the other hand, cropping systems and animals assemblages together with Eurostat farm types will be used to describe and verify of the pertinence of the clusters obtained per livestock sector.

Concerning climatic clusters, they will be used *a posteriori* to split sector-specific LPS into several sub-lists corresponding to a LPS per climatic zone.

7.1.1. The BOMILK sector

Classification over the whole set of regions on BOMILK production has been performed from nine remaining significant variables describing more specifically this livestock sector. Among all, one variable was expressing the magnitude of the BOMILK production: the (BOMILK) herd size expressed in livestock unit. This variable was very strongly correlated (>0.95) to other quantitative variables such as total milk production, total manure or again total revenue and consequently only one was conserved – we choose the herd size because of it eases the interpretation. It was used in parallel of the relative participation of the BOMILK production to the total "livestock" revenue (%). The other seven descriptors are describing the feeding strategy adopted in region by focusing on the fodder activities. The share of the two main fodder activities (Grass and maize, as a percentage of the total UAA), the percentage of the total "plant production" revenue coming from the fodder activities or again the level of intensification (in €/LU and in % of the total BOMILK production costs) were considered. The pressure exercised by the BOMILK size onto the fodder activities was considered through the use of the stocking density (No. of grazing LU per hectare of fodder, all fodder activities) and by the potential autonomy (%) of a region to fulfilled energy requirements of grazing animals from all cultivated fodders in this region.

Results from PCA pointed out that BOMILK revenues was generally correlated with the level of intensification, suggesting positive relationship between the production and the magnitude of the investment spent for feedstuffs and veterinary products in the total cost of the BOMLIK production (Table 1). On the second component, negative relationship between the relative intensification and the level of autonomy for energy from fodder crops (but also protein, data not shown) suggested that the investment for feedstuffs and veterinary products are proportionally less important when fodder area is high; BOMILK systems based on fodder production have at a lesser extent recourse to market for feedstuffs supplying. If they are less subjected to market prices' fluctuations, they are on the other hand highly dependent of the climatic conditions; in this case, the choice of the climatic zone could be of high importance. From the third component it appears that the herd size can be largely increase when a higher part of the total UAA is cultivated with fodder maize. The larger and more constant yields observed for fodder maize (when compare to uncertain fodder grass yields) should allow producers to free they potential of BOMILK production of the grass production uncertainty. Finally, component 4 of the PCA which absorbed approximately 72% of the cumulated variability of the data pointed out the relatively less weighted effect of herd size; we can also underline that a low positive relationship exists between herd size, fodder maize share and the energy autonomy. This confirms the trend observed before: from a certain threshold, higher herd size is (economically) conceivable if sufficient auto-supplying of feedstuffs is planned on farm.

Table 1: Results of the PCA – Varimax rotation onto the nine descriptors retained for the BOMILK production description and clustering

	PCA comp. 1	PCA comp. 2	PCA comp. 3	PCA comp. 4	PCA comp. 5
Eigenvalue	2.12	1.85	1.55	1.00	0.77
Percent	23.54	20.59	17.22	11.13	8.56
Cum Percent	23.54	44.13	61.35	72.47	81.03
Eigenvectors (after rotation)					
Herd size (LU)	0.06	-0.03	0.14	**0.89**	0.12
Intensification (€/LU)	**0.72**	0.43	-0.08	-0.19	-0.15
Intensification (%)	0.01	**0.87**	-0.25	0.19	-0.10
Stocking density (LU/ha)	0.05	0.04	**0.93**	-0.04	-0.10
Revenues fodder (%)	**0.80**	-0.12	-0.02	-0.01	0.28
Revenues BOMILK (%)	**0.78**	-0.11	0.15	0.24	0.06
NRJ Autonomy (%)	0.07	**-0.80**	-0.24	0.37	-0.04
Fodder grass (%UAA)	0.15	-0.05	-0.10	0.11	**0.95**
Fodder maize (%UAA)	0.02	-0.14	**0.71**	0.43	-0.01

From this, clustering has been performed and 7 final clusters decided. To describe clusters particularities, analyse of variances of the nine retained descriptors was processed. The results of the ANOVA are summarized inside Annex 8.

Regarding the descriptors used for classification, an interpretation as objective as possible of the clusters was made by considering five main aspects of the BOMILK production for which several modalities each were defined:

- The importance of the BOMILK production in the region – 3 modalities from "subsidiary production" to "of primary importance" was interpreted from the BOMILK revenue (%) and the herd size (LU)
- The level of intensification of the BOMILK production – 3 modalities from "very intensive" to "extensive" was interpreted from intensification expressed in €/LU as well as in % and from the stocking density (LU/ha)
- A potential animal keeping strategy was proposed from the stocking density and the grass share in the total UAA (%) – 3 modalities "indoor", "outdoor" and "mixed"
- The feedstuff autonomy was interpreted from the autonomy for energy of grazing livestock from fodders, the stocking density, the intensification (% and €/LU) and the fodder revenue

(%). The objective was to decide of the level of dependence of a cluster to the marketed feedstuffs - 3 modalities were decided from "very dependent" to "independent"

- Finally we proposed to identify the main aliment composing the BOMILK ration from grass and maize share, the level of intensification (€/LU), the fodder revenues (%), the stocking density (LU/ha) or again the level of autonomy for energy.

Qualitative description of the seven BOMILK clusters identified is given within table 2.

Table 2: Qualitative description of the seven BOMILK clusters identified

Clusters	Production	Intensification	Keeping strategy	Market dependence	Main feedstuffs used
1	Subsidiary	Intensive	Indoor	Very dependent	Marketed
2	Secondary	Extensive	Mixed	Independent	Pasture / Maize
3	Primary	Extensive	Indoor	Dependent	Haymaking
4	Primary	Extensive	Outdoor	Independent	Pasture / grazing
5	Primary	Intensive	Mixed	Dependent	Pasture / maize
6	Subsidiary	Medium	Mixed	Dependent	Haymaking
7	Secondary	Intensive	Indoor	Dependent	Maize

To ease the interpretation of the clusters obtained for BOMILK, different analyses (of variances, contingency…) have been performed on the animals assemblage or on the farm types per BOMILK cluster. It helped to describe more consistently the BOMILK clusters.

- Cluster 1 concerned regions for which the BOMILK production is subsidiary meaning that other productions are dominant; the analyse of the animals assemblages present in this cluster pointed out that granivores and ovine productions was of primary interest. When producing milk from cattle, the regions concerned are practicing very intensive BOMILK production from dairy cattle's housed and fed with marketed feedstuffs. The limited share of fodders and especially of fodder grasses indicated that the manures from dairy cattle could be sprayed on annual or permanent crops rather than on pastures. Or at least that pastures when exist are sprayed with manures from other livestock activity than the BOMILK activity. The regions are Mediterranean regions generally corresponding to Mediterranean islands: Malta, Cyprus, Madeira (Portugal) and the Canarias (Spain). The main farm types representing in this cluster are T44 – SHGOAT, T50 – Granivores and T82 – Crops + livestock. All together the BOMILK production in these regions appears as a second income production for diversification of the sources of incomes and for the limitation of the effects of failure of any other main activities (here, ovine and granivores for livestock production). This cluster has been called "Mediterranean intensive BOMILK".

- Cluster 2 corresponded to regions for which the BOMILK production is not considered as of primary importance due to the fact that other livestock activities are conducted in parallel and are sources of at least the same proportion of incomes. Approximately two third of the regions had another grazing activity such as BOMEAT or/and SHGOAT activities; the remaining one third were often dedicated to POULTRY production. This trend was confirmed when analysing the main farm types represented in this cluster. T41 – cattle dairy, T42 cattle fattening, T44 – SHGOAT, T81 – crops + grazing and T82 – crops + livestock are the most represented farm types. All together, BOMILK production is considered as a natural complement to other grazing livestock activities in place in these regions. The number of regions in this cluster is the highest (n=65) and a large range of countries are concerned. However most of them are localised at medium or high latitudes. Only few regions are identified in Italy, two in Portugal and several in Romania. The majority are situated in the Scandinavian Peninsula, in Latvia, Estonia and Slovakia or again in France (10), in Germany, Austria, Check Republic and Hungary. These regions are corresponding to oceanic or continental climates. Very low revenue from fodder activities together with a relatively low herd size and a medium to high fodder grass share of the total UAA suggested an outdoor keeping strategy with a high utilization of the biomass produced on farm. Furthermore, stocking density is relatively low suggesting an extensive use of the fodder area. However, because of a more limited duration of the grazing period on pasture, the feeding strategy is based on a mixed of pasture grazing and fodder maize supplies during winter period. The denomination proposed for this cluster refers to the complementarity between other grazing activities and the BOMILK production: “Grazing BOMILK complement”.

- For the third cluster, BOMILK production became of primary importance for the total revenue of the regions (n=32). With a medium herd size, these regions have large fodder grass areas at their disposal; but an important fodder revenue (mainly from grass) signified that fodder production could be also considered as a product of high interest. We proposed two assumptions: (i) part of the fodder production is sold and not directly used in the region; producers are preferring to have recourse partly to marketed feedstuffs such as rich protein feedstuffs to feed the animals – (ii) despite large grass areas, the biomass production or its exploitation by BOMILK animals could be too short because of climatic reasons. Almost all the regions concerned are located in the Scandinavian Peninsula (Norway, all regions in Finland, Sweden) or in high or medium mountain regions for Italy (Trentino Alto-Adige, Val d’Aosta regions) for Austria (Tyrol region) or for Spain (Pais Vasco, Cantabria and Asturias regions); so, they are under the influence of cold continental, alpine or even artic climates in elevated zones of Europe. Consequently the second option seems to be more relevant: BOMILK production is an essential source of income for holdings situated in less favoured areas for which the potential window to keep animals outdoor is limited by the climatic characteristics met. During winter period, animals housed are then fed with hay (explaining the high revenue share of fodder activities) and marketed feedstuffs (high intensification). For all these reasons, cluster 3 has been denominated “Climate constrained BOMILK”.
- Concerning cluster 4, regions for which BOMILK revenue is of primary importance presented very important area of grasslands and almost no fodder maize area. The level of autonomy for energy is very high (generally covering the all energy and protein grazing livestock requirements) and the recourse to marketed feedstuffs is nearly null. Feeding strategy of these regions appeared as fodder grass-based and presented and low stocking density. All together, these results clearly indicate an extensive BOMILK production. When considering the animals assemblages, other livestock activities such as poultry and SHGOAT activities (T44 – SHGOAT) are complementing the dominant dairy activity. The regions concerned are located in only two european countries: Ireland and the UK. This cluster has been denominated “Extensive grass BOMILK “production.
- As well as the two previous clusters, BOMILK activity is of first importance and even preponderant for most of the regions. But the major difference is that the feeding strategy in place in the 60 regions concerned is based on a mixed utilization of grass and maize fodder. The dual utilization of grass and maize allows regions to breed large size BOMILK herds at medium to high stocking density. But it asks for the utilization for part of feedstuffs from the market. As a consequence, the BOMILK production in these regions is very intensive based on a mixed keeping strategy. More than 80% of these regions are corresponding to “bovine” and “mixed without SHGOAT” animals assemblages. In parallel, the two major farm types represented in this cluster are T41 – “cattle dairy” and T44 – “SHGOAT + other grazing”. The corresponding regions are located in Italy (Lombardia, Piemonte, Emilia Romagna, and Veneto

regions), in France (Franche Conté, Pays de la Loire, Bretagne, Lorraine, the two Normandie or again the Auvergne regions), in Poland and in the Netherlands. It concerns also Lithuania, the Duché of Luxemburg and almost all the German regions. These regions are often identified as the main nitrate-phosphorus polluted regions from livestock activities in Europe. The denomination of this cluster is consequently "Intensive grass+maize BOMILK" production.

- With a very low share of fodder areas, a medium autonomy for energy supply from fodders and a low stocking density, BOMILK production in cluster 6 is considered as subsidiary. The size of the BOMILK herd is generally limited and the majority of the animals present in the regions are granivores or ovine livestock units. The major difference with the first cluster described above is that the BOMILK production is not considered as an assurance in case of failure of the other livestock activities; then, despite the fact that feedstuffs and veterinary products represent a very large proportion of the BOMILK production costs, the amount invested for the BOMILK production remains very limited. All together, limited grass (maize) areas and limited feedstuffs investment are describing situation where feeding of BOMILK could be undertaken from other sources of biomass. Moreover, the fact of the main countries concerned are Spain, Greece, Bulgary, Poland, Italy or again Portugal could correspond to feeding practices inherited from local cultures where the free-ranging of animal on common grassland areas is currently practiced. As said below, granivores and ovine are dominant activities in these regions. Consequently we assumed that BOMILK production in these regions is still considered as a subsistence production. For this reason, the denomination given to the cluster 6 is "Free-ranging subsistence BOMILK" production.
- Finally, cluster 7 depicts regions for which the BOMILK production is perceived as of primary importance. With medium to high herd size and very important stocking density, we assumed that the BOMILK are indoor kept. Beside this, fodder grass share is limited when the share of fodder maize in the total UAA is the highest we observed. With a relatively low to medium intensification (proportion of the feedstuffs and veterinary products investments in the total cost of the BOMILK production) level, the regions are basing their entire feeding strategy on the fodder maize production. They are nearly independent for feeding thanks to high energy autonomy obtained from maize. This feeding strategy should allow intensive BOMILK production at the condition that climatic conditions are very constant and favourable to maize growth. The regions identified in this cluster are corresponding to four regions in the Netherlands, almost all the Belgium regions and the Muenster region in Germany. They are benefiting of an oceanic temperate climate relatively favourable to green-fodder maize production. These regions are presenting granivores as major other possible animals assemblages. In accordance with denomination given to cluster 5, cluster 7 has been called "Intensive maize BOMILK" production.

Diversity of the BOMILK production systems in EU27 + Norway has been mapped to ease the visualisation of its spatial distribution (Figure 14). Later in paragraph §-7, the results of the classification of the BOMILK production systems will be confronted to results of the climatic and cropping systems' classifications to point out the number of sub-levels to be considered when deciding of the sampling effort for the survey addressing diversity of the manures management practices.

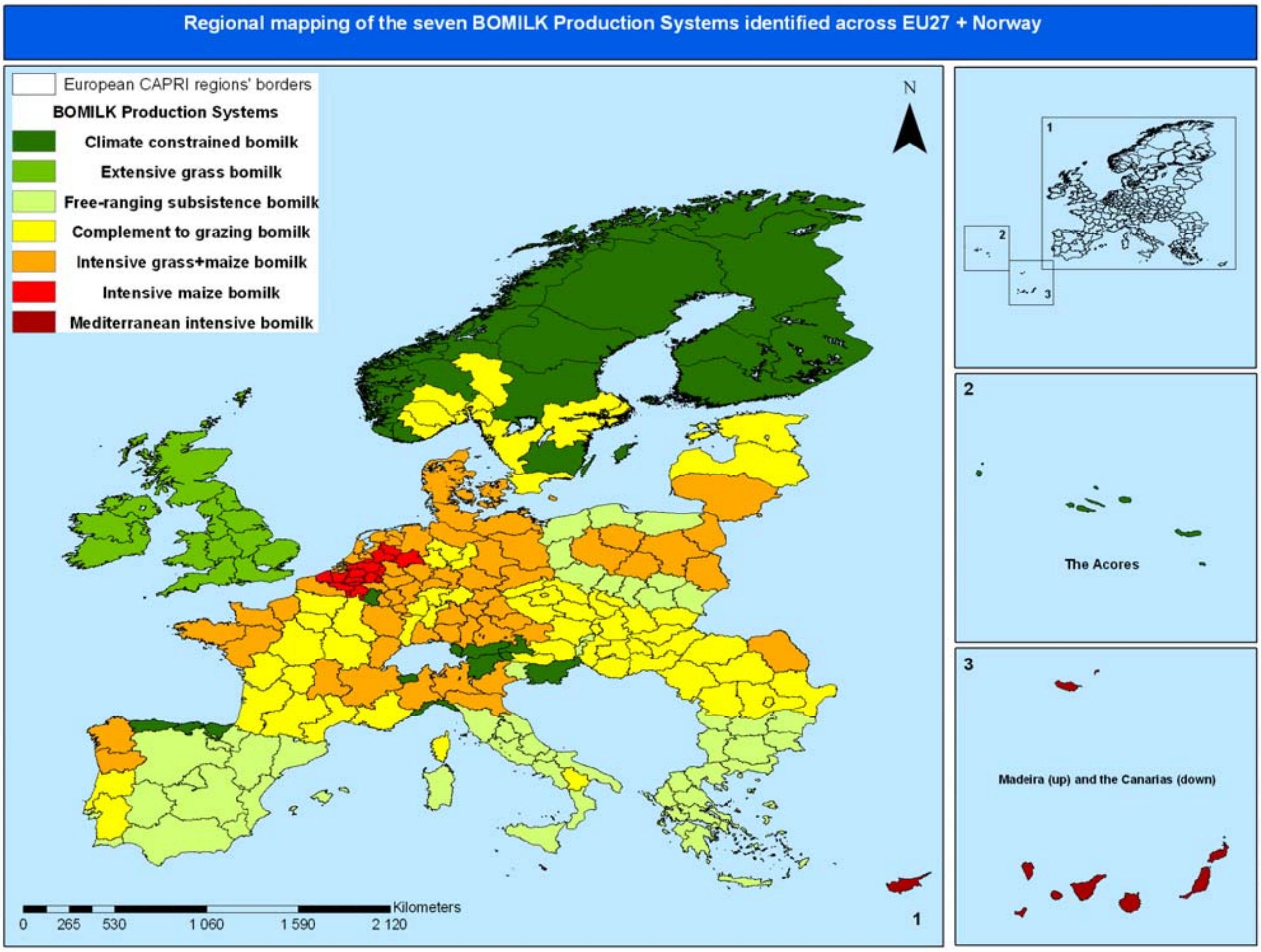

Figure 14: Diversity of the BOMILK Production Systems in EU27 + Norway

7.1.2. <u>The BOMEAT sector</u>

Classification over the whole set of regions for BOMEAT production has been performed from eight remaining significant variables describing more specifically feeding strategy related to the cropping system , the BOMEAT productivity and the level of intensification livestock sector. Among all, one variable was expressing the magnitude of the BOMEAT production: the (BOMEAT) revenue which was strongly correlated (>0.95) to the herd size or again manure production (result not shown). Others variables used were: the BOMEAT intensification level (€/LU) describing the investments made to provide feedstuffs and veterinary products to one BOMEAT livestock unit – the stocking density (LU/ha) calculated from the total fodders area – the fodder revenues (as a percentage of the total plant production revenue) and the share (%) in the total crop area of grass fodder and maize fodder were considered to described the cropping system and the main source of energy for BOMEAT – the later was used in parallel of the level of autonomy (%) for energy from all available fodders in a region – finally, to consider the importance of the BOMEAT herd size in the total number of livestock unit in a region, the percentage (%) of livestock units belonging to BOMET has been taken into account .

Results from PCA pointed out that the stocking density is strongly related to the proportion of fodder maize cultivated suggesting that the BOMEAT production depends highly of this fodder activity (Table 3). But feeding of BOMEAT depend also on the fodder grass production: the BOMEAT revenue as a percentage of the total livestock revenue in a region is correlated to the share (%) of fodder grass cultivated suggesting that fodder grass participates actively to the feeding strategy and/or the keeping strategy for a large range of regions in Europe. This is confirmed by the positive relationship existing between the revenues (%) of the BOMEAT activity and the revenue (%) of the fodders activity. When limited due to diverse reasons, the production of fodders is partly compensated by the utilisation of marketed feedstuffs as described by the negative relationship existing between the level of autonomy for energy and the level of intensification. Thus, the total revenue of the BOMEAT activity could increase in parallel of the level of energy autonomy as suggested by the fourth component of the PCA. From these first observations, it seems that feeding strategy and energy and protein autonomy from fodder activities is the key to produce BOMEAT in a region; effort has been made to interpret the BOMEAT diversity in EU27+Norway by considering this particular dimension of the production system.

Table 3: Results of the PCA – Varimax rotation onto the eight descriptors retained for the BOMEAT production description and clustering

	PCA comp. 1	PCA comp. 2	PCA comp. 3	PCA comp. 4
Eigenvalue	2.015	1.698	1.407	0.863
Percent	25.188	21.230	17.584	10.789
Cum Percent	25.188	46.418	64.002	74.790
Eigenvectors after rotation				
Intensification (€/LU)	-0.094	0.0589	0.910	0.059
Stocking density (LU/ha)	0.897	-0.033	0.127	0.001
Fodders revenue (% of total)	0.077	0.722	0.295	0.148
BOMEAT revenue (€)	0.183	0.0151	-0.039	0.805
Energy autonomy (%)	-0.058	0.074	-0.596	0.571
BOMEAT herd size (% of total LU)	-0.089	0.533	0.188	0.648
Fodder grass (%UAA)	-0.067	0.826	-0.285	0.003
Fodder maize (%UAA)	0.853	0.021	-0.218	0.131

Clustering has been performed and 6 final clusters decided to describe the diversity of the BOMEAT production. To describe clusters particularities, analyse of variances of the eight retained descriptors was processed. The results of the ANOVA are summarized inside annex 9.

Regarding the descriptors used for classification, an interpretation as objective as possible of the clusters was made by considering five main aspects of the BOMEAT activity for which several modalities each were defined:

- The importance of the BOMEAT activity as a source of income in a region – 3 modalities from "subsidiary production" to "of primary importance" was interpreted from the BOMILK revenue (%) and the herd size (LU) – 3 modalities from "subsidiary to "of primary importance"
- The level of pressure exerted onto the grass area from the revenue of BOMEAT coupled with the stocking density and the fodder maize share (%) – 3 modalities from "low" to "high"
- The feedstuff autonomy was interpreted from the autonomy for energy of grazing livestock from fodders, the level of intensification (€/LU) and the fodder revenue (%). The objective was to decide of the level of dependence of a cluster to the marketed feedstuffs - 3 modalities were decided from "very dependent" to "independent"
- A potential animal keeping strategy was proposed from the stocking density, the fodder revenue (%) and the grass share in the total UAA (%) and by taking into account the other grazing activities in competition for pastures' occupation – 3 modalities "indoor", "outdoor" and "mixed" were proposed

- Finally we proposed to identify the main aliment composing the BOMEAT ration from grass and maize share, the level of intensification (€/LU) and the fodder revenues (%).

Qualitative description of the seven BOMEAT clusters identified is given within table 4.

Table 4: Qualitative description of the six BOMEAT clusters identified

Clusters	Importance	Pressure on grassland	Market dependence	Keeping strategy	Main feedstuffs used
1	Secondary	Low	Very dependent	Indoor	Grass - Market
2	Primary	Medium	Dependent	Mixed	Grass - Maize
3	Secondary	Low	Independent	Mixed	Maize
4	Secondary	High	Dependent	Indoor	Maize
5	Subsidiary	Medium	Very dependent	Mixed	Market
6	Subsidiary	Low	Dependent	Outdoor	Market

To ease the interpretation of the clusters obtained for BOMEAT, different analyses (of variances, correspondence …) have been performed on the animals assemblage or on the farm types per BOMILK cluster. It helped to describe more consistently the BOMEAT clusters observed.

- Cluster 1 concerned regions for which the BOMEAT production is a second order livestock activity. The main animals assemblages other than "bovine" corresponded to poultry assemblages and at less extent to ovine / bovine assemblage. The main farm types observed in this clusters are those dealing with cattle productions (T41, T42) and the T44 – "SHGOAT +other grazing". The BOMEAT activity is generally based on a cropping system where fodder grass share is higher or at least equal to the fodder maize share. However, because BOMEAT activity is not of primary importance, the grassland area could be reserved for other grazing production such as the dairy or ovine production. Indeed, despite a relatively low pressure on grassland and a low stocking density, the dependence to marketed feedstuffs remains very high. Consequently BOMEAT animals could be housed rather than outdoor kept. But in the same time, the availability of relatively important area should allow producers to fulfil part of the BOMEAT feed requirement from fodder grass, the rest being provided by the market. The main countries concerned by this BOMEAT production system are Italy, Germany, Romania, Greece, Slovakia, Portugal, Norway, Austria, and Spain. For all these reasons, cluster 1 was called "complement to ovine BOMEAT".
- The BOMEAT activity is of primary importance for the second cluster identified. Due to important area of grass but a medium stocking density, keeping strategy is mixed and the feeding strategy is based on the utilisation of fodder grass as well as of fodder maize. The BOMEAT ration is then completed with feedstuffs from the market. This cluster corresponded to an intensive BOMEAT production system. The major farm types are those corresponding to the production of "cattle for fattening and rearing" (T42), dairy cattle (T41) and "SHGOAT + other grazing" (T44). Consequently these regions are specialized in the production of cattle and at less extent of ovine; the animals assemblages indicated that grazing animals are preferred to others in these regions. Related cropping systems is essentially composed of the four "grass" cropping systems identified; fodder maize is also of interest and contribute at significant level to the feeding strategy. The main regions are situated in France, in the north of Italy, in the UK (North West, South West and Wales regions), in Spain (Castilla-Leon, Extremadura and Andalucía regions) and the two Irish regions. The cluster 2 has been denominated "Intensive grass maize BOMEAT".
- Concerning cluster 3, the BOMEAT activity is of secondary importance and is generally dominated by granivores (porcine especially) production. Farm types corresponding to the

granivores activities (T50 and T72) represented more than 30% of the total number of farms belonging to this cluster. The feeding strategy relied on the use of a large part of fodder maize in the ration together with fodder grass. But another important source of protein and energy could be supplied from the rich-protein and annual crops composing around 90% of the cropping systems corresponding. As a consequence, the dependence to the market for feedstuffs provision is very low. Considering that the other livestock activities are indoor productions and that dairy cattle's are scarce, we can assume that the entire area of grass is available for BOMEAT animals. However, the level of dependence suggests that the fodder grass is used for haymaking rather than for grazing and BOMEAT animals keeping should correspond to a mixed strategy. It concerns a relatively low number of countries amongst them the Check Republic, Hungary, half of Slovakia, the northern and eastern regions of the UK plus the Burgenland region in Austria. It has been called "complement to porcine BOMEAT".

- Together with a relatively high level of autonomy for energy, the high dependence to market for feedstuffs provision and a feeding strategy based on the utilisation of fodder maize rather than fodder grass indicated that cluster 4 is an intensive BOMEAT production system. In the same time, a reduced area of fodder grass restricted the animals movement and suggested a indoor keeping strategy. On the other hand BOMEAT production is perceived as a secondary source of income for the corresponding regions. "Dairy cattle" (T41) and "SHGOAT + other grazing" (T44) represented more than 50% of the total number of farms belonging to this cluster. As for cluster 2, the animals assemblages indicated that grazing animals are preferred to other types of animals in these regions. Finally, clusters 2 and 4 are relatively similar but they differed essentially because of the feeding strategy and of the related cropping systems in use; cluster 4 is fodder maize-based intensive system. It was consequently denominated "Intensive maize BOMEAT". It corresponds to regions grouped in the part of Europe: in Belgium, the Netherlands, Denmark, Luxemburg, France and in Germany. We can also indicate that Malta, Cyprus and the Canarias in Spain are belonging to this cluster.
- Cluster 5 is very particular. With limited area of fodder grass and maize, and consequently a very high level of dependence to the market for feedstuffs provision, this cluster appeared disadvantages. On the other hand, the share of revenue coming from the fodder activities is very important suggesting that the production of fodder is mainly destined to the market rather than to be auto consumed on farm. Together with the medium share of fodder grass area this suggested that fodders cultivated are different and may correspond to root fodders or others. From this we also assumed that extreme climatic conditions could explain the subsidiary importance of the BOMEAT production and the relatively limited production of traditional (grass and maize) fodders. The major (>70%) farm types in these regions corresponded to dairy cattle (T41) and SHGOAT + other grazing (T44) and the main animals assemblages were the "bovine" and "grazing" assemblages. In these regions production of cattle for milk and of ovine is preferred to the meat production from cattle. The corresponding regions are located in Sweden, Norway and Finland; this confirming our assumptions. It has been called "Subsidiary Nordic BOMEAT".
- The last cluster (n°6) corresponded to regions where the BOMEAT production is considered as subsidiary. The limited amount of energy and protein available to fulfil the BOMEAT animals' requirements was explained by very limited area of fodder grass and maize. The cropping systems in place are mainly constituted from annual and permanent crops (>75%). Due to the low availability of fodder energy and fibbers, the feeding strategy is mainly based on the provision of marketed feedstuffs in the ration and the fodder revenue is almost inexistent. Beside this, the corresponding revenue being very low, BOMEAT activity is considered as subsidiary. Other activities such as ovine (T44) and granivores (T50, T72) productions are

preferred to the BOMEAT activity; in parallel the land use and occupation are preferentially reserved to the annual and permanent crops rather than to pasture or fodders production. As for cluster 5, we assumed that regions concerned are located in extreme climatic conditions limiting the potential biomass production of grasslands and asking for the breeding of smallest grazing livestock (ovine) or indoor livestock activity (granivores). The regions concerned are most of the regions in Greece, Spain and Bulgaria; surprisingly, it concerned almost all the regions in Poland too. A deeper consideration of the Polish situations showed us that the cropping system was very particular in the regions (high proportion of annual and permanent crops); together with a limited herd size, it explained why polish regions were considered together with other Mediterranean regions. To refer to cluster 5 and to consider that, apart from Poland, the regions concerned are located in the climatic extreme Mediterranean zone, this cluster has been called "Subsidiary Mediterranean BOMEAT".

Diversity of the BOMEAT production systems in EU27 + Norway has been mapped to ease the visualisation of its spatial distribution (Figure 15). Later in paragraph §-7, the results of the classification of the BOMEAT production systems will be confronted to results of the climatic and cropping systems' classifications to point out the number of sub-levels to be considered when deciding of the sampling effort for the survey addressing diversity of the manures management practices.

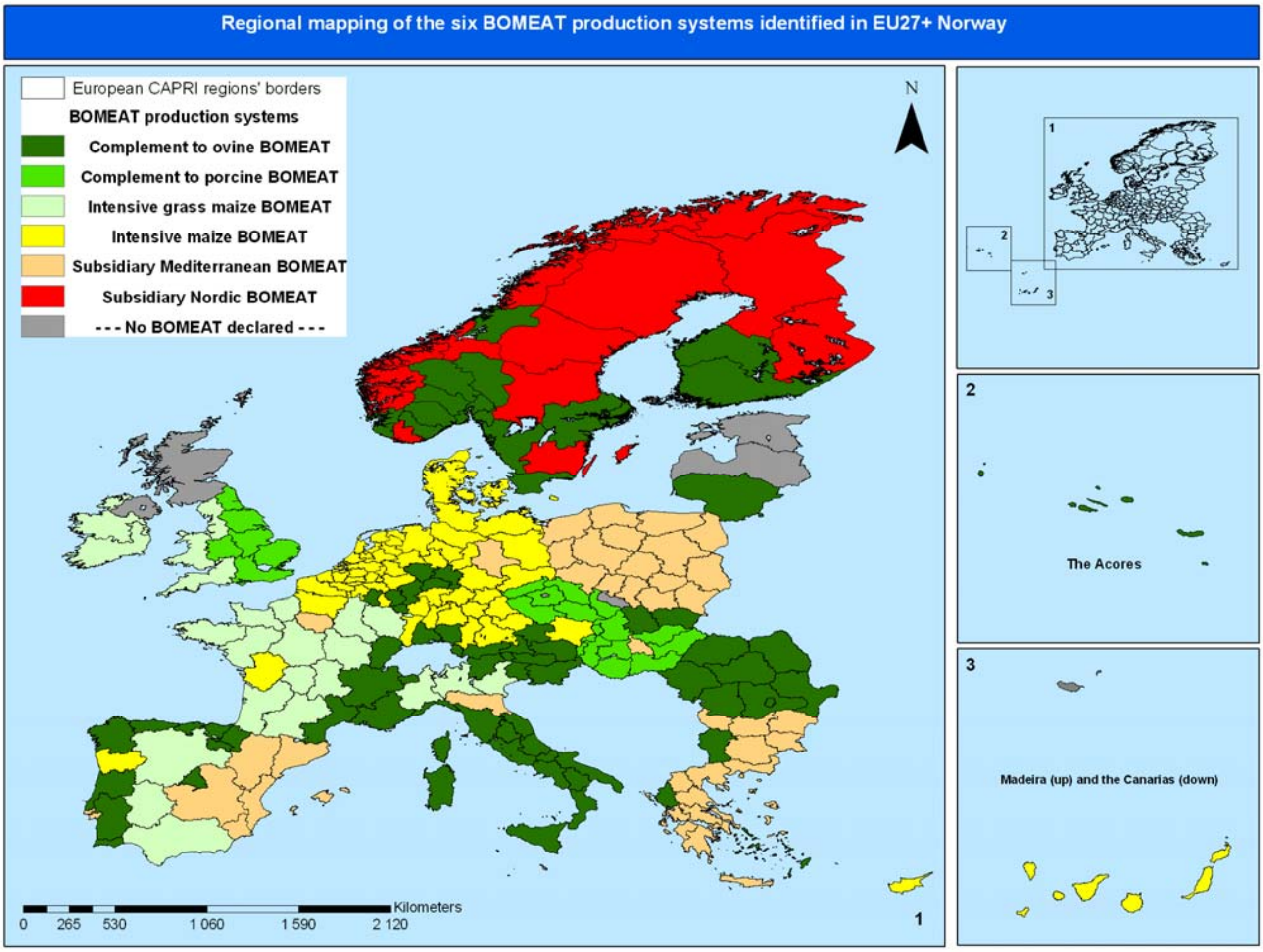

Figure 15: Diversity of the BOMEAT Production Systems in EU27 + Norway

7.1.3. *The SHGOAT sector*

Classification over the whole set of regions for SHGOAT production has been performed from seven remaining significant variables describing more specifically feeding strategy related to the cropping system , the SHGOAT level of productivity and the level of intensification. Among all, one variable was expressing the magnitude of the SHGOAT production: the (SHGOAT) revenue which was strongly correlated (>0.95) to the herd size or again manure production (result not shown). Others variables used were the SHGOAT herd size as a percentage of the total number of livestock units, the share (%) in area of the fodder grass over the total UAA, the intensification level (% of the total SHGOAT production costs) describing the investments made to provide feedstuffs and veterinary products to one SHGOAT livestock unit – the stocking density (LU/ha) calculated from the total fodders area – the fodder revenues (as a percentage of the total plant production revenue) and the level of autonomy (%) for energy from all available fodders in a region.

Results from PCA pointed out that SHGOAT revenue is strongly correlated to the share of the SHGOAT herd in the total number of livestock units in a region (Table 5); these two descriptors will be used later to address the importance of the SHGOAT activity in a region (from subsidiary to of primary importance).

Table 5: Results of the PCA – Varimax rotation onto the seven descriptors retained for the SHGOAT production description and clustering

	PCA comp. 1	PCA comp. 2	PCA comp. 3	PCA comp. 4
Eigenvalue	1.737	1.539	1.241	0.941
Percent	24.808	21.986	17.731	13.437
Cum Percent	24.808	46.794	64.525	77.962
Eigenvectors after rotation				
Stocking density (LU/ha)	-0.134	-0.011	-0.022	0.953
Energy autonomy (%)	-0.236	-0.671	0.217	-0.412
Fodder grass (%of total UAA)	0.278	-0.273	0.745	-0.070
Intensification (%)	-0.004	0.890	0.084	-0.136
SHGOAT revenues (€)	0.842	-0.095	0.007	-0.025
Herd size (% of LU tot)	0.814	0.283	-0.019	-0.109
Fodders revenues (%)	-0.24	0.197	0.842	-0.003

Not surprisingly, we observed a strong negative relationship between the level of autonomy for energy and the level of intensification; together with the fodder revenue, these two descriptors will be used to determine the level of dependence of the SHGOAT activity to the market for provision of feedstuffs (from independent to very dependent). The fodder grass share (%) in the total crops area will be used together with the stocking density and the level of intensification to propose a possible feeding strategy (3 modalities: grass, market, common grasslands); but it has to be weighted by the animals assemblages before to statute on the destination of the fodder grass to SHGOAT or to any other grazing animals. The level of intensification of the SHGOAT production will be confronted with the stocking density to determine the level of intensity (from extensive to very intensive) of the livestock production activity as an indicator of the pressure applied on grassland. Finally, despite the lack of information, from all the dimensions considered we tried to propose a keeping system (4 modalities: indoor, mixed, outdoor and free ranging).

Clustering has been performed and 6 final clusters decided to describe the diversity of the SHGOAT production systems. To describe clusters particularities, analyse of variances of the seven retained descriptors was processed. The results of the ANOVA are summarized inside annex 10.

At the opposite of the BOMILK and BOMEAT activities, SHGOAT production systems were more difficult to describe; the qualitative description of the six production systems identified involved a more subjective interpretation of the results, especially when describing possible keeping strategies. To avoid confusion and inconsistency with the reality, we performed supplementary analyses to describe as precisely as possible the clusters particularities. The qualitative description has been done in two steps: first, we proposed modalities from the sole results of the ANOVA on the seven descriptors, second, after analyses of contingence and ANOVA on variables not already used (cropping systems, animals assemblages, farm types or again SHGOAT for fattening carcass weight), the modalities have been reviewed. The final qualitative description of the SHGOAT production systems is summarized within table 6.

Table 6: Qualitative description of the six SHGOAT clusters identified

Clusters	Activity importance	Intensity	Market dependence	Feeding strategy	Keeping strategy (*as a proposition*)
1	Subsidiary	Intensive	Independent	Hays + fodders	Indoor
2	Primary	Extensive	Independent	Common grassland	Outdoor
3	Primary(shared)	Intensive	Dependent	Market + grass	Indoor
4	Subsidiary	Intensive	Very dependent	Market	Indoor
5	Subsidiary	Intensive	Dependent	Market + grass	Indoor
6	Subsidiary	Intensive	Dependent	Market + grass	Outdoor

- Cluster 1 corresponded to a production system where the revenue of the SHGOAT activity is not predominant and can be considered as subsidiary; Major farm types in this cluster are “dairy cattle” (T41, >75^{th}) and “SHGOAT + other grazing” (T44; >50^{th}). This was confirmed by the analyse of contingence from the animals assemblages: only four animals assemblages composed the cluster and corresponded to bovine and/or ovine activities; the granivores activities were totally absent. To perform bovine (predominant) and ovine (subsidiary) production, the cropping system of cluster 1 is composed at 50% of “fodder maize” and 40% of “cereals + other fodders” describing regions of intensive milk production where diversification is based on an ovine activity. The potential of energy/protein and fibbers production from the corresponding crops suggested a SHGOAT feeding strategy not requiring marketed feedstuffs; the SHGOAT animals could be potentially kept indoor if ration is based on haymaking and fodder supplementation or partially outdoor if grazing is not limited; this determined the “mixed” keeping strategy proposed. However, fodder grass area being very restrained, we finally proposed an “indoor” keeping strategy. From the same set of observations (limited fodder grass areas, fodder maize dominance for dairy cattle) we also thought that the dairy cattle in these regions is certainly intensive-indoor, so could be the SHGOAT production system. To verify this assumption, we analysed separately the level of intensification expressed in €/LU and we found that cluster 1 presented the highest investment for feedstuffs and veterinary products.

  For this cluster, large share of annual crops and high use of fodder maize suggested a constrained situation where BOMILK and SHGOAT production system could be climatic- or market-driven. The list of the regions was then analysed and the corresponding regions were all located in the Scandinavian Peninsula: in Norway and Sweden (Finland was not represented due to the fact that 4 over 5 regions did not present a SHGOAT activity declared in 2002). It tended to confirm a climatic-driven constraint; however, herd size is very limited and we could imagine a market-driven system dedicated to the production of niche market products at high added value. The denomination having to express the particularities identified, the SHGOAT production system has been called “Complement to dairy cattle Nordic SHGOAT”.

- Cluster 2 corresponded the traditional image one could have of the SHGOAT production: of primary importance (with the highest herd size observed), the corresponding SHGOAT production system is based on a low share of fodder grass (declared area), a very low proportion of the revenue coming from fodders activities and a low dependence (in % and even more in €/LU) to the market for feedstuffs provision. All these particularities suggested a very specialized but not intensive ovine production in region. This was confirmed first by the high proportion (around 50% of the total farms) of T44 “SHGOAT + other grazing” and T71 “mixed grazing” and second by the very low proportion of the other cattle- and poultry-specialised farm types T41, T42 and T43. Proportions of “crops + …” (T81 and T82) were also significant describing situation were farms are generally diversified. Not surprisingly, when analysing animals assemblages composition of the cluster, “ovine-poultry (47%) and “ovine-bovine” (37%) were the two main animals assemblages identified. In parallel, the main cropping system in place corresponded to vegetable and permanent crops (45%) followed by “cereals + other fodders”. This type of cropping system is describing climatic-restrained Mediterranean situation where fodder grass and maize production are very limited by the water deficit; it strongly influences the feeding strategy by having frequently recourse to the grazing of common grasslands (free-ranging on common areas) and/or of grasslands under permanent crops (owners’ areas). From all, cluster 2 has been called “Mediterranean free-ranging SHGOAT”.
- The SHGAOT activity inside cluster 3 was embedded inside the “Ovine/bovine” and “Grazing” animals assemblages. In parallel, the regions were characterized by a high diversity of animals assemblages: “granivores”, “bovine”, “mixed without SHGOAT” and “poultry” were all present. But none of the six animal assemblages observed was dominant. As any other livestock activities, SHGOAT was then considered of primary importance. If T44 “SHGOAT + other grazing” was the only one farm type present at more than the 75th percentile, we observed other farm types such as dairy cattle (T41), “cattle for fattening” (T42), “Granivores” (T50) and “mixed granivores” (T72) at 50th percentile; this confirmed the high level of diversification of the livestock production in these regions and the preponderance (55%) of the livestock activities in the total agriculture revenue.

  In parallel, cropping systems in place were also diverse but almost all corresponded to fodder grass and maize mix at different ratio each. The related regions are consequently regions where fodder activities are of primary importance for livestock feeding using fodder maize and from fodder grass (for haymaking as well as for direct grazing). From the cropping systems diversity, we also suspected relatively constant climatic conditions (water precipitation and temperature) favourable to the cultivation of fodder grass and maize; continental or oceanic climates could correspond. Effectively, all the regions are located in two single countries at medium latitudes under the influence of an oceanic temperate climate: the UK and the Netherlands. Because of the presence of numerous (grazing) livestock activities, stocking density appeared as high (around 1.4) and grazing pressure on the fodder grass areas should be high. Then, to perform the fodder grass biomass use, haymaking and green silage should be frequent practices. Together with a relatively high level dependence to the market for feedstuffs provision, the use of green silage indicated an intensive feeding strategy and suggested an indoor keeping strategy.

  All together, the characteristics listed hereinbefore suggested a “temperate intensive indoor SHGOAT” production system.

- Cluster 4 grouped together a large part (45%) of the regions to be considered when classifying the SHGOAT activities in EU27 + Norway. For all the 101 regions belonging to this cluster, the SHGOAT production was considered as subsidiary the majority of the UAA being used for annual cereals and rich protein crops, permanent crops and in less extent other fodders than grass and maize (73% in total). Mostly dedicated to the plant activities, it was logical to observe a total revenue form livestock activities not exceeding 40% (as for cluster 2) of the total agriculture revenue. On the other hand, when reared, SHGOAT animals are fed essentially with marketed feedstuffs; around 70% of the investments for SHGOAT activities concerned the supplying of feedstuffs and veterinary products (551 €.LU^{-1}.$year^{-1}$, fourth position). This explained partly the fact that despite small herd size, the total milk production was of medium magnitude requiring relatively high yearly yield of milk per animal. The cluster 4 was then declared as of intensive level of production. Together with the restricted areas of fodder grass, it suggested an indoor keeping strategy. Another aspect concerned the animals assemblages: cluster 4 grouped regions for which "poultry", "granivores" and "granivores/ovine" represented more than 55% of the total livestock units. Thus, SHGOAT was in most cases perceived as a complement to granivores (monogastric) production activities. It has been consequently denominated "complement to granivores intensive SHGOAT". The number of regions being huge, readers should refer to the figure 16 to visualise the regions concerned.
- Cluster 5 was very particular in this sense that it was composed at more than 85% of animals assemblages corresponding to "granivores" (21%) and "bovine" (64%) activities. Holdings specialized in the breeding of cattle and pigs were dominant: a very significant part of the cattle activities corresponded to dairy cattle (T41) and dairy cattle rearing (T43); T50 "granivores" and T72 "granivores + other grazing" were completing the farm types' profile of this cluster. As for the previous cluster, cereals, rich protein and fodder maize occupied a large part of the total UAA (around 65%) and suggested that the dependence to the market for feeding provision is high due to very limited fodder grass availability. On the other hand, the presence of large dairy cattle herd suggested a high competition for pasture grazing as well as for fodder maize consumption; SHGOAT being of subsidiary importance and stocking density being the highest one between clusters, the fodder grass and maize should be principally destined to dairy cattle rather to ovine herds. Consequently, SHGOAT was a complementary activity kept indoor and fed with marketed feedstuffs. The yields of the SHGOAT activities were medium-to-high depicting an intensive milk and meat production. Al together, the characteristics allowed us to denominate cluster 5 "complement to bovine intensive SHGOAT". The number of regions being huge, readers should refer to the figure 16 to visualise the regions concerned.
- Finally, cluster 6 was composed of the 21 remaining regions for which SHGOAT was perceived as a subsidiary production to the bovine activities (90% of the animals assemblage profile). The livestock activities were sustained by crop systems where fodder maize and fodder grass represented more than 90% of the land use; this could be considered as fodder monoculture. Consequently, the corresponding regions were very specialized in cattle production. The farm types concerned were T41, T42 and T43 describing situation where dairy production as well as cattle meat production were intensively conducted. Once again, the fact that fodder is the core of the livestock production system suggested a climate favourable to biomass production. Despite an important competition between the bovine activities and SHGOAT activities, the pasture areas were larger enough to propose a mixed keeping strategy. In parallel, the stocking density observed being small (<1), outdoor keeping is also conceivable. With 557€.LU-1.year-1, the level of intensification was intermediate but it represents approximately 75% of the production costs; this suggested that only feedstuffs acquisition is expensive; heating or cooling were negligible; this confirming the assumption

made concerning the climate. The regions belonging to the cluster are located In Austria, in Spain, France, Italy, Ireland and the UK. More remarkable was that the regions corresponded to mountainous zones in these countries: Tirol, Auvergne, Limousin, Asturias, Pais Vascos, Valle d'Aosta and Trentino Alto-Adige or Northern Ireland regions were identified as cluster 6. The Azores (Portugal) and the Smaaland med Oearn (Sweden) region were also identified as cluster 6. It appeared that for cluster 6, the intensive SHGOAT activity was limited to mountainous zones where bovine was the only livestock production in use. Consequently this cluster has been called "complement to bovine mountainous SHGOAT".

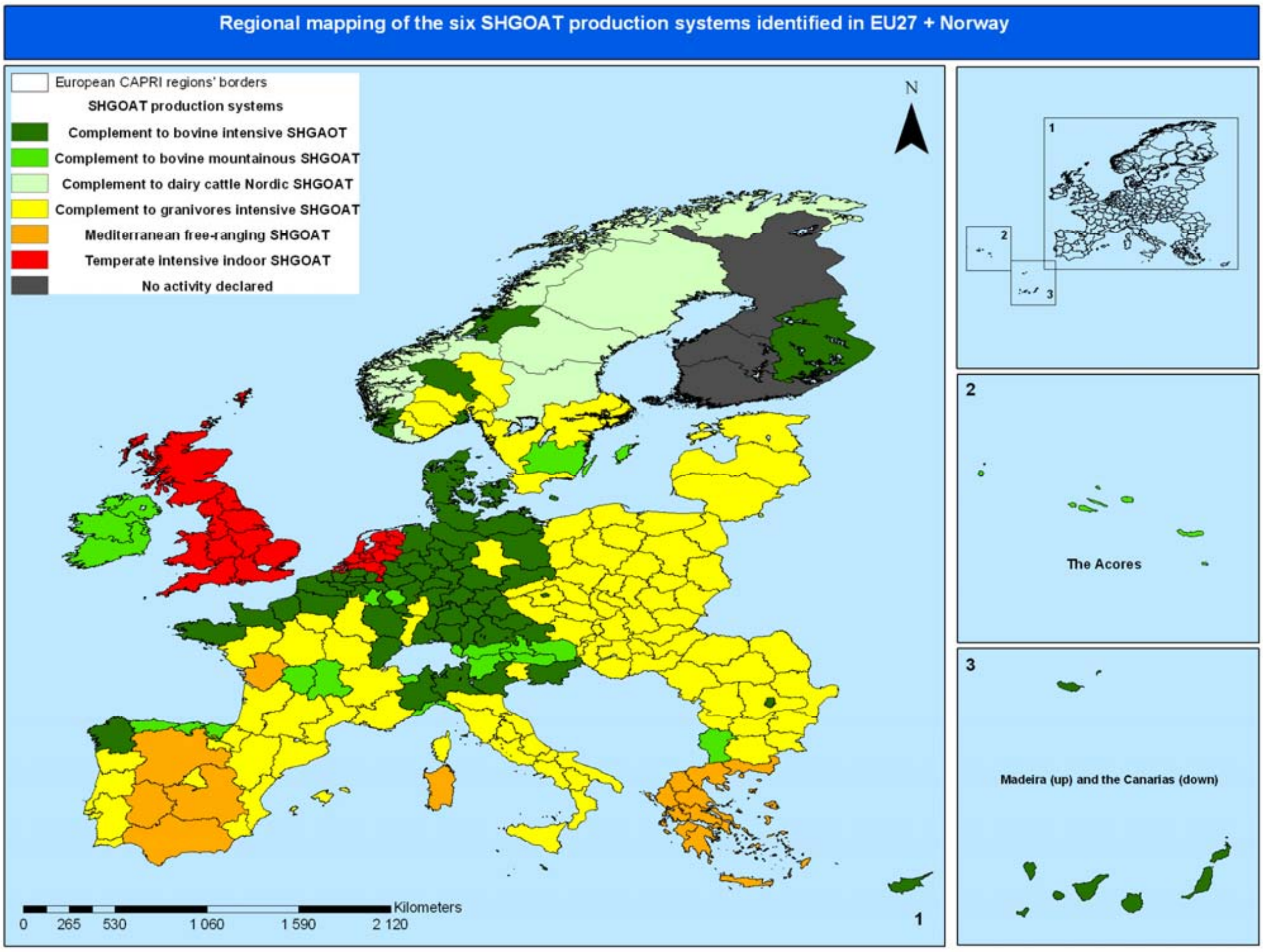

Figure 16: Diversity of the SHGOAT Production Systems in EU27 + Norway

7.1.4. The PORCIN sector

The clustering of the PORCIN activity was processed from a final set of 7 descriptors representing the productivity of the PORCIN activity (total digestible lysine requirement per year, $kg.herd^{-1}.year^{-1}$), the herd size as the percentage of the PORCIN livestock units in the total number of livestock units in a region, the level of intensification of the activity as the cost of the feedstuffs and veterinary products used per year per animal ($€.LU^{-1}$) and as the percentage of the total cost invested to produce one PORCIN livestock unit; the capacity of a region to fulfil its PORCIN herd requirements for energy and protein was approximated from the regional autosufficiency (%) for digestible lysine from "rich protein crops" cultivated in the region (see § - 4.2.3.). Respecting the approach used for grazing animals, a stocking density for monogastric animals has been calculated by dividing the total area (ha) of crops almost directly usable for monogastric livestock feeding (soybean, rape, sunflower, wheat, barley and potatoes) by the number of PORCIN livestock units; it is expressed in LU.ha^{-1}. Finally to assess the turn over and/or to confirm the intensity of the PORCIN production, we considered the yield as the averaged carcass weight of pigs for fattening when delivered to the slaughter plant (kg.head^{-1}).

These descriptors were selected from the initial set of variables describing the PORCIN activity by processing PCA and by a stepwise elimination of the correlations. The results of the PCA on the four rotated component are given in table 7.

Table 7: Results of the PCA – Varimax rotation onto the seven descriptors retained for the PORCIN production description and clustering

	PCA comp.1	PCA comp.2	PCA comp.3	PCA comp.4
Eigenvalue	2,27	1,752	1,001	0,816
Percent	32,424	25,034	14,299	11,658
Cum Percent	32,424	57,458	71,758	83,415
Eigenvectors after rotation				
Intensification (€/LU)	0,725	-0,269	0,478	-0,031
Intensification (%)	0,906	0,152	0,033	0,083
Lysine auto-sufficiency (%)	0,021	-0,074	-0,077	0,992
Total lysine requirement (kg/year)	0,068	0,825	0,188	-0,012
Carcass yield (kg/head)	0,848	0,166	-0,196	-0,04
Stocking density (LU/ha rich. prot.)	-0,048	0,349	0,857	-0,092
Herd size (% herd total)	0,09	0,876	0,08	-0,084

The results of PCA describes clearly that the final weight of individual was correlated to the level of intensification of the production stating that producers willing to rapidly reach the slaughter criteria tended to use largely feedstuffs from market and veterinary products. Together with the individual yield (kg.head^{-1}), these two descriptors were jointly used to characterise the level of intensity of the production (3 modalities from very intensive to natural growth). PCA component 2 linked the total lysine requirement of the herd a year to the herd size; they have been used together to statute onto the importance of the PORCIN production in a cluster (from subsidiary to of primary importance). PCA components 3 and 4 balanced the feeding requirements to the capacity of the region to produce necessary feedstuffs to cover these requirements. All together they were used to describe the potential dependence to the market for feedstuffs provision (3 modalities from very dependent to independent).

Before to interpret the qualitative description of the clusters, the results of the clustering process onto the seven descriptors are given in annex 11; it shows the results of the ANOVA applied on these descriptors by cluster.

Because the PORCIN production is not an activity closely related to one specific land cover, the use of the share in area of certain crops was not considered as previously done with grassland when considering grazing activities. Only three aspects were considered to perform the qualitative description of the PORCIN clusters: the importance, the intensity and the dependence of the PORCIN activity. Table 8 summarizes the qualitative description of the PORCIN production per cluster. However, dimensions such as dominant cropping systems in use, animals assemblages and farm types per cluster were considered separately to provide complementary information for the qualitative description of each cluster.

Table 8: Qualitative description of the seven PORCIN clusters identified

Clusters	Importance	Intensity	Dependence
1	Subsidiary	Normal growth	Independent-dependent
2	Primary	Intensive	Very dependent
3	Subsidiary	Intensive	Dependent
4	Secondary	Intensive	Independent-dependent
5	Secondary	Very intensive	Very dependent
6	Subsidiary	Intensive	Independent
7	Primary	Intensive	Dependent

- Cluster 1 presented the largest proportion of poultry activities (55%) completed by bovine activities (45%); PORCIN activity was present from the "mixed without SHGOAT" animals assemblages (5%). The animals assemblages' profile signified that the PORCIN production for the regions concerned was a subsidiary production. This was verified from the farm types T50 (granivores), T71 (mixed grazing) and T72 (mixed granivores) which were the three major types clustered. In parallel the cropping systems in place were at 60% composed of annuals crops such as cereals, rich protein crops and fodder maize. The rest was composed of fodder grass/maize at diverse ratio. Investments for the PORCIN activity was the lowest for cluster 1: the cost for feedstuffs and veterinary products represented less than 60% of the total production costs. In parallel, after slaughtering, the carcass weight had very common value in EU closed to 85 kg/head. From this, we supposed that the PORCIN producers in these regions could have recourse at a large extent to homemade feedstuffs from cereals and rich protein crops cultivated; and that the daily weight increase was relatively low, asking for a greater fattening duration. Consequently, PORCIN production of cluster 1 was considered as more close to natural growth situation. This could be consequence of higher animal welfare national requirements or of traditional practices inherited from the past. The regions concerned almost all the regions belonging to six countries: Bulgaria, Latvia, Lithuania, Slovenia, Romania (not the Bucuresti region) and Sweden. Cluster 1 has been called "Subsidiary traditional PORCIN".
- In cluster 2, more than 60% of the animals assemblages' profiles was composed of "granivores" and "granivores/ovine" assemblages. The rest was composed of "mixed without SHGOAT" which also integrates granivores production. The complete absence of "poultry" activities suggested that almost all the "granivores" assemblage should correspond to a PORCIN production rather than to a poultry production. Consequently, cluster 2 appeared as very specialized in PORCIN production. This has been confirmed when analysing the farm types' composition: T50 "granivores" was the major type present in the regions followed at less extent by T41 "dairy cattle", T42 "cattle rearing fattening" and T72 "mixed granivores". And later by the highest herd size observed for PORCIN clusters. From the previous results, PORCIN production has been declared as of primary importance for these regions; it is a primary source of revenue for farmers whose are rearing in parallel diverse bovine livestock. It was interesting to underline that the second cluster presented a total livestock revenue representing around 65% of the total agriculture revenue. Moreover, we observed a high level of intensification (694€/LU; 70%) and a very high stocking density per hectare of rich protein + potatoes area: it signified a very intensive production. Together with the standard carcass weight observed it also suggested a fattening period as reduced as possible for a higher turnover and productivity. Finally, corresponding cropping systems were only fodders-based, from "fodder grass>maize" to "fodder maize" (80%). The rest being equally composed of permanent crops and annual maize. Consequently, the regions did not grow rich protein crops, cereals or pulses as sources of feedstuffs for PORCIN production: the level of dependence to

the market was considered as very high for feedstuffs provision. The regions concerned were the Catalonia and Murcia regions in Spain, the Antwerpen and Limburg regions in Belgium, the German Muenster region and five regions in the Netherlands: the Overijssel, Gelderland, Utrecht, Noord-Brabant regions and the Limburg region. The name given to this cluster was "Primary intensive with bovine PORCIN".

- Cluster 3 corresponded to subsidiary PORCIN activity because of a very low herd size (% of the total regional herd), digestible lysine requirement (correlated with the number of livestock units) and stocking density. At the opposite, the investments for the provision of feedstuffs and veterinary products are standard (675€/head; 70%) meaning that despite a subsidiary production, the expectation of an optimal gross margin from the PORCIN activity is the same than for other activities present in region. For that, the regions concerned had at their disposal the largest lysine auto-sufficiency: cropping system was effectively at 85% composed of annual crops (cereals-maize, rich protein crops) and could fulfil approximately 400% of the PORCIN lysine requirements. However, T81 "crops + grazing" being the significant farm type followed by the T42, T43 and T44 types addressing bovine productions (confirmed by the animals assemblages' profile, 85% grazing livestock), farming targeted intensive crops production first and intensive indoor bovine production before all (plant production was 78% of the total agriculture revenue); yielded seeds were certainly destined to the market rather than to be autoconsumed on farm. In these regions, each production (crops as well as bovine, porcine or even ovine) seemed to be very intensive with a generalized indoor keeping strategy. Cluster 2 has been called "Subsidiary intensive with crops PORCIN". The regions concerned were regions in north of France (Picardie, Champagne Ardennes, Lorraine, Haute-Normandie and Ile de France) and in the eastern UK (South-East and North-East regions).

- With a relative herd size around 27% and a medium lysine requirement, the PORCIN activity is of secondary importance for the 114 regions belonging to cluster 4. The profile of animals assemblages was composed at 27% of "bovine", 25% of "mixed without SHGOAT" and of 22% of "granivores". The farm types mostly represented corresponded to the cattle production activities (T41, T42, T43 contributed at 35%). The rest was relatively well distributed between (T50 and T 72) "granivores …" and (T81 and T82) "crops + …" types. The profile appeared relatively diversified and balanced between types and assemblages; this was certainly due to the large set of regions classed as cluster 4. Furthermore, it confirmed that the PORCIN activity was not dominant as every other livestock activities and was of secondary importance. Approximately 50% of the land cover was composed of annual crops and 25% of all fodder grass/maize at variable ratio identified in paragraph § - 6.2.3. The level of intensification is important but closed to the main investment observed when fattening pigs in EU (general averages: 666€/head and 72% of the total cost). On the second hand, the carcass yield was conformed to the common fattening practices in EU. Finally, the regional level of autosufficiency corresponded also to the common situation where feeding strategy is based on the provision of feedstuffs from the market and the PORCIN gross margin is coming from an intensive and rapid turnover of the production cycles (livestock revenue counted for 50% of the total agriculture revenue – crops production activities were important at the same extent than the livestock activities). This PORCIN production system concerned almost all the regions in Austria, Belgium, Germany, France, Poland and Portugal. It also concerned Malta, Cyprus and the Luxembourg. It has been called "Common secondary intensive PORCIN".

- The herd size and the total lysine requirement illustrated a PORCIN production of secondary importance. From the previous cluster, the PORCIN production system was differentiated by the highest yield (115 kg/head) and the highest level of intensification (866€/LU and 80% of the total production cost) describing a very intensive production. The cropping system was composed of 40% of fodder maize and at a less extent fodder grass, 20% of permanent crops and 30% of annual crops when the animals assemblages profile was composed of 55% of granivores + poultry assemblages and of a mix of ovine + bovine (45%). The lysine autosufficiency being very limited, we assumed that the level of dependence to the market for feedstuffs provision was very high. T50 "granivores" and T72 "mixed granivores" were the major farm types identified in the cluster 5 together with T82 "crops + livestock". Consequently, these regions were very specialized in granivores production in parallel of bovine and ovine production; all the livestock productions were considered as important and are performed at a very intensive level. For these reasons, the cluster 5 has been denominated "<u>Primary very intensive PORCIN</u>". The corresponding regions (n=29) are located in Italy (20), in Hungary (7) and in Belgium (the Oost-Vlaanderen and Weat-Vlaanderen regions).

- With very limited herd size and lysine requirement, PORCIN activity was not considered as important for cluster 6. In addition, restricted carcass yield suggested (i) a low-to-medium level of intensification or (ii) a slow rhythm of growth of the animals at constant duration, or (iii) a reduced period of fattening to comply with certain transformation requirements. From available information, we were not able to confirm one of these assumptions. We just considered that the production was less intensive or even extensive. This could be the case for climatic or feeding constrained situations. A look on the list of regions showed that Greece, Portugal, Norway, Slovakia or again Ireland and the UK are concerned. If the first have to play with extreme climatic conditions, the last two countries are located in a temperate and more favourable zone; for them, more extensive practices or specific transformation requirements could explain the production system chosen. For cluster 6, the level of intensification corresponded to standard values (709€/LU) which represented a lower proportion of the total production cost (60%). Other expenditures such as cooling/heating could be necessary in response of the extreme climatic situations. The animals assemblages' profile depicted a livestock production essentially turned toward the ovine activities; "ovine …" assemblages represented around 50% of the total assemblages; the rest corresponded to bovine/ovine and "poultry" production (18%). Regions were specialized in ovine production first, then in bovine and poultry productions, PORCIN being subsidiary. This was verified by a large share of farm type "SHGOAT + other grazing" (37%). With more than 70% of the cropping system dedicated to fodders production and les than 10% to the annual crops productions, the regions were very deficient for lysine supplying. This low lysine autosufficiency could partly explained the subsidiary status of the PORCIN activity; at least, it confirmed the grazing specialisation of the regions. This cluster was called "<u>Subsidiary complement to grazing PORCIN</u>".

- The last cluster grouped together only three regions that a reduced number of cluster (up to 3) didn't succeed to merge with another cluster. These regions were very specific because of the highest lysine requirement and herd size (52%) and the second smallest lysine autosufficiency (3%). The proportion of the livestock revenue in the total agriculture revenue is closed to 75% meaning that these three regions had a livestock-driven economy for which the PORCIN production is of primary importance. The animals assemblages' profile was very simple and composed of the sole "granivores" class. The cops systems was composed of "fodder maize", "fodder grass = maize" and "cereals + other fodders". The two major farm types were T41 "dairy cattle" and"T50 "granivores". In these regions agriculture is made of two main livestock activities: dairy cattle and pigs for fattening production by using fodder grass and maize silage as basic constituents of the ration. Very intensive and very dependent regarding the PORCIN activity, this cluster was denominated "Specialized PORCIN". It concerned the Bretagne (France), the Weser-Ems (Germany) and Denmark regions.

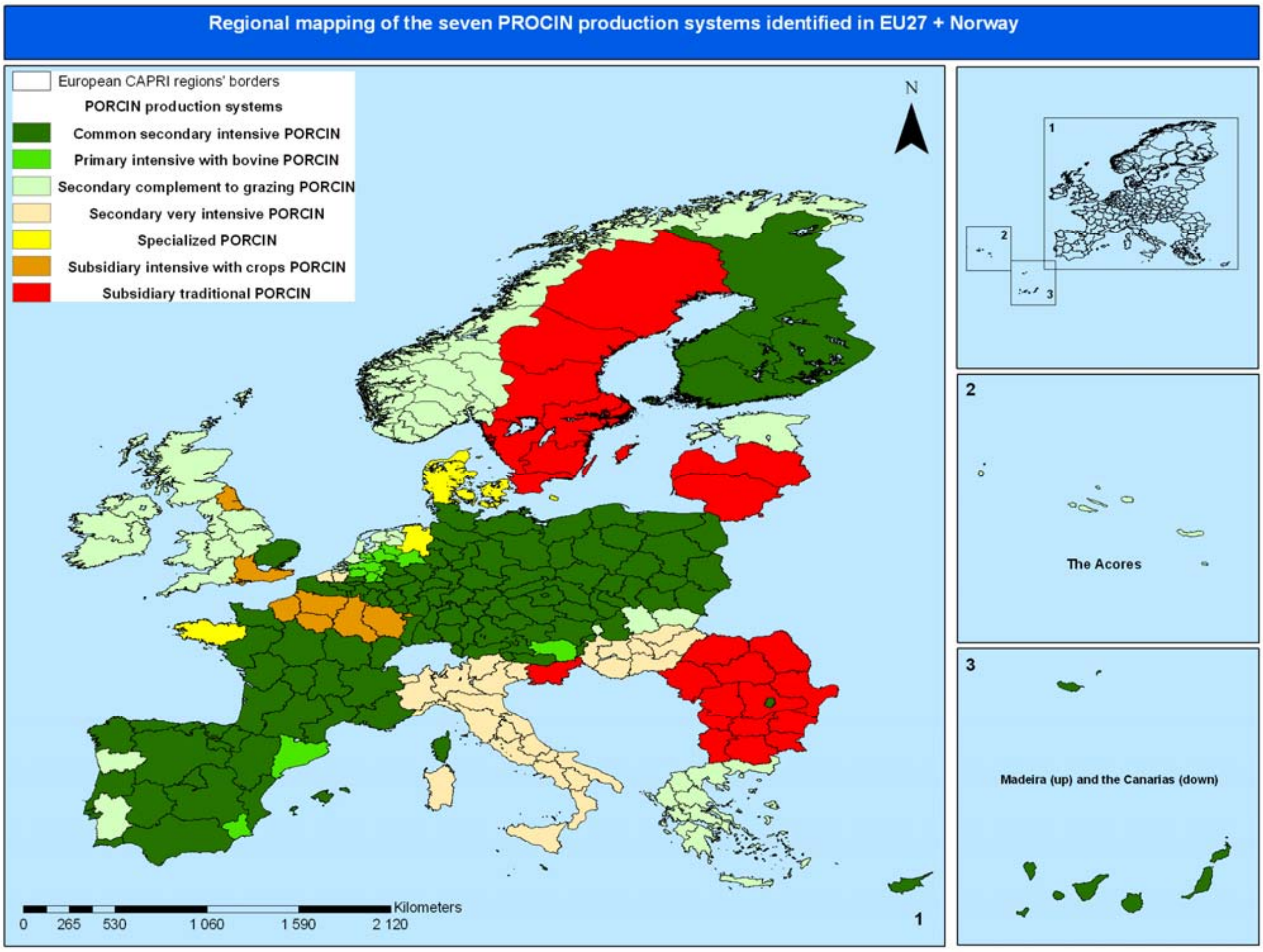

Figure 17: Diversity of the PORCIN Production Systems in EU27 + Norway

7.1.5. The LAHENS sector

For LAHENS, PCA was performed from seven remaining descriptors after elimination of high correlations between initial descriptors. The quantitative descriptor corresponding to the importance of the LAHENS production was the revenue expressed in million of euro; together with the herd size as the percentage of the total number of livestock units in a region corresponding to LAHENS production, it described the importance of the LAHENS production (3 modalities, from subsidiary to of primary importance). The other descriptors were the level of intensification (€/LU) of the LAHENS production which participates to the intensity of the production (3 modalities from normal rhythm to very intensive) together with yield (kg of eggs.year^{-1}.laying hens^{-1}). The feeding strategy (3 modalities from independent to very dependent) describing the level of LAHENS dependence to the market for feedstuffs provision was determined from three descriptors: the level of intensification expressed in % of the total cost – the stocking density calculated for granivores as the number of livestock units per hectare of rich protein crops (soybean, sunflower and rape for oilseeds, wheat and grain maize for cereals, and pulses areas) – and the regional level of autosufficiency for digestible lysine as the percentage of the monogastric lysine requirement covered by the rich protein crops cultivated in the region. Finally, the level of constraint due to a particular (agro)climatic situation was discussed by considering the level of intensification expressed in % from which a picture of the other production costs such as heating/cooling can be determined (3 modalities: low to high).

Results of the PCA are shown in table 9.

Table 9: Results of the PCA – Varimax rotation onto the seven descriptors retained for the LAHENS production description and clustering

	PCA comp. 1	PCA comp. 2	PCA comp. 3	PCA comp. 4
Eigenvalues	1.871	1.254	1.189	0.971
Percent	26.731	17.913	16.992	13.88
Cum Percent	26.731	44.643	61.635	75.51
Eigenvectors after rotation				
Intensification (€/LU)	0.771	0.459	0.124	0.003
Intensification (%)	-0.033	0.918	-0.073	-0.057
Revenue (€)	0.038	-0.097	-0.034	0.92
Lysine autosufficiency (%)	0.09	0.288	-0.659	0.076
Yield (kg/head)	0.91	-0.188	-0.056	-0.023
Stocking density (LU/ha)	0.059	0.155	0.796	0.128
LAHENS share (%)	-0.51	0.138	0.303	0.556

From the results of the ANOVA processed on the seven remaining descriptors (annex 12), a qualitative description of every one of the clusters was performed. The results are presenting in table 10.

Table 10: Qualitative description of the seven LAHENS clusters identified

Clusters	Importance	Dependence	Intensity	(Agro)climatic situation
1	Primary	Dependent	Natural rhythm	Medium
2	Subsidiary	Dependent	Intensive	Low
3	Primary	Very dependent	Intensive	Low
4	Subsidiary	Dependent	Very intensive	High
5	Subsidiary	Dependent	Intensive	Low

- Cluster 1 was presenting a high proportion (>55%) of the UAA used for annual crops (cereals, rich protein and grain maize) and around 15% for permanent crops and the proportion of fodder crops was consequently very low. Such a cropping system was not relevant for grazing breeding and it was not surprisingly that 50% of the animals assemblages was composed of poultry, granivores/ovine and granivores assemblages. The second highest assemblage was "Mixed without SHGOAT" (15%) which could also contain a certain proportion of poultry activities. The livestock activities of the cluster 1 seemed to be centred on the production of granivores (pigs for fattening) and poultries rather than on the production of grazing animals. This was confirmed by the preponderance of the T50 "granivores" and T72 "mixed granivores" farm types and then of T71 "mixed grazing" and T82 "crops + livestock". As a consequence, together with the porcine activities, production of poultry was perceived as of primary importance; ovine and then bovine activities were secondary productions. On the other hand, the LAHENS revenue was medium level when the herd size was high: if LAHENS were numerous, they didn't contribute so highly to the revenue. This suggested that LAHENS production for this cluster was not intensive. It has been verified when considering the intensity of the production: the yield was the lowest observed (9.63 kg/head, 50% of the maximum observed for cluster 4) and the investments consented for feedstuffs and veterinary products provision was the lowest (445€/LU). The level of intensification expressed in % showed that the regions belonging to this cluster were exposed to a low-to-medium level of agro-climatic constraint; almost 90% of the investments are destined for feedstuffs and veterinary products acquisition – a standard proportion in Europe. All together these elements suggested a non intensive production respecting a certain normality of the rhythm of production because of more animal-friendly practices or because of a reduced capacity of investment. The low level of intensification (E/LU) not being counterbalanced by a medium/high lysine autosufficiency, the second hypothesis could be real. The LAHENS production system of cluster 1 has been called "Primary economically restricted LAHENS". The regions concerned corresponded to almost all the regions of Greece, Poland, Romania, Bulgaria and the Latvia, Lithuania, Cyprus and Slovenia.

- For the second cluster, the cropping system was well balanced between annual crops (44%) and fodder crops (45%) – the remaining 10% being covered by permanent crops. In parallel, only 25% of the animals assemblages was composed of "poultry" and "granivores" – the rest corresponding essentially to "bovine" and "Mixed without SHGOAT". The total revenue was low and the herd size (%) very low. The LAHENS production for cluster 2 appeared as a subsidiary activity to the bovine activity. Because of important investments and a limited lysine autosufficiency, the cluster 2 was considered as dependent to the market for feedstuffs and veterinary products supply. The prevalent use of marketed feedstuffs was related to the level of intensity; with a mean yield higher than the European average (14.73 ± 3.25 kg/head/year), LAHENS production for cluster 2 appeared as intensive. Finally, the proportion of the production costs not invested for animals feeding and health was reduced (less than 10%); the regions concerned were not located in constrained agroclimatic zones. The production system of cluster 2 was relatively standard and respected a large range of practices and decisions traditionally set up in Europe; it has been consequently denominated "Subsidiary common intensive LAHENS". The number of regions being huge, readers should refer to the figure 18 to visualise the regions concerned.
- Cluster 3 differed from the two first clusters first, because of the high importance of the LAHENS activity (highest revenue and herd size observed) and because of a very limited lysine autosufficiency (13.13%) asking for the purchasing of a very large part of the feedstuffs and veterinary products necessary for intensive production (yield = 14.69 kg/head/year). Intensive and very dependent, the LAHENS production of cluster 3 was of primary importance. The LAHENS production (25%) was generally accompanied by "granivores" (28%), "Mixed without SHGOAT" (25%) and "ovine …" (10%) assemblages. In parallel of the prevalence of monogastric livestock, the cropping system was composed of one third of annual crops and 2 thirds of fodder crops. This described a situation where livestock production was relatively diversified with monogastric productions dominance. No significant farm types were observed; almost all the farm types were represented (>50th percentile) with at some extent the prevalence of "dairy cattle" (T41) and "SHGOAT + other grazing" (T44). The level of intensification (%) being high, no particular agro-climatic constraint was retained – it could correspond to favourable temperate situations. All together, the data seemed to describe regions where granivores and grazing productions were of primary importance. At the opposite of the grazing activities which had dedicated fodder areas at its disposal, the LAHENS feeding is based on ration made of feedstuffs from the market. For these reasons, cluster 3 was called

"Primary very dependent LAHENS". Half of the regions in the Netherlands, in the UK, in Slovakia, Hungary, Norway, Italy and Spain were concerned.

- With the highest yield and one of the lowest lysine autosufficiency, this cluster could be dependent on the market to fulfil LAHENS requirements. When considering the cropping system, the regions presented a simple share of the total UAA with 87.5% of "annual cereals + …" and 12.5% of "fodder grass = maize"; the proportion of rich protein crops being null, the supplying of protein to LAHENS activities was very limited. And the LAHENS activity was effectively dependent on the market. In this cluster, 62.5% of the animals assemblages corresponded to bovine (50%) and "grazing"; the rest was composed by the sole "Mixed without SHGOAT" (37.5%). The profile of animals assemblages suggested a grazing dominant profile which didn't dispose of large fodder areas to be fed. Thus, indoor rearing with marketed feedstuffs seemed usual practices for all species. A look on the intensification (%) showed that more than 40% of the total production cost was used for something else than feeding. This could correspond to regions with important agroclimatic constraints. Finally, the assemblages' profile, the revenue and the herd size showed that LAHENS was a subsidiary production in these regions. To summarized all these characteristics, the cluster 4 was denominated "Subsidiary climatically constrained LAHENS". It corresponded to the Swedish regions.
- The last cluster presented the highest level of intensification (€/LU and %) despite a very high lysine autosufficiency (320%); it has been considered as dependent on the market for feedstuffs supply. The revenue as well as the herd size depicted an activity of subsidiary importance. And the intensification (%) indicated that no particular constraint should be applied on the LAHENS activity in these regions. And until now, cluster 5 appeared as very similar to cluster 2.However, when analysing the cropping system and animals assemblages' profile, we observed a very specialized farming system: 75% of annual crops (rest was fodders) and almost 85% of "bovine + …" activities (17% of "poultry"). Consequently, in these regions the LAHENS activity was perceived as a complement to the bovine activity. But in the same time, these regions presented the lowest livestock revenue (35%) meaning that the economy of these regions was based on the plant production rather than on the livestock production. If bovine production (T4 and T43 were >75th percentile) could be considered as of primary importance, LAHENS was a niche market for certain holdings or a diversification tool to counterbalance risk of failure of the bovine activity. This cluster was called "Complement to crops LAHENS". These twelve regions were situated in France (11) and in the Check Republic (the Praha region).

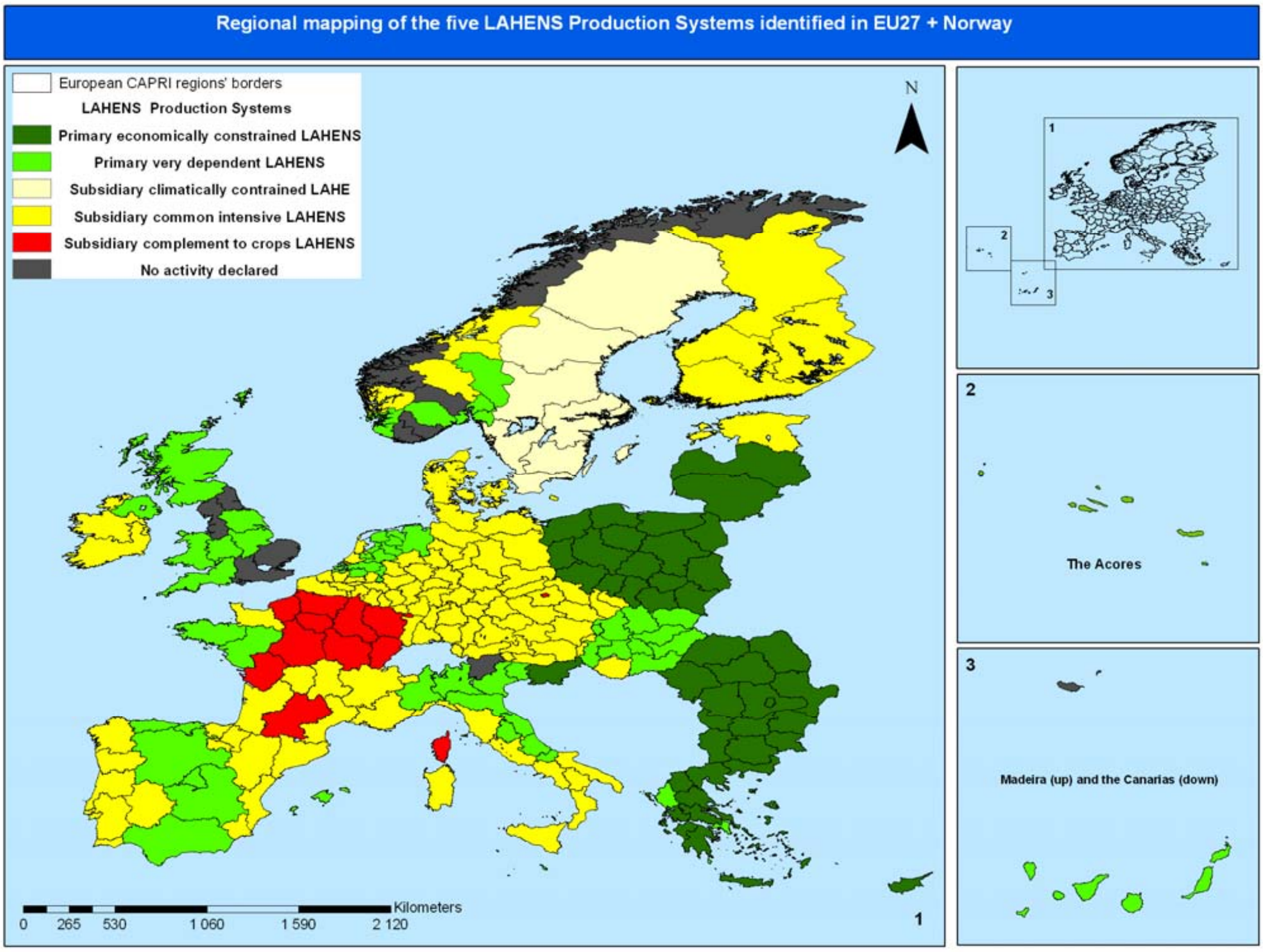

Figure 18: Diversity of the LAHENS Production Systems in EU27 + Norway

7.1.6. The POUFAT sector

From the beginning, we assumed that POUFAT production systems should follow the same trends tan the ones observed for LAHENS; consequently, we used the same seven descriptors to process the multivariate analysis of the regional variability. Results of the PCA are shown in table 11.

Table 11: Results of the PCA – Varimax rotation onto the seven descriptors retained for the POUFAT production description and clustering

	PCA comp. 1	PCA comp. 2	PCA comp. 3	PCA comp. 4	PCA comp. 5
Eigenvalue	1.8	1.29	1.08	0.87	0.81
Percent	25.66	18.46	15.46	12.44	11.53
Cum Percent	25.66	44.12	59.59	72.03	83.56
Eigenvestors after rotation					
Intensification (€/LU)	0.00	0.93	-0.05	-0.01	0.02
Intensification (%)	0.14	0.55	0.35	0.29	0.2
Revenues (M€)	0.84	0.11	-0.18	0.23	-0.14
Lysine autosufficiency (%)	-0.02	0.05	0.94	0.08	-0.1
Yield (kg/head)	0.04	0.08	0.09	0.95	0.03
Stocking density (LU/ha)	0.07	0.1	-0.09	0.04	0.96
Herd size (%)	0.82	-0.03	0.19	-0.15	0.28

Then, we performed a qualitative description of the seven clusters identified from the results of the analyse of variance applied to the seven remaining descriptors. Results of the ANOVA are presenting inside annex 13. From this, four following dimensions of the production systems have been characterized (Table 12):

- The importance of the POUFAT production (3 modalities, from subsidiary to of primary importance) by considering the POUFAT revenue (€) and relative herd size (%),
- The level of intensity of the production (3 modalities, from normal rhythm to very intensive) when considering together the level of intensification (€/LU) and the yield (kg/head),
- The level of dependence on the market for feedstuffs and veterinary products supplying (3 modalities, from independent to very dependent) when considering the level of intensification (%), the lysine autosufficiency (%) and the stocking density (LU/ha of rich protein, wheat, grain maize and pulses),
- Finally, the level of agroclimatic constraint (3 modalities from low to high) buy taking into account the complement of level of intensification (%) as an indication of the production cost dedicated to production practices other than the feeding (heating, cooling…).

Table 12: Qualitative description of the seven POUFAT clusters identified

Clusters	Importance	Dependence	Intensity	(Agro)climatic situation
1	Subsidiary	Independent	Natural rhythm	High
2	Subsidiary	Dependent	Intensive	Low
3	Secondary	Very dependent	Intensive	Low
4	Subsidiary	Dependent	Very intensive	Low
5	Primary	Very dependent	Very intensive	Medium
6	Subsidiary	Dependent	Intensive	Medium
7	Subsidiary	Very dependent	Very intensive	Medium

- The revenue as well as the relative herd size of cluster 1 indicated POUFAT as a subsidiary production in complement to the bovine and ovine activities. The POUFAT number of livestock was explained by the monogastric assemblages (25% of the complete profile) observed from which the "poultry" activity counted for 11% and the PORCIN and LAHENS activities for 14% of the complete profile. The profile of the animals assemblages showed a very diversified livestock production where all the activities were present; at the exception of T44 (SHGOAT), all the farm types showed values higher or equal to the 50th percentile values. Dependence on the market for feedstuffs provision was considered as medium; the lowest investment for feeding and health (1255€/LU), a stocking density almost null and a lysine autosufficiency relatively high suggested the possibility to have directly recourse to regional crop production to feed POUFAT; cluster 1 was considered as independent. This was explained when considering the cropping system: around 60% of the total UAA corresponded to annual crops and 10% were permanent crops. The yield as the carcass weight of POUFAT when slaughtered was of standard value. Together with level of intensification (€/LU), it suggested a non intensive production practices where individual growth duration could be higher and closed to a more natural rhythm of growth. Finally, the complement to the level of intensification (%) being the highest observed, we assumed other production costs to be considered for POUFAT production: this could be the consequence of important agroclimatic constraints. The corresponding regions were located in Austria, Bulgaria, Cyprus, Germany, Italy, Lithuania, Poland and Sweden and corresponded to continental temperate or cold climates where heating and cooling costs could be important. Cluster 1 has been called "Subsidiary constrained natural rhythm POUFAT".

- Cluster 2 corresponded to a production system of subsidiary importance and was very similar to the previous one. Major differences were a higher level of intensification (€/LU) and a higher yield suggesting a more intensive production system. The cropping system was centred on the fodder activities (55%) and cattle rearing and fattening activity (T42 and T43, >75th) was the major type of livestock production met. The POUFAT activity was represented essentially through the "ovine/poultry" assemblage; the ovine production was certainly a secondary production after the cattle rearing activity; it had at its disposal a high proportion of permanent crops(24%) for free-ranging feeding strategy. As cattle rearing activity was fed from fodders and especially from fodder maize (an intensive practice), we assumed that the same trend should be applied to the POUFAT activity. We have considered the POUFAT activity as intensive; it was confirmed by the high yield observed. A medium stocking density, a lower lysine autosufficiency together with a high intensification level described a dependent situation where producers should have recourse to the market to fulfil the POUFAT feeding requirements. Finally the complement of the level of intensification (%) was closed to 83% and suggested no particular other production constraint. The cluster was called "Subsidiary with cattle intensive POUFAT". Regions were located in Belgium, Spain Greece and France; other regions such as Malta, Slovenia or again the Luxembourg were concerned too.
- Cluster 3 contained only one region. For this reason, it has been very difficult to conclude of the real production system in place. Only subjective interpretation was possible in absence of intra-cluster variability. Whatever the number of clusters (>3) tested, this region was always identified alone. It was a very particular region composed of 100% of the permanent crops assemblage (in fact 45% of fodders was also declared) with one single assemblage: "ovine/poultry". Consequently, POUFAT appeared as a production system of secondary importance completing the ovine activity in the region. This region was the Canarias region in Spain (ES70). With one prevalent farm type (T44) counting for 45% of the farms, and a livestock revenue of 9.6% of the total revenue, all the livestock production could be considered as a "subsistence production" or destined to the local market without high market standards. On the other hand, the absence of rich protein crops, a relatively standard yield and the highest stocking density suggested a high dependence on the market to feed POUFAT animals. The name given to this production system was "Secondary very dependent Canarias POUFAT".
- Cluster 4 had the second highest intensification level (€/LU) and in the same time the highest autosufficiency level for lysine. Yield being the highest, it required important quantities of feedstuffs per animal to fulfil energy and protein requirements. A look on the crops groups share showed that fodders and cereals were equally cultivated (35% of the total UAA); but oilseeds areas represented 7.5% of the total UAA, the highest share observed between clusters for this crop group. Consequently, the energy and protein availability appeared as not limiting if POUFAT would be the sole livestock production. However, the profile of the animals assemblages showed that 80% of the animals corresponded to grazing animals and especially of cattle for rearing and fattening (T42 and T43) which require high amount of energy and protein. POUFAT not being of primary importance (it has been considered as subsidiary), we assumed that most of the feed availability was preferentially attributed to the cattle activities. So, POUFAT was considered as dependent and very intensive to reach specific yield observed. On the other hand, intensification (%) closed to 86% suggested that no particular constraints had to be taken into account. Cluster 4 appeared as "Subsidiary with cattle very intensive POUFAT". All the regions (11) were located in France and coincided with the eleven regions called "Complement to crops LAHENS".

- Cluster 5 was the cluster for which POUFAT appeared as of primary importance: highest animals share and highest revenue were observed. The animal assemblages' profile was made of granivores (33%) and of poultry (40%). With a very limited lysine autosufficiency and a standard yield, it appeared normal to observe a medium level of intensification (around 1500 €/LU); POUFAT production has been considered as very dependent. Moreover, major farm types were T50 and T72 meaning that monogastric production was prevalent (followed by cattle rearing and fattening) and that porcine and poultry activities could compete for regional feedstuffs availability. Porcine as well as poultry activities being dominant productions and conducted indoor generally at high production intensity, the observation of a high carcass weight (yield) conducted to consider the POUFAT production system as very intensive. The complement to the total production cost was considered as medium (25%) suggesting supplementary investments to be granted. Unfortunately, neither the list of the regions concerned (in France, Hungary, Italy, the UK and in less extent in Spain) nor the details of the total production cost inside CAPRI dataset allowed us to identify the reasons of the supplement; we assumed that the investments were due to decision of modernization (buildings, manure collecting system…) or diversification (transformation chain, packaging…). This cluster was called "Primary very intensive POUFAT".
- When considering the animals assemblages, livestock activities in cluster 6 appeared as balanced between grazing activity (50%) and monogastric activities (granivores = 20% and poultry = 30%). It has been confirmed by the farm types observed: T50 and T72 were prevalent followed by T41 "dairy cattle". On the other hand, the herd size equalled an intermediate value (5.5%) and the POUFAT revenue was relatively low. Altogether, the last two arguments suggested a subsidiary production when the first suggested a secondary production. It was the first time that we were not able to statute clearly on the importance of a production. The analyse of contingence of the animals assemblages containing more approximation than the ANOVA when the relative herd size is obtained from the real number of livestock units per species in a region, we choose to conform to the last result and POUFAT in cluster 6 was considered as a subsidiary production system.

  Despite a high proportion of annual crops (60%), the level of lysine autosufficiency was very limited. Main area were destined to fodders (for dairy cattle) and cereals when oilseeds (5%) and even more pulses (0.8%) were limited. The POUFAT was considered as dependent on the market to fulfil feeding requirements. Yield of 1.2 kg/head was the lowest observed; extensive practices not existing for poultry, it suggested a decrease of the growth period duration to allow producers to increase the number of production cycles in a year or to match the specific market requirements. Finally, the complementary investments to the total production cost were relatively important (25%) – according to the list of countries concerned (Slovakia, Norway, Romania, Portugal, Latvia, Ireland or again Finland), the climatic constraint could explain this supplementary investments. "Subsidiary constrained intensive POUFAT"
- The last cluster was particular with area dedicated at 100% to fodders activities and a profile of the animals assemblages showing predominant grazing activities (85%) and complementary granivores activity (15%). The main farm types were T41 and T44 describing a strong preference for milk production in the corresponding regions. The herd size as well the revenue confirmed that POUFAT is a subsidiary production in cluster 7. Even if subsidiary, the level of investment was the highest (2400€/LU) observed. The fact that Fodders, root crops and industrial crops were the major groups occupying the total area suggested the null availability of rich protein crops to feed animals and consequently a very high dependence on the market. Together with the level of intensification (€/LU), a standard yield suggested an intensive-to-very intensive production with a high turnover. To decide of the final level of intensity, we

then checked the livestock revenue (50% of the total agriculture revenue) and the total UAA: the regions belonged to the same country, The Netherlands and the total UAA is very limited regarding the total agriculture revenue. Consequently, each agriculture activity must be very intensive to justify land occupation from agriculture activities. We conclude (subjectively) that POUFAT should be very intensive activity. The cluster was called "Subsidiary very dependent POUFAT".

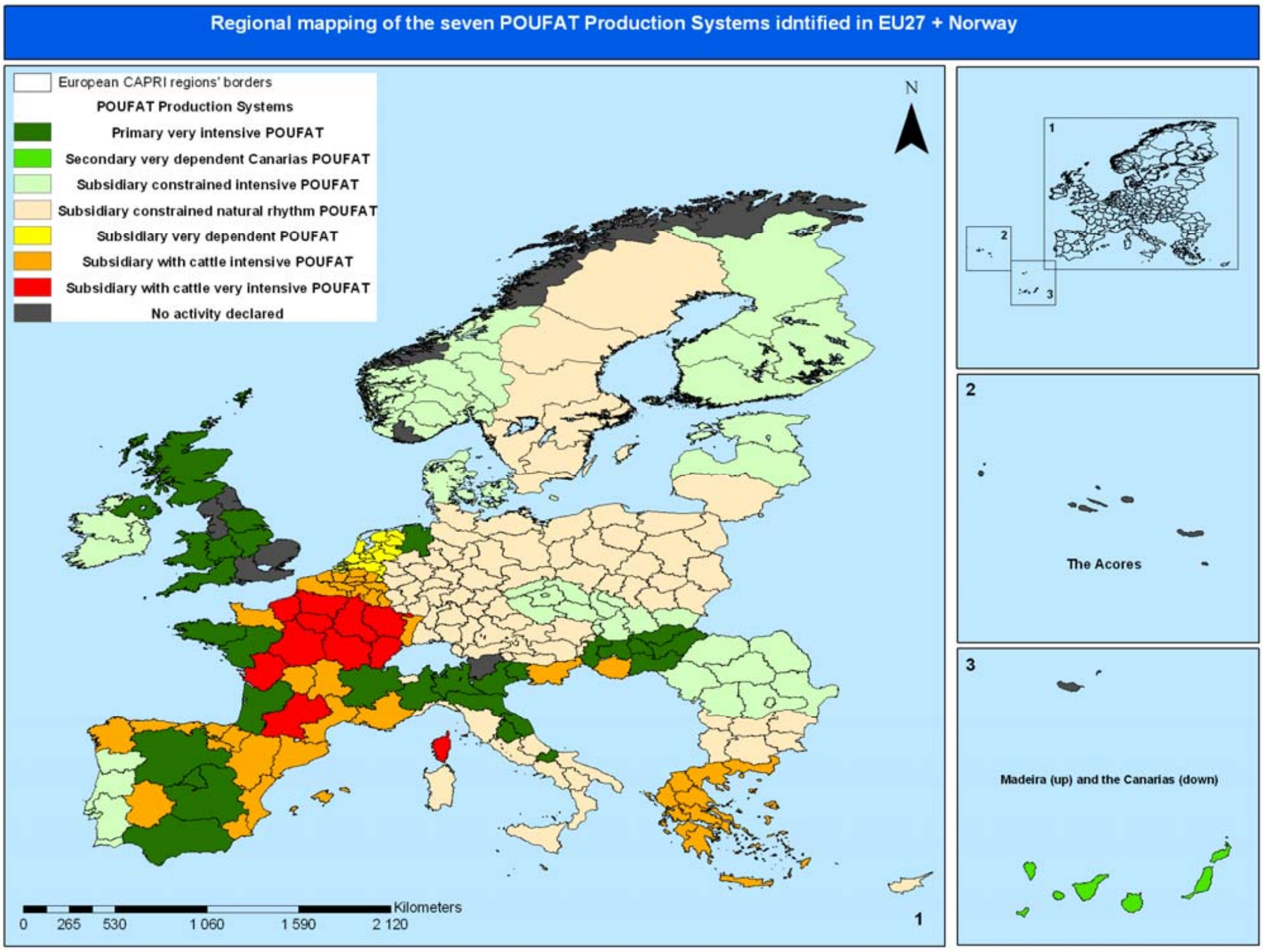

Figure 19: Diversity of the POUFAT Production Systems in EU27 + Norway

8. Ranking and sampling of the regions

Every survey requires the selection of those individuals which should provide the necessary and sufficient information to describe of the effects of the tested factors. This set of individuals is called sample. The sample comes from larger group of individuals (i.e. the targeted population) from which we expect general statements based on the sample findings (Remenyi *et al*., 2007). The sample must be ideally chosen so that no significant difference exists between the sample and the population in any important characteristics, the model being used as a model for the whole population.

But to be useful to characterize the population, sample must be representative of the whole population otherwise results would be biased and not applicable to the population. To avoid bias and to assure a sufficient level of representativeness, we applied a *probability sampling* technique. Probability sampling uses some random procedure for the selection of the individuals; this is done to remove the possibility of selection bias. Each individual of the whole population has a known probability, not necessary equal, to be sampled. And the probability sample obtained can be rigorously analysed by means of statistical techniques, whereas it's not applicable for *non-probability* techniques.

The type of probability sampling chosen was a *stratified sampling*: the whole population is made of strata (i.e. clusters) from which random samples are drawn from each of the strata. In our case, strata corresponded to "*livestock sector clusters * climatic clusters*" ; for instance, 5 clusters have been identified for POUFAT; together with the 8 climatic clusters identified, this gives 40 possible strata to be randomly sampled.

Sample size i.e. the minimum recommended number of regions to consider when assessing the diversity of the manure management strategies in place in EU27 + Norway, is statistically determined. The results expected from the survey is the average percentage of liquid/mixed/solid manures produced, the percentage of manures stocked using a certain stocking material or again the percentage of manures sprayed on fields with a certain spraying material, this per production system and per livestock sector. Thus, the situation corresponds to *the determination of the sample size needed to estimate a population proportion (as percentage) to a specified margin of error, within a specified level of confidence* (Remenyi *et al*., 2007). This corresponded to probabilistic determination of sample size when sampling an infinite population where the expected sample will be less than 10% of the population. To that end, it was assumed that manure practices, as a discrete variable, were described statistically by the binomial distribution with only two parameters:

p = the proportion of liquid manures, and
$q = 1 - p$, the proportion of non-liquid manure.

The true proportion of liquid manure being unknown, rule of thumb is to consider p equal to 0.5 (50%). Then, the sample size was determined by considering an acceptable margin of error (d = 0.1 or 10%) in the estimate of p and the probability (α = 0.1) of not achieving this margin of error. This led to use of the normal approximation to the confidence interval given by the formula:

$$\hat{p} \pm t_\alpha s_{\hat{p}} \qquad \text{(equation 15)}$$

where $\hat{p}$ = observed proportion of anomalous reference parcels (0.0576),

t_α = the value of the Student's t-distribution for n-1 degrees of freedom and

$s_{\hat{p}}$ = the standard error of $\hat{p}$.

The desired margin of error is then:

$$d = t_\alpha s_{\hat{p}} = t_\alpha \sqrt{\frac{\hat{p}\hat{q}}{n}}$$ (equation 16)

Solving for n, the sample size required for an infinite population is:

$$n = \frac{t_\alpha^2 \hat{p}\hat{q}}{d^2}$$ (equation 17)

Finally, if the sample size equals more than 10% of the initial population, the procedure is to calculate the sample size from equation 3 above and then to correct it with the following finite population correction:

$$n' \cong \frac{n}{1 + (n/N)}$$ (equation 18)

where *n'* = estimated sample size required for finite population N,
n = estimated sample size required for an infinite population,
N = total size of the finite population (243 regions).

In our case where p= 0.5 (q= 0.5), *p* is estimated within an error limit of ± 0.1 (10%) with α = 0.1 (t_α = 1.645). From equation 17:

$$n = \frac{(1.645)^2 (0.5)(0.5)}{(0.1)^2} = 67.65$$

Because the 67.65 regions to be sampled (n) equalled more than 5% of the total number of regions (N=243), the finite population correction was applied and the final number of region to sample is 53.09 regions rounded at 54 as the minimum number of regions necessary to obtain statistically representative sample of the whole population. This number is valid for all the six livestock sectors.

Then, for *one given livestock sector*, we calculated the corresponding proportion for each one of the "*climates * LPS*" sub-strata and we multiplied this proportion to the minimum number of regions to be sampled (53.09) to obtain the number of regions *i* to be sampled from this particular "climate*LPS" association[21]. Regions corresponding to a "climate*LPS" association were then randomly ranked and the first i^{th} regions per association were labelled to be sampled during the survey on manures management strategies.

For each livestock sector, we obtained a list of regions presenting:

- the LPS denomination
- the corresponding climate association
- the number of regions by association
- the number of regions to be sampled per association
- the leader regions randomly selected
- and the other regions corresponding to the association but not randomly selected (they could be switched with leader regions to avoid overload of a certain national expert).

[21] For instance: 3 regions were identified as "*Primary very intensive POUFAT * Alpine*" corresponding to a proportion of 0.0123 over the total number of 243 regions, multiplied by 53.09 equalled 0.66 region rounded up at 1 region for this particular association

The different lists obtained are presented in the following tables (from table 13 to table 18) respecting the order in which livestock sectors were considered hereinbefore. Lists of regions per "climate*LPS" association are one possible ranking of the regions; anybody who wants to conduct survey from our results could decide of other regions to be surveyed but the change should be undertaken inside each single association to respect the approach from which classifications were done.

Table 13: List of the leader regions per BOMILK "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
Climate constrained bomilk	Alpine	4	1	AT33	ITD2 SI ES21
Climate constrained bomilk	Arctic	8	2	SE08 FI13	NO122 NO233 SE07 NO111 NO121 FI1A
Climate constrained bomilk	Continental cold	6	2	FI18 NO231	FI19 NO123 SE06 FI20
Climate constrained bomilk	Continental temperate	1	1	SE09	
Climate constrained bomilk	Mediterranean dry	4	1	PT20	ITC3 ES12 ES13
Climate constrained bomilk	Oceanic cold	7	2	NO243 NO252	NO242 AT34 NO241 NO244 AT32
Climate constrained bomilk	Oceanic temperate	2	1	ITC2	BE34
Extensive grass bomilk	Alpine	2	1	UKL	UKM
Extensive grass bomilk	Oceanic temperate	11	3	UKD UKC UKE	UKH UKK IE01 UKF UKN UKJ UKG IE02
Free-ranging subsistence bomilk	Alpine	1	1	ITD4	
Free-ranging subsistence bomilk	Continental temperate	18	4	PL62 EL13 PL32 PL63	BG04 AT11 PL22 BG01 PL51 PL33 BG02 BG05 PL42 PL21 PL52 BG06 PL43 BG03
Free-ranging subsistence bomilk	Mediterranean dry	25	6	ES62 EL41 EL24 EL30 ES30 ES23	ES41 ES61 ITG2 ES24 EL42 EL25 PT17 ES43 ITF4 PT15 EL12 ES42 ITG1 ES51 EL43 EL14 ITF3 ES52 ES53
Free-ranging subsistence bomilk	Mediterranean wet	12	3	EL11 ITE3 ES22	EL22 ITE4 ITE1 ITE2 EL23 ITF1 EL21 ITF2 ITF6
Grazing complement bomilk	Alpine	4	1	SE0A	FR63 AT21 AT22
Grazing complement bomilk	Arctic	1	1	NO232	
Grazing complement bomilk	Continental cold	9	2	LV NO254	EE SE02 NO262 NO255 NO253 NO261 SE01
Grazing complement bomilk	Continental temperate	30	7	SK04 CZ03 RO08 AT12 DE26 SK01 FR82	CZ06 CZ05 RO03 RO04 CZ04 RO02 RO05 CZ08 HU03 HU06 RO07 CZ01 HU04 SE04 SK03 HU02 RO06 CZ02 HU01 SK02 CZ07 HU05 HU07
Grazing complement bomilk	Mediterranean dry	2	1	PT18	FR83
Grazing complement bomilk	Mediterranean wet	6	2	PT16 FR81	FR61 FR62 ITF5 FR53
Grazing complement bomilk	Oceanic cold	1	1	NO251	
Grazing complement bomilk	Oceanic temperate	12	3	FR42 FR26 DE92	DE91 FR24 DE12 DEB3 DE71 FR21 FR10 FR22 DEA4
Intensive grass+maize bomilk	Alpine	8	2	PT11 DE13	DE21 DE14 ES11 FR43 DE27 AT31
Intensive grass+maize bomilk	Continental cold	1	1	LT	
Intensive grass+maize bomilk	Continental temperate	18	4	DE24 DE23 PL11 DE25	DE73 PL31 DE40 PL34 DK PL41 DEE0 RO01 PL12 DED0 PL61 DE80 DEG0 DE22
Intensive grass+maize bomilk	Mediterranean wet	5	2	ITD3 ITD5	FR51 ITC4 ITC1
Intensive grass+maize bomilk	Oceanic temperate	41	9	NL33 DEF0 DE93 DEA1 NL12 DE72 DEB2 DEA2 FR25	FR30 DEC0 DE94 FR52 FR23 FR72 NL34 BE33 LU00 NL13 NL31 DE11 NL11 NL32 FR41 DEA5 NL23 FR71 DEB1 BE32 BE24 BE25 BE23 NL42 NL22 NL21 BE22 BE21 BE31 DEA3 NL41 BE35
Mediterranean intensive bomilk	Mediterranean dry	4	1	ES70	CY MT PT30

Table 14: List of the leader regions per BOMEAT "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
Complement to ovine BOMEAT	Alpine	13	3	ITD2 FR43 AT33	ES21 DE14 ITD4 DE13 SE0A ES11 AT22 AT21 AT31 SI
Complement to ovine BOMEAT	Arctic	3	1	NO232	FI1A NO233
Complement to ovine BOMEAT	Continental cold	10	3	NO255 NO123 SE02	LT NO261 NO262 NO254 SE01 FI18 NO253
Complement to ovine BOMEAT	Continental temperate	14	4	SK03 RO06 RO02 FR82	RO07 RO03 SE04 RO04 RO08 DE73 BG04 RO05 RO01 SK04
Complement to ovine BOMEAT	Mediterranean dry	11	3	ITG1 PT18 PT20	FR83 PT15 ES23 ITG2 ES30 EL42 ITF4 ITF3
Complement to ovine BOMEAT	Mediterranean wet	15	4	ITF6 PT16 ES13 ITE1	ITC3 ITE3 ITE4 ES12 ITF5 ITF2 EL21 ITF1 FR81 ES22 ITE2
Complement to ovine BOMEAT	Oceanic cold	4	1	NO244	AT34 NO251 AT32
Complement to ovine BOMEAT	Oceanic temperate	8	2	DE72 FR71	ITC2 DEB1 DEB2 BE34 DEC0 DEA5
Complement to porcine BOMEAT	Continental temperate	15	4	CZ04 HU03 CZ05 HU02	CZ06 HU04 SK01 HU05 AT11 CZ02 SK02 HU07 HU06 CZ03 CZ07
Complement to porcine BOMEAT	Oceanic temperate	6	2	UKG UKC	UKH UKE UKF UKJ
Intensive grass maize BOMEAT	Alpine	2	1	UKL	FR63
Intensive grass maize BOMEAT	Mediterranean dry	3	1	ES61	ES43 ES41
Intensive grass maize BOMEAT	Mediterranean wet	6	2	ITC1 FR62	ITD3 FR61 ITC4 FR51
Intensive grass maize BOMEAT	Oceanic temperate	12	3	FR23 FR21 FR25	FR52 IE01 UKD IE02 FR41 FR24 FR26 UKK FR72
Intensive maize BOMEAT	Alpine	3	1	PT11	DE27 DE21
Intensive maize BOMEAT	Continental temperate	11	3	DE40 DE23 DE22	DEG0 AT12 DE26 DED0 DE24 DE80 DK DE25
Intensive maize BOMEAT	Mediterranean dry	2	1	ES70	CY
Intensive maize BOMEAT	Mediterranean wet	1	1	FR53	
Intensive maize BOMEAT	Oceanic temperate	38	9	NL34 NL12 DEA3 NL22 BE32 NL13 DE11 BE21 NL21	FR42 DE94 BE33 DEA1 NL11 DEA2 FR22 BE31 DEA4 BE22 NL42 NL33 DEB3 DE71 DEF0 LU00 BE23 BE35 DE93 DE91 NL41 BE24 NL23 NL31 NL32 DE12 BE25 FR30 DE92
No BOMEAT activity	Alpine	1	1	UKM	
No BOMEAT activity	Continental cold	3	1	EE	LV FI20
No BOMEAT activity	Continental temperate	2	1	CZ08	CZ01
No BOMEAT activity	Mediterranean dry	2	1	MT	PT30
No BOMEAT activity	Oceanic temperate	1	1	UKN	
Subsidiary Mediterranean BOMEAT	Continental temperate	24	6	PL32 DEE0 PL62 PL34 PL63 PL42	BG06 PL33 PL41 HU01 EL13 PL52 PL11 PL21 BG01 PL51 BG02 BG03 BG05 PL22 PL31 PL43 PL12 PL61
Subsidiary Mediterranean BOMEAT	Mediterranean dry	14	4	EL14 ES52 EL12 ES62	EL43 ES24 ES42 EL25 ES51 PT17 EL30 EL41 ES53 EL24
Subsidiary Mediterranean BOMEAT	Mediterranean wet	4	1	EL23	ITD5 EL11 EL22
Subsidiary Mediterranean BOMEAT	Oceanic temperate	1	1	FR10	
Subsidiary Nordic BOMEAT	Arctic	6	2	SE08 NO122	NO111 SE07 FI13 NO121
Subsidiary Nordic BOMEAT	Continental cold	3	1	NO231	FI19 SE06
Subsidiary Nordic BOMEAT	Continental temperate	1	1	SE09	
Subsidiary Nordic BOMEAT	Oceanic cold	4	1	NO242	NO241 NO243 NO252

Table 15: List of the leader regions per SHGOAT "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
Complement to bovine intensive SHGAOT	Alpine	8	2	ES11 AT31	FR43 DE13 DE21 SI DE27 DE14
Complement to bovine intensive SHGAOT	Arctic	2	1	FI13	NO233
Complement to bovine intensive SHGAOT	Continental cold	2	1	NO123	NO254
Complement to bovine intensive SHGAOT	Continental temperate	13	3	DK DE25 DE80	DE23 DED0 DE73 DE24 CZ01 DE40 DEG0 DE22 DE26 RO08
Complement to bovine intensive SHGAOT	Mediterranean dry	4	1	ES70	PT30 CY MT
Complement to bovine intensive SHGAOT	Mediterranean wet	3	1	ITD3	ITC4 ITC1
Complement to bovine intensive SHGAOT	Oceanic cold	1	1	NO244	
Complement to bovine intensive SHGAOT	Oceanic temperate	32	7	BE35 DEA4 DEA2 BE23 DEA5 DE11 BE21	FR23 BE24 DEB1 LU00 FR52 FR30 BE31 FR41 DEA3 FR25 DE71 BE32 BE22 DE92 BE33 DE72 DE94 DEF0 DE12 DEA1 FR22 DEC0 DE93 BE25 DE91
Complement to bovine mountainous SHGOAT	Alpine	6	2	AT33 ITD2	ES21 FR63 AT22 AT21
Complement to bovine mountainous SHGOAT	Continental temperate	2	1	SE09	BG04
Complement to bovine mountainous SHGOAT	Mediterranean dry	1	1	PT20	
Complement to bovine mountainous SHGOAT	Mediterranean wet	3	1	ES12	ITC3 ES13
Complement to bovine mountainous SHGOAT	Oceanic cold	2	1	AT32	AT34
Complement to bovine mountainous SHGOAT	Oceanic temperate	7	2	IE02 BE34	DEB2 UKN IE01 ITC2 FR72
Complement to dairy cattle Nordic SHGOAT	Arctic	5	2	SE08 NO122	SE07 NO111 NO121
Complement to dairy cattle Nordic SHGOAT	Continental cold	2	1	NO231	SE06
Complement to dairy cattle Nordic SHGOAT	Oceanic cold	4	1	NO241	NO242 NO243 NO252
Complement to granivores intensive SHGOAT	Alpine	3	1	PT11	SE0A ITD4
Complement to granivores intensive SHGOAT	Arctic	1	1	NO232	
Complement to granivores intensive SHGOAT	Continental cold	9	2	EE NO253	SE01 LT NO262 SE02 NO261 NO255 LV
Complement to granivores intensive SHGOAT	Continental temperate	51	12	BG05 RO01 AT11 BG03 PL32 HU07 CZ05 FR82 AT12 SE04 CZ07 PL34	PL21 PL11 CZ08 HU02 PL33 PL12 PL22 CZ02 RO04 CZ03 PL41 BG02 PL43 BG01 HU04 RO03 PL62 PL31 CZ04 RO06 PL51 PL63 RO07 RO02 HU06 CZ06 PL42 PL61 HU03 PL52 HU01 HU05 RO05 DEE0 BG06 SK03 SK01 SK04 SK02
Complement to granivores intensive SHGOAT	Mediterranean dry	14	4	ES51 FR83 ES24 PT15	ES52 ITG1 ES53 ITF4 ES23 ES30 PT18 PT17 ES62 ITF3
Complement to granivores intensive SHGOAT	Mediterranean wet	15	4	FR51 ITF5 ITF6 ITE2	ITD5 ITE4 FR61 ITF1 ES22 FR62 FR81 ITF2 ITE3 PT16 ITE1
Complement to granivores intensive SHGOAT	Oceanic cold	1	1	NO251	
Complement to granivores intensive SHGOAT	Oceanic temperate	7	2	FR42 FR71	FR24 FR10 DEB3 FR21 FR26
Mediterranean free-ranging SHGOAT	Continental temperate	1	1	EL13	
Mediterranean free-ranging SHGOAT	Mediterranean dry	13	3	ITG2 EL43 ES43	EL41 ES42 ES41 ES61 EL25 EL24 EL14 EL30 EL12 EL42
Mediterranean free-ranging SHGOAT	Mediterranean wet	5	2	EL22 FR53	EL23 EL21 EL11
No activity declared	Arctic	1	1	FI1A	
No activity declared	Continental cold	3	1	FI19	FI18 FI20
Temperate intensive indoor SHGOAT	Alpine	2	1	UKM	UKL
Temperate intensive indoor SHGOAT	Oceanic temperate	20	5	NL33 NL23 NL21 UKJ NL32	NL42 NL34 UKD NL13 UKH UKK UKC UKG UKF NL41NL12 NL22 NL31 NL11 UKE

Table 16: List of the leader regions per PORCIN "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
Common secondary intensive PORCIN	Alpine	11	3	FR43 ES21 AT33	ES11 DE21 FR63 AT21 DE27 DE14 AT31 DE13
Common secondary intensive PORCIN	Arctic	2	1	FI1A	FI13
Common secondary intensive PORCIN	Continental cold	3	1	FI20	FI19 FI18
Common secondary intensive PORCIN	Continental temperate	40	9	PL21 DE73 AT11 DE80 CZ06 DE24 DE26 DEG0 PL32	CZ08 DE40 PL52 PL43 PL62 CZ02 PL63 PL22 PL41 DE25 PL11 PL42 CZ01 PL34 PL33 CZ07 CZ05 PL51 PL61 CZ04 FR82 DE22 DE23 CZ03 PL31 DED0 DEE0 RO08 SK02 AT12 PL12
Common secondary intensive PORCIN	Mediterranean dry	16	4	ES52 PT17 PT30 PT15	ES24 ES30 ES41 ES61 ES42 FR83 ES23 MT ES70 ES53 ES43 CY
Common secondary intensive PORCIN	Mediterranean wet	9	2	PT16 FR51	FR81 FR53 ES22 ES12 FR61 ES13 FR62
Common secondary intensive PORCIN	Oceanic cold	2	1	AT34	AT32
Common secondary intensive PORCIN	Oceanic temperate	31	7	FR30 DE12 FR42 DE91 BE35 DE92 DEF0	DE71 FR72 DEA4 BE24 FR71 DEA1 BE31 FR24 DE72 BE32 DEA2 LU00 DEB2 UKH DE11 DEA5 BE34 DEB3 FR26 FR25 DEC0 DE93 DEB1BE33
Primary intensive with bovine PORCIN	Alpine	1	1	AT22	
Primary intensive with bovine PORCIN	Mediterranean dry	2	1	ES51	ES62
Primary intensive with bovine PORCIN	Oceanic temperate	8	2	NL41 NL22	BE21 BE22 NL42 NL21 DEA3 NL31
Secondary complement to grazing PORCIN	Alpine	3	1	PT11	UKL UKM
Secondary complement to grazing PORCIN	Arctic	5	2	NO122 NO233	NO232 NO111 NO121
Secondary complement to grazing PORCIN	Continental cold	8	2	NO253 NO254	NO255 NO261 NO123 NO262 NO231 EE
Secondary complement to grazing PORCIN	Continental temperate	4	1	SK04	SK01 SK03 EL13
Secondary complement to grazing PORCIN	Mediterranean dry	10	3	EL43 PT18 EL25	PT20 EL42 EL30 EL41 EL14 EL12 EL24
Secondary complement to grazing PORCIN	Mediterranean wet	4	1	EL23	EL22 EL11 EL21
Secondary complement to grazing PORCIN	Oceanic cold	6	2	NO242 NO241	NO243 NO252 NO244 NO251
Secondary complement to grazing PORCIN	Oceanic temperate	15	4	NL11 UKE NL23 NL12	UKD UKF IE01 NL32 UKK UKN NL33 IE02 NL34 UKG NL13
Secondary very intensive PORCIN	Alpine	2	1	ITD2	ITD4
Secondary very intensive PORCIN	Continental temperate	7	2	HU01 HU07	HU02 HU03 HU04 HU06 HU05
Secondary very intensive PORCIN	Mediterranean dry	4	1	ITG2	ITF3 ITF4 ITG1
Secondary very intensive PORCIN	Mediterranean wet	13	3	ITE4 ITC1 ITF5	ITE3 ITD5 ITE2 ITE1 ITD3 ITF1 ITF6 ITC4 ITC3 ITF2
Secondary very intensive PORCIN	Oceanic temperate	3	1	BE25	ITC2 BE23
Specialized PORCIN	Continental temperate	1	1	DK	
Specialized PORCIN	Oceanic temperate	2	1	FR52	DE94
Subsidiary intensive with crops PORCIN	Oceanic temperate	7	2	FR10 UKC	UKJ FR23 FR21 FR41 FR22
Subsidiary traditional PORCIN	Alpine	2	1	SI	SE0A
Subsidiary traditional PORCIN	Arctic	2	1	SE07	SE08
Subsidiary traditional PORCIN	Continental cold	5	2	LT SE02	LV SE06 SE01
Subsidiary traditional PORCIN	Continental temperate	15	4	SE04 RO04 BG03 RO05	SE09 BG05 BG02 RO07 RO02 RO01 RO06 BG01 BG06 BG04RO03

Table 17: List of the leader regions per LAHENS "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
No declared activity	Alpine	1	1	ITD2	
No declared activity	Arctic	3	1	NO122	NO121 NO111
No declared activity	Continental cold	1	1	NO255	
No declared activity	Mediterranean dry	2	1	PT30	PT20
No declared activity	Oceanic cold	4	1	NO251	NO242 NO252 NO241
No declared activity	Oceanic temperate	4	1	UKD	UKC UKJ UKH
Primary economically constrained LAHENS	Alpine	1	1	SI	
Primary economically constrained LAHENS	Continental cold	2	1	LV	LT
Primary economically constrained LAHENS	Continental temperate	31	7	RO02 PL63 RO03 PL32 RO07 BG01 RO06	RO08 PL51 PL31 RO05 PL62 BG02 BG04 PL11 RO01 BG03 BG05 PL42 PL33 EL13 RO04 PL61 BG06 PL41 PL12 PL52 PL34 PL43 PL22 PL21
Primary economically constrained LAHENS	Mediterranean dry	8	2	EL42 EL43	EL12 EL24 EL25 EL14 CY EL41
Primary economically constrained LAHENS	Mediterranean wet	3	1	EL11	EL23 EL22
Primary very dependent LAHENS	Alpine	3	1	UKL	UKM ITD4
Primary very dependent LAHENS	Arctic	1	1	NO232	
Primary very dependent LAHENS	Continental cold	4	1	NO261	NO254 NO253 NO262
Primary very dependent LAHENS	Continental temperate	10	3	HU06 HU05 HU02	HU01 HU03 SK01 SK03 HU07 SK02 SK04
Primary very dependent LAHENS	Mediterranean dry	8	2	EL30 ES41	ES70 ES53 ES30 ES61 MT ES42
Primary very dependent LAHENS	Mediterranean wet	12	3	ITC4 ITE3 FR51	ITD5 ES12 ITF1 ITC1 ITF2 EL21 ITD3 ES13 ITE2
Primary very dependent LAHENS	Oceanic cold	1	1	NO244	
Primary very dependent LAHENS	Oceanic temperate	18	4	UKE NL42 DE94 UKF	BE21 NL22 NL11 FR52 UKG NL12 UKN NL13 NL34 NL41 NL31 NL21 UKK NL23
Subsidiary climatically contrained LAHENS	Alpine	1	1	SE0A	
Subsidiary climatically contrained LAHENS	Arctic	2	1	SE07	SE08
Subsidiary climatically contrained LAHENS	Continental cold	3	1	SE02	SE01 SE06
Subsidiary climatically contrained LAHENS	Continental temperate	2	1	SE04	SE09
Subsidiary common intensive LAHENS	Alpine	12	3	ES21 ES11 AT31	AT21 DE21 DE27 AT22 FR63 PT11 DE14 DE13 AT33
Subsidiary common intensive LAHENS	Arctic	3	1	NO233	FI1A FI13
Subsidiary common intensive LAHENS	Continental cold	6	2	NO231 FI19	FI20 FI18 NO123 EE
Subsidiary common intensive LAHENS	Continental temperate	23	6	CZ04 DED0 HU04 CZ02 AT12 DE23	DK DE26 DE80 DEE0 AT11 CZ08 DEG0 FR82 DE25 CZ03 DE22 DE24 DE40 DE73 CZ06 CZ05 CZ07
Subsidiary common intensive LAHENS	Mediterranean dry	13	3	ES52 ES43 ES23	ES24 ES51 PT17 ITG2 PT18 ITF4 ITG1 ES62 ITF3 PT15
Subsidiary common intensive LAHENS	Mediterranean wet	9	2	PT16 ITE1	ES22 ITF6 FR81 ITF5 FR61 ITC3 ITE4
Subsidiary common intensive LAHENS	Oceanic cold	3	1	AT32	NO243 AT34
Subsidiary common intensive LAHENS	Oceanic temperate	37	9	NL33 FR42 DE12 BE24 ITC2 DEA3 DEA4 DE11 DE92	DE91 DE72 FR72 FR25 IE02 BE31 DEB2 BE25 FR71 DEA1 DEF0 BE22 FR30 DEB3 DE93 BE34 DEC0 LU00 NL32 BE33 IE01 DEA5 BE32 BE23 DEA2 DE71 DEB1 BE35
Subsidiary complement to crops LAHENS	Alpine	1	1	FR43	
Subsidiary complement to crops LAHENS	Continental temperate	1	1	CZ01	
Subsidiary complement to crops LAHENS	Mediterranean dry	3	1	FR83	FR53 FR62
Subsidiary complement to crops LAHENS	Oceanic temperate	7	2	FR22 FR26	FR10 FR23 FR21 FR24 FR41

Table 18: List of the leader regions per POUFAT "climate * LPS" association to be surveyed

LPS	Climates	No regions per association	No. regions to be sampled	Leader regions	Other regions
No activity declared	Alpine	1	1	ITD2	
No activity declared	Arctic	3	1	NO122	NO111 NO121
No activity declared	Mediterranean dry	2	1	PT30	PT20
No activity declared	Oceanic cold	2	1	NO241	NO252
No activity declared	Oceanic temperate	4	1	UKH	UKC UKD UKJ
Primary very intensive POUFAT	Alpine	3	1	ITD4	UKM UKL
Primary very intensive POUFAT	Continental temperate	6	2	HU02 HU05	HU03 HU06 HU01 HU07
Primary very intensive POUFAT	Mediterranean dry	4	1	ES61	ES41 ES42 ES30
Primary very intensive POUFAT	Mediterranean wet	9	2	FR51 ITD5	ITD3 ITC4 ITF2 ITE3 ITE2 FR61 ITC1
Primary very intensive POUFAT	Oceanic temperate	8	2	UKN UKK	UKG UKE DE94 UKF FR52 FR71
Secondary very dependent Canarias POUFAT	Mediterranean dry	1	1	ES70	
Subsidiary constrained intensive POUFAT	Alpine	1	1	PT11	
Subsidiary constrained intensive POUFAT	Arctic	4	1	NO233	FI13 FI1A NO232
Subsidiary constrained intensive POUFAT	Continental cold	12	3	FI19 EE NO255	NO253 NO231 LV FI18 NO254 NO261 NO262 FI20 NO123
Subsidiary constrained intensive POUFAT	Continental temperate	21	5	DK RO08 CZ01 CZ03 SK01	SK04 RO03 RO01 CZ04 RO02 RO04 CZ02 CZ06 RO05 SK02 CZ05 RO06 CZ07 CZ08 SK03 RO07
Subsidiary constrained intensive POUFAT	Mediterranean dry	3	1	PT18	PT15 PT17
Subsidiary constrained intensive POUFAT	Mediterranean wet	1	1	PT16	
Subsidiary constrained intensive POUFAT	Oceanic cold	4	1	NO251	NO244 NO242 NO243
Subsidiary constrained intensive POUFAT	Oceanic temperate	2	1	IE02	IE01
Subsidiary constrained natural rhythm POUFAT	Alpine	9	2	AT21 AT31	DE27 AT33 DE21 DE14 DE13 AT22 SE0A
Subsidiary constrained natural rhythm POUFAT	Arctic	2	1	SE08	SE07
Subsidiary constrained natural rhythm POUFAT	Continental cold	4	1	LT	SE02 SE01 SE06
Subsidiary constrained natural rhythm POUFAT	Continental temperate	37	9	DE73 AT12 DEG0 BG03 DE24 PL21 PL62 DE22 DE25	PL52 SE04 DE80 PL32 BG05 BG06 PL11 BG01 PL22 DE26 PL43 PL42 PL12 DE40 SE09 BG04 PL34 PL51 PL61 PL31 AT11 PL63 DED0 DE23 PL33 DEE0 PL41 BG02
Subsidiary constrained natural rhythm POUFAT	Mediterranean dry	5	2	ITF3 ITG1	ITG2 CY ITF4
Subsidiary constrained natural rhythm POUFAT	Mediterranean wet	6	2	ITC3 ITF1	ITF6 ITE4 ITF5 ITE1
Subsidiary constrained natural rhythm POUFAT	Oceanic cold	2	1	AT32	AT34
Subsidiary constrained natural rhythm POUFAT	Oceanic temperate	18	4	DEA2 DE71 DEA1 DEF0	DE93 DEB1 DEA5 DEB3 DE91 DEC0 ITC2 DEA3 DE92 DE12 DEA4 DE72 DEB2 DE11
Subsidiary very dependent POUFAT	Oceanic temperate	12	3	NL32 NL22 NL41	NL13 NL21 NL31 NL12 NL42 NL23 NL33 NL34 NL11
Subsidiary with cattle intensive POUFAT	Alpine	4	1	SI	FR63 ES11 ES21
Subsidiary with cattle intensive POUFAT	Continental temperate	3	1	EL13	HU04 FR82
Subsidiary with cattle intensive POUFAT	Mediterranean dry	16	4	EL25 ES52 EL12 ES23	ES43 ES62 ES24 EL30 EL42 EL41 MT ES53 EL14 EL24 ES51 EL43
Subsidiary with cattle intensive POUFAT	Mediterranean wet	8	2	ES12 FR81	EL22 EL23 ES22 EL21 EL11 ES13
Subsidiary with cattle intensive POUFAT	Oceanic temperate	15	4	FR25 LU00 BE22 BE32	BE34 BE25 BE24 BE33 FR42 BE23 BE31 FR72 BE35 FR30 BE21
Subsidiary with cattle very intensive POUFAT	Alpine	1	1	FR43	
Subsidiary with cattle very intensive POUFAT	Mediterranean dry	1	1	FR83	
Subsidiary with cattle very intensive POUFAT	Mediterranean wet	2	1	FR53	FR62
Subsidiary with cattle very intensive POUFAT	Oceanic temperate	7	2	FR23 FR22	FR21 FR10 FR26 FR41 FR24

9. Final conclusions

The aim of this study was to zone Livestock Production Systems existing of the six main livestock sectors in Europe and Norway: the dairy cows (BOMILK), the cattle rearing and fattening (BOMEAT), the sheep's and goats activities for milk as well for meat (SHGOAT), the rearing and fattening of pigs (PROCIN), the eggs production (LAHENS) and the meat production from broilers (POUFAT). This six livestock sectors were described from a set of variables extracted from the CAPRI Modelling System for year 2002 (the baseline year). The statistical classification of the livestock sectors allowed us to identify and suggest a set of LPS per livestock sector at regional level according to few livestock production dimensions:

- the feeding strategy
- the level of intensification of the production
- the keeping strategy
- the dependence on the market for feedstuffs supplies
- and the economic importance of a livestock sector

By having recourse to external to CAPRI datasets such as Eurostat farm types or again JRC Agri4cast meteorological database and profile of animals assemblages, we have been able to cross-validate and propose effective description of every one of the LPS identified. Then, by livestock sector, mapping of the main LPS identified has been done and a sampling proposed to perform survey on LPS related manures management practices in vigour in EU27 and Norway.

From the forthcoming survey, we expect to complete the scientific and expert knowledge concerning the manures management strategies set up in respect to the LPS retained on farm. A better understanding of the link between main LPS and main manures management strategies should ease the building of a multidimensional and complete LPS typology in the next future. However, if the dimensions retained appeared as effective to correctly describe LPS, certain lack of knowledge or certain limits to our approach have been observed; the identification and further the understanding of these limits would allow us to perform the next LPS typology as expected in the GGELS project.

We showed that an important source of differentiation of the LPS was coming from the feeding strategy and more particularly from the relationship existing between regional livestock requirements for energy and protein and the potential supply of energy and protein from the local crops i.e. the autonomy level. Autonomy level of a region was based on (i) the regionalized crops share processed by CAPRI from national statistics and Corinne Land Cover, (ii) the crop productions registered and provided by national authorities, (iii) the attribution of crops production according to animals feeding requirements without a clear knowledge of the proportion homegrown and auto-consumed per region. To make effective the next LPS typology, many aspects of the feeding strategy have to be deeply analysed:

- The attribution of certain cereals and rich protein crops to feed monogastric animals was partly subjective and didn't correspond fully to the real practices. Other data concerning the feedstuffs composition and provision per livestock sector should be considered – some databases describing the main crop products used for the preparation of the feedstuffs are already available on-line[22].
- Autonomy level was considered as a proportion of the animals requirements being potentially fulfilled from the cultivated crops and fodders. However, never information concerning the real

[22] For instance, the French institute of agriculture statistics, AGRESTE, delivers statistics on the regional feedstuffs composition
http://agreste.agriculture.gouv.fr/publications_2/chiffres_donnees_56/premieres_alimentation_3825.html

share of the homegrown and auto-consumed plant productions have been considered; only intensification as the investment for feedstuffs and veterinary products provision was used as a proxy. Effective approach should consider or model the real proportion of feedstuffs produced and used on farm together with the proportion of purchased feedstuffs (Kristensen et al., 2005; Dalgaard et al., 2006).

- To determine the level of dependence to the market of a LPS, we considered the energy and protein (and fibbers) autonomy. However, calculation were done from CAPRI dataset and no verification of the data was made before processing classification. One solution could be the use of more accurate values of the regional grassland productivity as proposed by Smit et al. (2008) to decide of the correctness to use CAPRI values.

But other dimensions considered in the study are suffering of subjectivity or imprecision. The best example concerned the keeping strategy of grazing livestock interpreted from the variables available in CAPRI. As mentioned for the description of the classes, modalities of the keeping strategy have been proposed by the author as "possible" strategies and decided from his own experience of functioning of LPS; from this, they cannot be considered as true strategies and one could interpret differently the results of the classification. To avoid misunderstanding and inconsistency when integrating keeping dimension within the next LPS typology, we planned to have recourse to expert's network to verify the interpretation made of the diverse LPS. Partnership with Institut de l'Elevage in France has been initially thought to provide expertise to the GGELS responsible as well as to actively participate to the building of the LPS typology. Together with Institut de l'Elevage, yearly and daily grazing period duration could be assessed or even modelled; silage practices could also be decided and integrated as classifiers when processing the LPS typology.

Other contact with MATRESA experts concerned by manures management practices (a dimension to integrate to the typology after obtaining of the results from the survey) or COPA-COGECA[23] should allow us to provide suitable LPS typology.

Finally, concerning the sampling design and size proposed, it has been done according to well accepted probabilistic requirements allowing surveyors to obtain significant and representative results. Survey having to be performed by national experts, the sampling has been decided independently of any risk of overloading (too much regions in a Member State to be surveyed and consequently too much work for one single national expert). If some regions or some European Member States appeared as overloaded, contractor responsible of the survey could envisage changing the lists of regions to be surveyed in the way to reduce work for each expert. If a certain flexibity to inter-change one region by another of the same "LPS*climate" association exists, it should be done respectively to the minimum number of regions to be surveyed we proposed. If decision would be taken to reduce the number of regions, it should be decided altogether after an ex-ante evaluation of the consequences on the expected accuracy and representativeness of the results obtained from a restrained sample.

[23] http://www.copa-cogeca.be/Main.aspx?page=HomePage

Annex 1. List of the variables obtained or calculated from 2002CAPRI baseline (per region)

Variables	Categories of descriptors	Description	Units
NUTS0_cod	Regions identification	Acronym of the country	(na)[i]
NUTS2_cod	Regions identification	Acronym of the region	(na)
NUT2_names	Regions identification	Name of the region	(na)
BOMILK_heads [ii]	Animal numbers	True number of heads for BOMILK sector	head
BOMILK_Lutot	Animal numbers	True number of livestock units for BOMILK sector	LU (livestock unit)
BOMILK_sqrt(LU+1)	Animal numbers	Root square (the true number of livestock unit for BOMILK sector + 1)	LU (livestock unit)
NMDS_sqrt(LU+1)_axe1	Animal numbers	Region coordinate on axe 1 from the Non-Metric multiDimensional Scaling used to class animals assemblages	(na)
NMDS_sqrt(LU+1)_axe2	Animal numbers	Region coordinate on axe 2 from the Non-Metric multiDimensional Scaling used to class animals assemblages	(na)
NMDS_sqrt(LU+1)_axe3	Animal numbers	Region coordinate on axe 3 from the Non-Metric multiDimensional Scaling used to class animals assemblages	(na)
ACP_sqrt(LU+1)_comp1	Animal numbers	Region coordinate on component 1 from the Principal Component Analysis used to class animals assemblages	(na)
ACP_sqrt(LU+1)_comp2	Animal numbers	Region coordinate on component 2 from the Principal Component Analysis used to class animals assemblages	(na)
ACP_sqrt(LU+1)_comp3	Animal numbers	Region coordinate on component 3 from the Principal Component Analysis used to class animals assemblages	(na)
BOMILK_intensification_€/LU	Intensification	Total costs dedicated to the use of feedstuffs and veterinary products per livestock unit in a year	€.LU-1
BOMILK_intensification_€/hd	Intensification	Total costs dedicated to the use of feedstuffs	€.head-1

		and veterinary products per head in a year	
BOMILK_intensification_%	Intensification	Proportion of total costs per activity dedicated to the use of feedstuffs and veterinary products per livestock unit in a year	%
DIV_margaleff	Animals assemblages	Margaleff index of diversity	(na)
DIV_MacIntosh	Animals assemblages	Mac Intosh index of diversity	(na)
DIV_Shannon	Animals assemblages	Shannon index of diversity	(na)
DIV_Simpson	Animals assemblages	Simpson index of diversity	(na)
EVEN_MacIntosh	Animals assemblages	Mac Intosh index of evenness	(na)
EVEN_shannon	Animals assemblages	Shannon index of evenness	(na)
Freez_day	Climate	Averages number of freezing days a year (from 1998-2007 observations)	days
Snow_day	Climate	Averages number of snowy days a year (from 1998-2007 observations)	days
Rain_day	Climate	Averages number of rainy days a year (from 1998-2007 observations)	days
Rainfal_3(mm)	Climate	Cumulative precipitation over the first three months (from 1998-2007 observations)	mm
Rainfal_6(mm)	Climate	Cumulative precipitation over the first six months (from 1998-2007 observations)	mm
Rainfal_12(mm)	Climate	Cumulative precipitation over the year (from 1998-2007 observations)	mm
PAR_3_(MJ/m2)	Climate	Cumulative photosynthetic active radiation over the first three months (from 1998-2007 observations)	MJ.m-2
PAR_6_(MJ/m2)	Climate	Cumulative photosynthetic active radiation over the first six months (from 1998-2007 observations)	MJ.m-2
PAR_12_(MJ/m2)	Climate	Cumulative	MJ.m-2

		photosynthetic active radiation over year (from 1998-2007 observations)	
Tcum_3(°C.d)	Climate	Averaged cumulative daily temperature for the first three months (from 1998-2007 observations)	°C.day-1 (base temperature = 0°C)
Tcum_6(°C.d)	Climate	Averaged cumulative daily temperature for the first six months (from 1998-2007 observations)	°C.day-1 (base temperature = 0°C)
Tcum_12(°C.d)	Climate	Averaged cumulative daily temperature over the year (from 1998-2007 observations)	°C.day-1 (base temperature = 0°C)
Tmoy_3(°C)	Climate	Averaged daily temperature for the first three months (from 1998-2007 observations)	°C
Tmoy_6(°C)	Climate	Averaged daily temperature for the first six months (from 1998-2007 observations)	°C
Tmoy_12(°C)	Climate	Averaged daily temperature over the year (from 1998-2007 observations)	°C
Elevation_moy(m)	Climate	Averaged elevation from a 1*1 km grid	m
Typ_41_cattll_dairy(%)	Farm type	Proportion of farm type 41 (dairy cattle) in a region	%
Typ_42_cattl_rear_fat(%)	Farm type	Proportion of farm type 42 (rearing/fattening cattle) in a region	%
Typ_43_cattl_dairy_rear_fat(%)	Farm type	Proportion of farm type 43 (dairy and rearing/fattening cattle) in a region	%
Typ_44_SHGOAT_othgraz(%)	Farm type	Proportion of farm type 44 (Sheep and goats + other grazing livestock) in a region	%
Typ_50_granivor(%)	Farm type	Proportion of farm type 50 (granivore) in a region	%
Typ_71_mixed_graz++(%)	Farm type	Proportion of farm type 71 (mixed grazing livestock) in a region	%
Typ_72_mixed_granivor++(%)	Farm type	Proportion of farm type 72 (mixed granivore livestock) in a region	%
Typ_81_crop+graz(%)	Farm type	Proportion of farm type 81 (annual crops and	%

		grazing livestock) in a region	
Typ_82_crops+livestock(%)	Farm type	Proportion of farm type 82 (annual crops and livestock) in a region	%
Typ_LPS/Total(%)	Farm type	Proportion of farms with livestock production (all sector confounded) in a region	%
UAAtot_calculée	Cropping system	Total used arable area	ha
Cereals(ha)(iii)	Cropping system	Total UAA dedicated to wheat (soft + durum)	Ha
Cereals(%)	Cropping system	Proportion of the total UAA dedicated to wheat (soft + durum)	%
Stocking_density (grazingLU/ha)	Intensification	Number of grazing livestock per hectare of fodder activities	$LU.ha^{-1}$
Stocking_density (allLU/ha)	Intensification	Number of livestock per hectare of fodder activities	$LU.ha^{-1}$
Revenues_Cereals(€)	Production	Total revenues of the cereals' activities	€
Revenues_Cereals(%)	Production	Proportion of the total crops revenues coming from the cereals' activities	%
Revenues_BOMILK(€)	Production	Total revenues of the BOMILK activity	€
Revenues_BOMILK(%)	Production	Proportion of the total livestock revenue coming from the BOMILK activity	%
REVENUE_CROPS(€)	Production	Total revenue of crops	€
Revenues_ANIMAL(€)	Production	Total revenue of livestock	€
Revenues_AGRICULTURE(€)	Production	Total revenue of Agriculture	€
Revenues_CROPS(%oftot)	Production	Proportion of the total agriculture revenue from crops	%
Revenues_ANIMAL(%oftot)	Production	Proportion of the total agriculture revenue from livestock	%
NRJ_Autonomy_fodgras (%)	Feeding strategy	Proportion of the grazing livestock energy requirements a year covered by the grasses production	%
NRJ_Autonomy_fodgras+maiz (%)	Feeding strategy	Proportion of the grazing livestock energy requirements a year covered by the grasses + fodder maize production	%
NRJ_Autonomy_fodall (%)	Feeding strategy	Proportion of the grazing livestock energy requirements a	%

		year covered by the fodders production	
PROT_Autonomy_fodgras (%)	Feeding strategy	Proportion of the grazing livestock protein requirements a year covered by the grasses production	%
PROT_Autonomy_fodgras+maiz (%)	Feeding strategy	Proportion of the grazing livestock protein requirements a year covered by the grasses + fodder maize production	%
PROT_Autonomy_fodall (%)	Feeding strategy	Proportion of the grazing livestock protein requirements a year covered by the fodders production	%
GrazingLU_NRJtot_requirement_(MJ/year)	Feeding strategy	Total energy requirement a year for all grazing livestock	$MJ.year^{-1}$
GrazingLU_PROTtot_requirement_(MJ/year)	Feeding strategy	Total protein requirement a year for all grazing livestock	$kg.year^{-1}$
Monogastric_Lysdig_autosufficency(%)	Feeding strategy	Proportion of the granivores digestible lysine requirements a year covered by the rich protein crops + wheat + barley	%
PORCIN_Lysdig_(kg/year)	Feeding strategy	Total digestible lysine requirements for pigs production	$kg.year^{-1}$
POUFAT_Lysdig_(kg/year)	Feeding strategy	Total digestible lysine requirements for poultry for fattening production	$kg.year^{-1}$
LAHENS_Lysdig_(kg/year)	Feeding strategy	Total digestible lysine requirements for laying hens production	$kg.year^{-1}$
BOMILK_Production(liters) (iv)	Production	Total BOMILK production a year	l (milk) tons (meat) tons (eggs)
DCOH_prod(liter/head) (v)	Production	Milk yield from dairy cow “high yield”	$l.head^{-1}$ (milk) $kg.head^{-1}$ (carcass weight or eggs produced)
Manure_BOMILK_N(Kg)	Manure production	Total quantity of nitrogen in manure from BOMILK a year	kg
Manure_BOMILK_P(Kg)	Manure production	Total quantity of phosphorus in manure from BOMILK a year	kg
Manure_BOMILK_K(Kg)	Manure production	Total quantity of potassium in manure from BOMILK a year	kg

Manure_BOMILK_N(%)	Manure production	Proportion of total quantity of nitrogen in manure coming from BOMILK a year	%
Manure_BOMILK_P(%)	Manure production	Proportion of total quantity of phosphorus in manure coming from BOMILK a year	%
Manure_BOMILK_K(%)	Manure production	Proportion of total quantity of potassium in manure coming from BOMILK a year	%
Ntot_kg/ha	Manure production	Total quantity of nitrogen used per hectare (fertilizer + residues + manure)	$kg.ha^{-1}$
%_Nmanure	Manure production	Proportion of the total nitrogen used per hectare coming from manures	%
Ptot_kg/ha	Manure production	Total quantity of phosphorus used per hectare (fertilizer + residues + manure)	$kg.ha^{-1}$
%_Pmanure	Manure production	Proportion of the total phosphorus used per hectare coming from manures	%
Ktot_kg/ha	Manure production	Total quantity of potassium used per hectare (fertilizer + residues + manure)	$kg.ha^{-1}$
%_Kmanure	Manure production	Proportion of the total potassium used per hectare coming from manures	%
Nsurplus_sol(kg/ha)	Environmental impact	Total nitrogen surplus at soil level (after run off)	$kg.ha^{-1}$
Nsurplus_tot(kg/ha)	Environmental impact	Total nitrogen surplus	$kg.ha^{-1}$
Psurplus_sol(kg/ha)	Environmental impact	Total potassium surplus at soil level (after run off)	$kg.ha^{-1}$
Psurplus_tot(kg/ha)	Environmental impact	Total potassium surplus	$kg.ha^{-1}$
Ksurplus_sol(kg/ha)	Environmental impact	Total phosphorus surplus at soil level (after run off)	$kg.ha^{-1}$
Ksurplus_tot(kg/ha)	Environmental impact	Total phosphorus surplus	$kg.ha^{-1}$

[(i)] *(na) = non applicable*

[(ii)]*Six different livestock sectors have been considered: BOMILK (cattle milk production), BOMEAT (cattle meat production), SHGOAT (ovine milk and meat production), PORCIN (pig meat production and pig rearing activities), LAHENS (laying hens) and POUFAT (meat from poultry) – variables are explained for BOMILK only.*

[iii] Crops have been grouped into eight different activities of crop production: Cereals, Fodder, Oilseeds, Pulses, Roots, Set aside and fallow lands, Vegetables and permanent crops, all remaining area are grouped inside a Rest category – variables are explained for Cereals only.
[iv] Total quantities produced a year are given for BOMILK, BOMEAT, POUFAT, LAHENS, PORCIN and separately SHGOAT-meat and SHGOAT-milk
[v] Production as a yield is given for more numerous livestock activities: DCOH, dairy cow high yield – DCOL, dairy cow low yield – SCOW, suckler cow – CAFF, female calf for fattening – CAMF, male calf for fattening – HEIH, heifer for fattening high yield – HEIL, heifer for fattening low yield – BULH, bull for fattening high yield – BULL, bull for fattening low yield – HENS, laying hens (eggs production) – POUF, poultry for fattening – PIGF, pig for fattening – SHGMILK, sheep and goat for milk – SHGFAT, sheep and goat for fattening.

Annex 2. List of the different “regions” that the CAPRI Modelling System is using

NUTS0	NUTS2	NUTS2_names
AT	AT11	Burgenland
AT	AT12	Niederoesterreich
AT	AT21	Kaernten
AT	AT22	Steiermark
AT	AT31	Oberoesterreich
AT	AT32	Salzburg
AT	AT33	Tirol
AT	AT34	Vorarlberg
BE	BE21	Antwerpen
BE	BE22	Limburg (B)
BE	BE23	Oost-Vlaanderen
BE	BE24	Vlaams Brabant
BE	BE25	Weat-Vlaanderen
BE	BE31	Brabant Wallon
BE	BE32	Hainaut
BE	BE33	Liege
BE	BE34	Luxembourg (B)
BE	BE35	Nmanur
BG	BG01	Severozapaden
BG	BG02	Severen tsentralen
BG	BG03	Severoiztochen
BG	BG04	Yugozapaden
BG	BG05	Yuzhen tsentralen
BG	BG06	Yugoiztochen
CY	CY	Cyprus
CZ	CZ01	Praha
CZ	CZ02	Strednφ Cechy
CZ	CZ03	Jihozßpad
CZ	CZ04	Severozßpad
CZ	CZ05	Severov²chod
CZ	CZ06	Jihov²chod
CZ	CZ07	Strednφ Morava
CZ	CZ08	Moravskoslezko
DE	DE11	Stuttgart
DE	DE12	Karlsruhe
DE	DE13	Freiburg
DE	DE14	Tuebingen
DE	DE21	Oberbayern
DE	DE22	Niederbayern
DE	DE23	Oberpfalz
DE	DE24	Oberfranken
DE	DE25	Mittelfranken
DE	DE26	Unterfranken
DE	DE27	Schwaben
DE	DE40	Brandenburg
DE	DE71	Darmstadt
DE	DE72	Giessen
DE	DE73	Kassel
DE	DE80	Mecklenburg-vorpommern
DE	DE91	Braunschweig
DE	DE92	Hannover
DE	DE93	Lueneburg
DE	DE94	Weser-Ems
DE	DEA1	Duesseldorf
DE	DEA2	Koeln
DE	DEA3	Muenster
DE	DEA4	Detmold
DE	DEA5	Arnsberg
DE	DEB1	Koblenz
DE	DEB2	Trier
DE	DEB3	Rheinhessen-Pfalz
DE	DEC0	Saarland
DE	DED0	Sachsen
DE	DEE0	Sachsen-Anhalt
DE	DEF0	Schleswig-Holstein
DE	DEG0	Thueringen
DK	DK	Danmark
EE	EE	Estonia
EL	EL11	Anatoliki makedonia
EL	EL12	Kentriki makedonia
EL	EL13	Dytiki makedonia
EL	EL14	Thessalia
EL	EL21	Ipeiros
EL	EL22	Ionia nisia
EL	EL23	Dytiki ellada
EL	EL24	Sterea ellada
EL	EL25	Peloponnisos
EL	EL30	Attiki
EL	EL41	Voreio aigaio
EL	EL42	Notio aigaio
EL	EL43	Kriti
ES	ES11	Galicia
ES	ES12	Asturias
ES	ES13	Cantabria
ES	ES21	Pais vasco
ES	ES22	Navarra
ES	ES23	Rioja
ES	ES24	Aragon
ES	ES30	Communidad de Madrid
ES	ES41	Castilla-Leon
ES	ES42	Castilla-la Mancha
ES	ES43	Extremadura
ES	ES51	Cataluna
ES	ES52	Comunidad Valenciana
ES	ES53	Baleares
ES	ES61	Andalucia
ES	ES62	Murcia
ES	ES70	Canarias
FI	FI13	Itae-Suomi
FI	FI18	Laensi-Suomi
FI	FI19	Pohjois-Suomi
FI	FI1A	Etelae-Suomi
FI	FI20	Ahvenanmaa/Aaland
FR	FR10	Ile de france
FR	FR21	Champagne-Ardenne
FR	FR22	Picardie
FR	FR23	Haute-Normandie
FR	FR24	Centre
FR	FR25	Basse-Normandie
FR	FR26	Bourgogne
FR	FR30	Nord-Pas-De-Calais
FR	FR41	Lorraine
FR	FR42	Alsace
FR	FR43	Franche-Comte
FR	FR51	Pays de la loire
FR	FR52	Bretagne
FR	FR53	Poitou-Charentes
FR	FR61	Aquitaine
FR	FR62	Midi-Pyrenees
FR	FR63	Limousin
FR	FR71	Rhone-Alpes
FR	FR72	Auvergne
FR	FR81	Languedoc-Roussillon
FR	FR82	Provence-Alpes-Cote dAzur
FR	FR83	Corse
HU	HU01	Közép-Magyarország
HU	HU02	Közép-Dunántúl
HU	HU03	Nyugat-Dunántúl
HU	HU04	Dél-Dunántúl
HU	HU05	Észak-Magyarország
HU	HU06	Észak-Alföld

HU	HU07	Dél-Alföld
IE	IE01	Border
IE	IE02	Southern and Eastern
IT	ITC1	Piemonte
IT	ITC2	Valle dAosta
IT	ITC3	Liguria
IT	ITC4	Lombardia
IT	ITD2	Trentino-Alto Adige
IT	ITD3	Veneto
IT	ITD4	Friuli-Venezia Giulia
IT	ITD5	Emilia-Romagna
IT	ITE1	Toscana
IT	ITE2	Umbria
IT	ITE3	Marche
IT	ITE4	Lazio
IT	ITF1	Abruzzo
IT	ITF2	Molise
IT	ITF3	Campania
IT	ITF4	Puglia
IT	ITF5	Basilicata
IT	ITF6	Calabria
IT	ITG1	Sicilia
IT	ITG2	Sardegna
LT	LT	Lithuania
LU	LU00	Luxembourg (Grand-Duche)
LV	LV	Latvia
MT	MT	Malta
NL	NL11	Groningen
NL	NL12	Friesland
NL	NL13	Drenthe
NL	NL21	Overijssel
NL	NL22	Gelderland
NL	NL23	Flevoland
NL	NL31	Utrecht
NL	NL32	Noord-Holland
NL	NL33	Zuid-Holland
NL	NL34	Zeeland
NL	NL41	Noord-Brabant
NL	NL42	Limburg (NL)
NO	NO111	Finnmark
NO	NO121	Troms
NO	NO122	Nordland
NO	NO123	Nord-Troendelag
NO	NO231	Soer-Troendelag
NO	NO232	Hedmark
NO	NO233	Oppland
NO	NO241	Moere og Romsdal
NO	NO242	Sogn og Fjordane
NO	NO243	Hordaland
NO	NO244	Rogaland
NO	NO251	Aust-Agder
NO	NO252	Vest-Agder
NO	NO253	Telemark
NO	NO254	Vestfold
NO	NO255	Buskerud
NO	NO261	Oslo og Akershus
NO	NO262	Oestfold
PL	PL11	L≤dzkie
PL	PL12	Mazowieckie
PL	PL21	Malopolskie
PL	PL22	Slaskie
PL	PL31	Lubelskie
PL	PL32	Podkarpackie
PL	PL33	Swietokrzyskie
PL	PL34	Podlaskie
PL	PL41	Wielkopolskie
PL	PL42	Zachodniopomorskie
PL	PL43	Lubuskie
PL	PL51	Dolnoslaskie
PL	PL52	Opolskie
PL	PL61	Kujawsko-Pomorskie
PL	PL62	Warminsko-Mazurskie
PL	PL63	Pomorskie
PT	PT11	Norte
PT	PT15	Algarve
PT	PT16	Centro
PT	PT17	Lisboa
PT	PT18	Alentejo
PT	PT20	Acores
PT	PT30	Madeira
RO	RO01	Nord-Est
RO	RO02	Sud-Est
RO	RO03	Sud
RO	RO04	Sud-Vest
RO	RO05	Vest
RO	RO06	Nord-Vest
RO	RO07	Centru
RO	RO08	Bucuresti
SE	SE01	Stockholm
SE	SE02	Oestra mellansverige
SE	SE04	Sydsverige
SE	SE06	Norra mellansverige
SE	SE07	Mellersta norrland
SE	SE08	Oevre norrland
SE	SE09	Smaaland med Oearna
SE	SE0A	Vaestsverige
SI	SI	Slovenia
SK	SK01	Bratislavský kraj
SK	SK02	Západné Slovensko
SK	SK03	Stredné Slovensko
SK	SK04	Východné Slovensko
UK	UKC	North East
UK	UKD	North West (including Merseyside)
UK	UKE	Yorkshire and The Humber
UK	UKF	East Midlands
UK	UKG	West Midlands
UK	UKH	Eastern
UK	UKJ	South East
UK	UKK	South West
UK	UKL	Wales
UK	UKM	Scotland
UK	UKN	Northern Ireland

Annex 3: Results of the analyse of variance applied to the main descriptive variables of the 8 climatic clusters in EU25 + Norway

Clusters	(n)	No. freezing days			No. rainy days			Rainfall (mm/12months)			Cum T° (°C.d^{-1}/6months)			PAR ($MJ.m^{-2}$)		
Cluster 1	66	17.4	10.1	f	96.3	11.1	b	827.5	91.2	c	1697.7	103.8	c	9.9	0.9	d
Cluster 2	8	78.5	12.7	c	113.9	7.3	a	1278.7	147.4	a	988.9	251	e	8.6	1.6	ef
Cluster 3	32	2.8	3	g	41.9	7	f	482.2	91.4	f	2544.9	248.4	a	15.9	1.6	a
Cluster 4	67	50.4	12.8	d	69.2	11.4	d	632.1	70.7	e	1622	212.9	d	11.1	1.4	c
Cluster 5	16	97	15.8	b	83.9	12.7	c	711.6	125.6	d	965	149.1	e	8.8	0.8	e
Cluster 6	26	7.1	5.3	g	61.7	12	e	724.7	82.2	d	2213.9	158.5	b	14.1	1.6	b
Cluster 7	19	37.3	25.3	e	94.6	14.2	b	1045.2	83.8	b	1659	294.3	cd	11.6	1.6	c
Cluster 8	9	149.6	10.7	a	81	5.2	c	658.8	46.8	de	637.6	107.3	f	7.6	0.9	f
r^2		0.89			0.76			0.81			0.86			0.77		
F (p-values)		266.2 (< 0.0001)			108.6 (< 0.0001)			138.9 (< 0.0001)			204.7 (< 0.0001)			110.3 (< 0.0001)		
RMSE		12.34			10.99			88.27			191.93			1.30		

Annex 4: Results of the analyse of variance applied to the two variables used to obtain the 5 elevation clusters in EU25 + Norway

Clusters	(n)	Elevation (m)			Elevation dispersion index		
Cluster 1	39	453.47	160.51	c	410.8	174.18	a
Cluster 2	95	81.01	44.85	e	24.41	22.57	e
Cluster 3	7	1494.93	317.61	a	269.31	53.82	b
Cluster 4	63	296.33	93.99	d	70.58	47.61	d
Cluster 5	39	630.17	159.08	b	172.48	74.51	c
r^2		0.86			0.74		
F (p-values)		354.6 (<0.0001)			173 (<0.0001)		
RMSE		117.44			81.21		

Annex 5: Results of the analyse of variance applied to the number of livestock per livestock sector for each one of the 10 animals assemblage clusters

Clusters	(n)	BOMILK (%)			BOMEAT (%)			SHGOAT (%)			PORCIN (%)			LAHENS (%)			POUFAT (%)			Clusters' denominations
Cluster 1	1	0.12	-	def	0.42	-	ef	**85.85**	-	d	6.50	-	cde	4.95	-	bcd	2.16	-	abcde	**OVINE**
Cluster 2	7	5.22	6.07	ef	12.38	6.57	ef	**20.82**	5.51	de	**45.08**	20.73	a	7.68	5.11	b	**8.82**	5.70	abcde	**GRANIVORES / OVINE**
Cluster 3	21	12.62	9.10	de	33.87	14.02	c	**37.13**	13.33	a	11.20	9.33	d	2.73	2.45	cd	2.45	2.43	de	**OVINE / BOVINE**
Cluster 4	13	24.65	7.88	bc	**43.75**	11.17	b	**17.16**	6.82	b	7.16	3.08	de	3.42	2.07	cd	3.85	2.05	cd	**BOVINE / OVINE**
Cluster 5	46	**36.15**	11.22	a	**39.20**	10.90	b	1.86	1.51	c	16.64	7.85	c	3.30	2.11	c	2.85	2.13	de	**BOVINE**
Cluster 6	22	**35.02**	15.25	a	**51.05**	16.31	a	7.03	6.58	e	5.16	3.27	e	0.82	1.07	d	0.92	1.16	e	**GRAZING**
Cluster 7	47	27.65	8.32	b	24.46	7.27	d	1.47	1.50	f	32.95	7.91	b	7.72	4.63	b	5.75	3.01	bc	**MIXED without SHGOAT**
Cluster 8	40	16.28	4.63	d	14.86	5.28	ef	1.82	2.09	g	**50.08**	10.79	a	**9.28**	5.31	b	**7.69**	4.09	a	**GRANIVORES**
Cluster 9	8	2.61	2.50	f	6.69	3.37	f	**59.67**	16.31	g	8.34	3.56	de	**14.93**	10.60	a	**7.76**	5.93	ab	**OVIN / POULTRY**
Cluster 10	38	21.84	9.19	c	29.85	8.72	c	14.30	6.01	g	16.90	8.51	c	**9.37**	4.32	b	**7.74**	5.28	a	**POULTRY**
r^2		0.52			0.60			0.86			0.76			0.41			0.34			
F (p-values)		28.07 (<0.001)			38.68 (<0.001)			154.26 (<0.001)			81.84 (<0.001)			18.06 (<0.001)			13.19 (<0.001)			
RMSE		9.35			9.94			6.14			8.69			4.20			3.55			

Dark and grey cells indicate averaged values for one cluster higher than the 75th and the 50th percentile respectively; they highlight the livestock sectors those are participating very highly and highly to each one of the 10 animals assemblage retained (i.e. clusters).

Annex 6: Results of the analyse of variance applied to the share of livestock farm types as provided by Eurostat for the 10 animals assemblages clusters identified (To be continued)

Clusters	Clusters	(n)	Cattle dairy (T41) (%)			Cattle fattening (T42) (%)			Cattle dairy + fattening (T43) (%)			Sheep & goat + grazing (T44) (%)			Granivores (T50) (%)		
1	OVINE	1	-	-	-	-	-	-	-	-	-	36.44	-	abcde	2.69	-	bcd
2	GRANIVORES / OVINE	7	3.30	3.30	de	6.17	5.29	bcd	0.23	0.37	c	34.45	12.90	abc	19.54	13.21	a
3	OVINE / BOVINE	21	8.64	9.86	cde	10.63	8.66	bc	1.07	0.80	c	43.42	14.83	a	5.89	5.51	cd
4	BOVINE / OVINE	13	23.80	15.77	ab	19.32	18.74	a	1.47	0.75	bc	35.96	12.65	ab	2.34	1.66	cd
5	BOVINE	46	29.94	14.90	a	11.70	8.67	b	4.45	4.31	a	20.54	12.03	d	4.14	7.49	cd
6	GRAZING	22	27.40	12.28	ab	21.52	16.13	a	4.63	5.17	a	30.40	17.14	bc	2.36	1.98	d
7	MIXED without SHGOAT	47	24.22	13.90	b	9.10	6.86	bc	3.37	4.32	ab	21.25	11.61	d	6.48	3.29	c
8	GRANIVORES	40	14.65	13.27	c	6.04	6.85	cd	2.26	2.19	bc	12.42	13.02	e	19.31	11.41	a
9	OVINE / POURLTRY	8	1.85	3.95	e	0.98	0.47	d	0.71	1.07	c	44.89	9.48	a	3.76	2.37	cd
10	POULTRY	38	12.40	12.59	cd	8.17	9.95	bcd	0.92	1.16	c	25.96	16.07	cd	9.86	8.34	b
r²			0.30			0.20			0.17			0.33			0.40		
F (p-values)			12.55 (<0.0001)			7.39 (<0.0001)			5.82 (<0.0001)			12.75 (<0.0001)			17.29 (<0.0001)		
RMSE			13.09			9.81			3.29			13.58			7.32		

Clusters	Clusters	(n)	Mixed grazing (T71) (%)			Mixed granivores (T72) (%)			Crops + grazing (T81) (%)			Crops + livestock (T82) (%)		
1	**OVINE**	1	**7.21**	-	abcd	**2.50**	-	ab	0.29		bc	**50.87**	-	a
2	**GRANIVORES / OVINE**	7	**5.06**	4.82	abcd	**3.21**	2.38	b	7.55	5.49	c	**20.53**	13.20	c
3	**OVINE / BOVINE**	21	**4.91**	4.91	abcd	**2.36**	2.17	b	**11.74**	8.79	c	**11.81**	9.56	de
4	**BOVINE / OVINE**	13	2.45	2.90	cd	1.89	1.77	b	6.10	4.62	c	6.68	7.20	ef
5	**BOVINE**	46	**5.62**	8.78	abc	1.98	2.13	b	**16.39**	10.32	ab	5.34	4.33	f
6	**GRAZING**	22	2.16	2.42	d	1.66	1.15	b	6.96	6.65	c	3.13	3.40	f
7	**MIXED without SHGOAT**	47	**5.58**	6.02	abc	**4.26**	4.13	b	**16.86**	9.71	a	**9.07**	7.65	e
8	**GRANIVORES**	40	**4.91**	4.13	bcd	**11.60**	9.93	a	9.96	6.88	c	**18.91**	12.23	c
9	**OVINE / POURLTRY**	8	**8.91**	3.65	ab	**2.53**	1.56	b	6.65	4.74	c	**29.71**	13.15	b
10	**POULTRY**	38	**7.96**	6.48	a	**11.32**	12.56	a	10.15	6.61	c	**13.26**	8.97	d
r²			0.08			0.28			0.20			0.39		
F (p-values)			2.23 (0.021)			10.07 (<0.0001)			6.3 (<0.0001)			16.4 (<0.0001)		
RMSE			5.97			6.83			8.20			8.61		

Dark and grey cells indicate averaged values of the farm type share higher than the 75th and the 50th percentile respectively; they highlight the farm types those are participating very highly and highly to each one of the 10 animals assemblages retained (i.e. clusters).

Annex 7: Results of the analyse of variance applied to the share of utilized arable area per crop categories used for cropping systems classification

Clusters	Clusters	(n)	Wheat (%)			Barley (%)			Fodder grasses (%)			Fodder maize (%)		
1	Cereals + other fodders	17	8.23	9.81	cd	22.84	8.03	a	7.26	5.76	g	0.22	0.78	c
2	Fodders Grass > Maize	25	5.52	3.56	d	3.02	2.70	d	62.77	6.26	b	3.06	4.66	b
3	Permanent + Vegetables	23	7.57	8.25	cd	1.78	2.29	d	22.90	11.97	e	0.89	1.78	c
4	Fodder Grass = Maize	36	7.33	4.34	cd	5.54	5.16	c	40.57	7.39	c	3.08	3.54	b
5	Fodder Maize > Grass	32	9.71	5.93	c	3.38	3.13	cd	19.47	5.97	e	6.72	7.38	a
6	Annual + rich protein	48	23.02	5.98	a	9.90	4.69	b	14.10	4.39	f	2.31	1.96	bc
7	Fodder Grass	16	0.56	0.61	e	1.22	1.64	d	86.26	6.55	a	1.54	2.45	bc
8	Annual + Fodder maize	46	16.22	5.25	b	10.66	5.23	b	30.78	7.49	d	2.85	2.83	b
	r^2		0.59			0.60			0.90			0.18		
	F (p-values)		47.93 (<0.0001)			50.39 (<0.0001)			304.41 (<0.0001)			7.3 (<0.0001)		
	RMSE		5.84			4.55			7.06			3.78		

Clusters	Clusters	(n)	Rich protein (%)			Pulses (%)			Set-aside & fallow lands (%)			Vegetable and permanent crops (%)		
1	Cereals + other fodders	17	1.66	1.85	c	0.18	0.32	d	3.16	3.68	cd	2.20	4.10	c
2	Fodders Grass > Maize	25	0.98	1.19	c	0.33	0.29	cd	3.17	2.35	cd	5.59	5.80	bc
3	Permanent + Vegetables	23	0.52	1.38	c	0.80	0.56	bc	8.48	5.78	a	34.53	10.83	a
4	Fodder Grass = Maize	36	1.72	1.86	c	0.54	0.66	cd	4.99	3.86	bc	4.94	5.02	bc
5	Fodder Maize > Grass	32	1.22	2.13	c	0.33	0.60	d	4.09	2.97	c	6.24	5.32	b
6	Annual + rich protein	48	6.68	4.40	a	1.27	1.26	a	6.30	3.30	b	3.79	3.59	bc
7	Fodder Grass	16	0.26	0.61	c	0.13	0.17	d	0.88	0.96	d	2.57	2.45	c
8	Annual + Fodder maize	46	4.71	3.05	b	1.04	1.04	ab	8.77	5.81	a	4.01	4.65	bc
	r^2		0.44			0.20			0.26			0.73		
	F (p-values)		25.96 (<0.0001)			8.34 (<0.0001)			11.71 (<0.0001)			91.2 (<0.0001)		
	RMSE		2.71			0.83			4.09			5.49		

Dark and grey cells indicate averaged values of the farm type share higher than the 75th and the 50th percentile respectively; they highlight the crop categories those are participating very highly and highly to each one of the 8 cropping systems retained (i.e. clusters).

Annex 8: Results of the analyse of variance applied to the nine variables used for the classification of BOMILK production systems

Clusters	Clusters	(n)	Herd size (LU)			Intensification (€/LU)			Intensification (%)			Stocking density (LU/ha)			Revenues fodders (%)		
1	Mediterranean intensive BOMILK	4	10897.50	10463.88	b	1150.19	375.40	ab	79.86	3.30	a	3.66	0.29	a	2.11	2.24	cd
2	Grazing BOMILK complement	65	62528.31	56042.29	b	957.67	244.82	b	74.68	8.01	a	0.80	0.45	de	11.79	8.05	c
3	Climate constrained BOMILK	32	51202.50	39197.50	b	1405.47	671.84	a	72.49	9.75	a	0.93	0.37	d	45.25	21.74	a
4	Extensive grass BOMILK	13	259160.00	226488.18	a	446.50	143.64	d	44.83	12.59	c	0.80	0.27	de	20.29	20.62	b
5	Intensive grass+maize BOMILK	60	222292.83	163726.59	a	882.58	190.22	b	73.89	8.85	a	1.35	0.39	c	17.07	10.59	b
6	Free-ranging subsistence BOMILK	56	42881.25	44180.61	b	695.81	264.13	c	75.60	6.51	a	0.67	0.23	e	5.22	3.41	d
7	Intensive maize BOMILK	13	103524.62	83284.30	b	654.84	155.19	cd	59.03	6.21	b	2.33	0.28	b	13.74	11.09	bc
r²			0.38			0.37			0.45			0.68			0.53		
RMSE			105699.78			323.90			8.34			0.36			11.76		
F (p-value)			23.78 (<0.0001)			22.95 (<0.0001)			32.23 (<0.0001)			84.78 (<0.0001)			43.57 (<0.0001)		

Clusters	Clusters	(n)	Revenues BOMILK (%)			Energy autonomy (%)			Fodder grass area (%)			Fodder maize area (%)		
1	Mediterranean intensive BOMILK	4	13.89	9.46	c	21.48	18.86	e	12.77	21.58	cd	0.55	0.73	cd
2	Grazing BOMILK complement	65	29.89	11.17	b	96.72	16.70	b	24.67	19.51	d	2.07	1.95	c
3	Climate constrained BOMILK	32	51.53	11.23	a	66.44	23.81	d	45.56	33.09	b	0.70	1.57	d
4	Extensive grass BOMILK	13	29.66	12.15	b	137.25	4.70	a	60.52	23.12	a	0.75	0.78	cd
5	Intensive grass+maize BOMILK	60	46.80	13.68	a	83.29	16.26	c	32.98	16.35	c	5.18	3.45	b
6	Free-ranging subsistence BOMILK	56	16.65	12.27	c	60.00	13.47	d	27.24	13.91	cd	0.52	0.59	d
7	Intensive maize BOMILK	13	29.05	10.92	b	85.77	6.15	c	28.64	14.46	cd	14.15	6.33	a
r²			0.53			0.62			0.19			0.63		
RMSE			12.12			16.31			20.06			2.55		
F (p-value)			45.07 (<0.0001)			64.8 (<0.0001)			9.48 (<0.0001)			65.61 (<0.0001)		

Annex 9: Results of the analyse of variance applied to the eight variables used to classify the BOMEAT production systems

Clusters	Clusters	(n)	Intensification (€/LU)			Stocking density (LU/ha)			Fodders revenue (% of total)			BOMEAT revenue (M€)		
1	Complement ovine BOMEAT	78	680.65	184.62	b	0.79	0.39	c	17.92	13.13	b	124.0	101.4	bc
2	Intensive grass maize BOMEAT	23	542.25	210.25	c	1.11	0.35	b	19.03	15.45	bc	992.6	424.4	a
3	Complement porcine BOMEAT	21	280.99	101.47	d	0.58	0.20	d	5.73	4.14	d	118.6	142.4	bc
4	Intensive maize BOMEAT	55	513.14	112.48	c	1.80	0.60	a	13.84	10.58	c	179.0	144.43	b
5	Subsidiary Nordic BOMEAT	14	790.39	95.69	a	0.93	0.23	bc	62.29	12.73	a	61.6	53.0	c
6	Subsidiary Mediterranean BOMEAT	43	515.49	135.58	c	0.77	0.29	cd	5.17	3.24	d	75.6	77.8	c
r^2			0.408			0.535			0.581			0.708		
RMSE			153.574			0.410			10.973			169.8		
F (p-values)			31.47 (<0.0001)			52.46 (<0.0001)			63.11 (<0.0001)			110.78 (<0.0001)		

Clusters	Clusters	(n)	Energy autonomy (%)			BOMEAT herd size (% of total)			Fodder grass (%UAAtot)			Fodder maize (%UAAtot)		
1	Complement ovine BOMEAT	78	77.60	22.49	d	33.85	12.44	b	40.63	26.33	a	1.23	1.66	c
2	Intensive grass maizeBOMEAT	23	96.37	27.74	b	47.49	17.19	a	40.92	22.78	a	3.91	4.46	b
3	Complement porcine BOMEAT	21	113.01	18.45	a	22.02	12.97	d	24.78	15.34	b	2.90	2.03	b
4	Intensive maize BOMEAT	55	86.24	17.11	c	28.81	13.68	c	28.12	15.96	b	7.36	5.48	a
5	Subsidiary Nordic BOMEAT	14	75.19	25.03	cd	38.21	6.69	b	21.70	16.48	b	0.04	0.06	c
6	Subsidiary Mediterranean BOMEAT	43	59.15	10.96	e	14.04	6.50	e	21.87	9.33	b	0.79	0.91	c
r^2			0.355			0.385			0.146			0.408		
RMSE			20.053			12.256			19.919			3.237		
F (p-values)			25.05 (<0.0001)			28.57 (<0.0001)			7.79 (<0.0001)			31.36 (<0.0001)		

Annex 10: Results of the analyse of variance applied to the eight variables used to classify the SHGOAT production systems

Clusters	Clusters	(n)	Stocking density (LU/ha)			Energy autonomy (%)			Fodder grass (%of total UAA)			Intensification (%)		
1	Complement to dairy cattle Nordic SHGOAT	11	0.899	0.227	c	78.294	24.741	b	16.01	12.768	e	79.394	3.401	a
2	Mediterranean free-ranging SHGOAT	19	0.79	0.302	c	55.721	19.167	c	32.746	16.122	c	77.479	2.609	ab
3	Temperate intensive indoor SHGOAT	22	1.413	0.694	b	107.337	28.741	a	46.194	25.683	b	39.465	7.981	d
4	Complement to granivores intensive SHGOAT	101	0.69	0.302	c	82.121	22.105	b	23.853	14.592	de	73.466	10.983	bc
5	Complement to bovine intensive SHGOAT	65	1.669	0.688	a	80.729	22.69	b	27.837	15.182	cd	73.511	7.292	bc
6	Complement to bovine mountainous SHGOAT	21	0.87	0.402	c	82.684	33.616	b	74.071	15.679	a	71.461	10.339	c
r^2			0.439			0.17			0.461			0.561		
RMSE			0.486			24.026			16.196			9.073		
F (p-values)			36.525 (<0.0001)			9.53 (<0.0001)			39.829 (<0.0001)			59.443 (<0.0001)		

Clusters	Clusters	(n)	SHGOAT revenues (M€)			Herd size (% of LU tot)			Fodders revenues (%)		
1	Complement to dairy cattle Nordic SHGOAT	11	7.3	4.8	c	17.977	11.600	b	64.171	13.627	a
2	Mediterranean free-ranging SHGOAT	19	252.1	195.5	a	50.546	20.240	a	6.157	4.865	d
3	Temperate intensive indoor SHGOAT	22	81.5	117.8	b	9.605	9.410	c	10.549	12.932	d
4	Complement to granivores intensive SHGOAT	101	34.0	45.8	c	9.215	10.231	c	8.79	6.280	d
5	Complement to bovine intensive SHGOAT	65	13.1	22.3	c	3.197	7.557	d	17.937	11.407	c
6	Complement to bovine mountainous SHGOAT	21	38.8	53.9	bc	6.145	6.490	cd	33.936	18.309	b
r^2			0.422			0.579			0.619		
RMSE			74.096			10.47			10.311		
F (p-values)			34.049 (<0.0001)			63.972 (<0.0001)			75.757 (<0.0001)		

Annex 11: Results of the analyse of variance applied to the seven variables used to classify the PORCIN production systems

Clusters	Clusters	(n)	Intensification (€/LU)			Intensification (%)			Lysine auto-sufficiency (%)			Total lysine requirement (ton/year)		
1	**Subsidiary traditional PORCIN**	**24**	393.63	36.87	d	50.99	2.92	e	30.81	23.65	bc	792.36	491.63	de
2	Primary intensive with bovine PORCIN	**11**	694.23	78.87	bc	69.56	5.94	c	0.72	0.82	c	5416.23	4272.36	b
3	Subsidiary intensive with crops PORCIN	**7**	674.77	37.53	bc	69.37	7.25	c	466.86	181.97	a	372.45	232.59	de
4	Common secondary intensive PORCIN	**114**	648.21	103.6	c	72.98	4.96	b	37.29	53.24	b	1630.61	1778.71	cd
5	Secondary very intensive PORCIN	**29**	865.91	43.94	a	80.09	2.12	a	18.46	14.97	bc	2351.29	3254.77	c
6	Subsidiary complement to grazing PORCIN	**55**	709.74	95.42	b	59.84	4.57	d	11.23	18.41	c	403.68	603.14	e
7	Specialized PORCIN	**3**	687.43	39.15	bc	71.97	3.21	bc	3.9	3.73	bc	22969.49	7181.97	a
r^2			0.62			0.78			0.71			0.63		
RMSE			88.863			4.56			48.56			2022.46		
F (p-values)			65.25 (<0.0001)			141.74 (<0.0001)			95.99 (<0.0001)			67.06 (<0.0001)		

Clusters	Clusters	(n)	Carcass yield (kg/head)			Stocking density (LU/ha rich prot)			Herd size (% herd total)		
1	**Subsidiary traditional PORCIN**	**24**	84	4.47	c	2.21	2.33	c	18.08	6.87	cd
2	Primary intensive with bovine PORCIN	**11**	87.41	6.12	bc	68.22	30.49	a	52.68	15.84	a
3	Subsidiary intensive with crops PORCIN	**7**	83.53	6.78	c	0.36	0.26	c	8.29	3.88	d
4	Common secondary intensive PORCIN	**114**	89.5	7.36	b	4.35	5.07	c	27.22	16.54	b
5	Secondary very intensive PORCIN	**29**	115.64	6.36	a	5.75	9.65	c	25.46	20.18	bc
6	Subsidiary complement to grazing PORCIN	**55**	72.05	8.82	d	6.38	9.27	c	13.08	9.83	d
7	Specialized PORCIN	**3**	85.97	11.53	bc	27.01	14.34	b	52.42	10.94	a
r^2			0.74			0.69			0.30		
RMSE			7.37			9.20			14.77		
F (p-values)			113.29 (<0.0001)			86.58 (<0.0001)			16.69 (<0.0001)		

Annex 12: Results of the analyse of variance applied to the seven variables used to classify the LAHENS production systems

Clusters	Clusters	(n)	Intensification (€/LU)			Intensification (%)			Revenue (M€)			Lysine autosufficiency (%)		
1	Primary economically constrained LAHENS	45	445.10	105.17	b	90.09	7.74	b	41.36	33.65	b	24.31	23.14	b
2	Subsidiary Common intensive LAHENS	106	766.27	122.64	a	92.71	3.31	a	23.16	24.75	b	23.68	26.82	b
3	Primary very dependent LAHENS	57	759.26	86.15	a	87.95	8.26	b	94.76	114.45	a	13.13	14.89	b
4	Subsidiary climatically constrained LAHENS	8	494.38	3.78	b	58.97	4.66	c	17.98	19.39	b	16.58	13.38	b
5	Subsidiary complement to crops LAHENS	12	794.31	3.99	a	94.97	0.37	a	20.36	20.44	b	320.08	205.39	a
r^2			0.62			0.54			0.19			0.64		
RMSE			105.5			5.90			61.91			50.86		
F (p-values)			90.379 (<0.0001)			64.764 (<0.0001)			13.39 (<0.0001)			98.921 (<0.0001)		

Clusters	Clusters	(n)	Yield (kg/head)			Stocking density (LU/ha)			Herd size (%)		
1	Primary economically constrained LAHENS	45	9.63	1.45	d	0.25	0.33	b	9.15	4.47	b
2	Subsidiary Common intensive LAHENS	106	16.37	1.91	b	0.25	0.38	b	3.63	2.29	c
3	Primary very dependent LAHENS	57	14.69	1.92	c	2.11	4.03	a	11.78	5.69	a
4	Subsidiary climatically constrained LAHENS	8	19.24	0.46	a	0.07	0.05	b	3.84	2.43	c
5	Subsidiary complement to crops LAHENS	12	16.57	2.36	b	0.07	0.14	b	3.49	3.50	c
r^2			0.69			0.14			0.46		
RMSE			1.83			2.04			3.91		
F (p-values)			124.328 (<0.0001)			9.14 (<0.0001)			47.741 (<0.0001)		

Annex 13: Results of the analyse of variance applied to the seven variables used to classify the POUFAT production systems

Clusters	Clusters	(n)	Intensification (€/LU)			Intensification (%)			Revenues (M€)			Lysine autosufficiency (%)		
1		**83**	1254.79	256.48	d	67.17	6.95	c	30.55	28.56	b	28.4	26.79	b
2		**46**	1502.77	157.72	c	83.01	2.69	a	33.79	33.64	b	14.17	22.35	b
3		**1**	1351.8		bcd	85.28		ab	97.37		ab	0.16		b
4		**11**	1690.79	5.19	b	85.69	0.28	a	63.88	58.65	b	326	214.34	a
5		**30**	1498.41	114.22	c	74.54	10.41	b	303.76	273.38	a	18.31	12.1	b
6		**48**	1560.19	244.71	bc	74.5	7.75	b	42.97	54.48	b	24.65	39.96	b
7		**12**	2397.49	118.32	a	78.43	0.86	b	58.12	57.42	b	1.24	1	b
r²			0.61			0.48			0.43			0.61		
RMSE			209.81			6.77			105.55			52.61		
F (p-values)			57.394 (<0.0001)			34.385 (<0.0001)			27.906 (<0.0001)			59.195 (<0.0001)		

Clusters	Clusters	(n)	Yield (kg/head)			Herd size (%)			Stocking density (LU/ha)		
1		**83**	1.78	0.17	c	3.74	2.9	d	0.15	0.27	d
2		**46**	2.08	0.33	ab	4.34	3.33	cd	0.86	1.86	c
3		**1**	1.93		abc	16.93		a	26.48		a
4		**11**	2.18	0.01	a	4.67	5.11	bcd	0.1	0.19	d
5		**30**	2	0.14	b	11.13	4.07	a	0.52	0.73	cd
6		**48**	1.2	0.2	d	5.25	3.56	bc	0.22	0.35	d
7		**12**	1.7	0	c	7.19	3.46	b	2.33	2.03	b
r²			0.71			0.35			0.76		
RMSE			0.21			3.45			1.01		
F (p-values)			89.311 (<0.0001)			20.243 (<0.0001)			119.951 (<0.0001)		

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Annex 3

Task 4.1: Definition of emission parameters

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(document embedded as pdf on the following page: double click to open)

Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions – Phase 1 (GGELS)

Administrative Arrangement (AA) No. AGRI-2008-0245

GGELS

Task 4.1
Definition of emission parameters

Part of GGELS Work Package 4

Franz Weiss

AFOLU, Climate Change Unit, IES

Summary

The objective of Task 4.1 was to provide the emission factors and parameters to be used for the calculation of GHG-emissions (CO_2, CH_4, and N_2O) and emissions of NH_3 related to livestock production in the EU27. With a few exceptions, the basic tool for the calculation will be the CAPRI modelling system, which on the one hand provides an extensive database on agricultural production, on the other hand has already incorporated the calculation of agricultural GHG-emissions in the code. The calculation of GHG, however, is not based on a unique methodology, since the CAPRI modelling system was developed and extended in several research projects and by several research teams. The basic module for the calculation of GHG-emissions was developed in the course of a PhD thesis (see Perez, 2006), strictly following the methodology recommended by the Intergovernmental Panel on Climate Change (see IPCC, 1996). CH4-emissions will be determined according to this approach, using updated parameters and emission factors (see IPCC, 2006). During the MITERRA-EUROPE project (see Velthof et al., 2007) the calculation of nitrogen-emissions from agriculture was incorporated into CAPRI using a mass-preserving nitrogen flow approach, which is considered to be more precise and detailed than the IPCC default approach. Therefore, for the calculation of nitrogen emissions, like NH_3 and N_2O, the MITERRA-approach will be applied. Finally, direct and indirect CO_2-emissions from on-farm energy use have been introduced into the CAPRI system recently as an outcome of another PhD thesis (see Kraenzlein, 2008), and, therefore, will be used for those emissions in the present project.

At the beginning of the project a detailed documentation was only available for the calculation of methane emissions and the on-farm energy use, but not for the MITERRA implementation into CAPRI. However, even those available documentations do not provide all necessary information in order to assess the reasonability of the applied parameters. Moreover, the calculations have partly been based on default parameters of the old IPCC guidelines (IPCC, 1996, 2001), which have been updated recently (see IPCC, 2006). So, the main effort within Task 4.1 was devoted to providing a detailed documentation of those CAPRI components, which will be in use for the calculation of emissions, and to update the parameters in accordance with the latest values recommended by the IPCC. To a minor extent, also changes in the calculation method have been carried out, as far as it was considered to be reasonable for consistency reasons. Finally, for most emission sources a first estimation of emissions on member state level is provided together with the documentation, and presented in comparison with the respective values provided by the member states in the national inventories (see EAA, 2008). However, those estimations should rather be seen as an additional tool in order to evaluate the used parameters, than a provisional assessment of total emissions from livestock production. The full documentation can be found in the annex of this document.

The following work steps remain open for the second phase of the project: First, the now presented parameters will be evaluated by a subcontractor. The outcome of this evaluation process will be the delivery of alternative parameter values, wherever the currently applied values are considered to be wrong, weak or insufficiently detailed for the production of reliable estimates. Those required changes will have to be implemented together with those parameter values being an output of WP2 (i.e.: data on manure management systems on NUTS2-level). Secondly, the use of different calculation methods for the various gases, developed by different research groups, creates a consistency problem, which, so far, has not been solved. So, for the calculation of methane emissions some of the required parameters might be the same as for the calculation of nitrogen emissions. However, it happens that the two modules use different values for the same or similar parameters, which are not consistent among each other. One of the mayor efforts for the second project phase will be to remove those inconsistencies and to use the same parameter values in all three modules as far as possible. Sometimes this will require not only changing the values but also slight changes in the methodology. Most of the inconsistencies are mentioned in the documentation.

Another shortcoming of the current CAPRI version, with respect to the present study, is the fact that a life cycle approach, except for the energy module, is not yet realised. So, there is no methodology implemented, which allocates emissions of inputs to their causing sources. This, above all, affects the allocation of feedings and manure to livestock and crops, since i.e. it is not straightforward to which extent the emissions of manure used as fertilizer are caused by the excreting animal or by the fertilized crop. Finding and implementing a methodology for this allocation will, therefore, be a second emphasis of phase II of the project. Furthermore, the on-farm energy module is currently not integrated in the standard version of the CAPRI modelling system. Therefore, for the current documentation, only data of past runs could be used, while carrying out own runs, as in the case of the other modules, is for the moment not possible. This has to be changed in cooperation with the CAPRI-developers in Bonn and will require outsourcing of some of those development activities. Finally, emissions from land use changes are not estimated by CAPRI. Until now, parameters and data for a serious assessment of those emissions could not be found, ensuing that a considerable share of time has to be devoted to this issue during the second project phase.

Introduction

Task 4.1 provides the emission factors and parameters to be used to calculate emissions of GHG (CO_2, CH_4, and N_2O) and NH_3. For CO_2 and CH_4, calculation of emissions will be based on standard methodologies developed by the Intergovernmental Panel on Climate Change (IPCC 1997; 2000; 2006). N-emissions, in contrast, are estimated by a mass-preserving nitrogen flow approach, developed by MITERERA-EUROPE (Velthof et al., 2007). The calculations are mainly carried out with the CAPRI modelling system, a regionalised agricultural sector model, which has implemented both a large data base on the European agricultural system and the above approaches for the estimation of GHG emissions. The data used by the CAPRI modelling system are based on various sources like national statistics on slaughtering, herd size, crop production, land use, farm and market balance and foreign trade as well as regional statistics on the same issues from the REGIO database, if available. However, since frequently the various sources are not consistent with each other, data first have to pass a consistency check and, if necessary, they are modified by an automatic procedure, based on a “Highest Posterior Estimator” approach. So, in a first step a complete and consistent data base on member state level (COCO) is built, while in a second step regional data are adapted in order to be consistent with the national data of COCO. For a detailed description of the basic CAPRI-model see Britz (2004).

The activities included in the GHG calculations are

- Livestock rearing,
- Animal feed production, and
- Transport of products.

The individual sources are reported in Table 1 and will be discussed in detail in the subsequent sections. Therefore, for methane emissions enteric fermentation and manure management are considered. For nitrogen emissions, above all those of N_2O, manure management, manure deposited by grazing animals, application of manure and mineral fertilizers to agricultural soils, N delivery by crop residues, fertilizer production, and indirect emissions from volatilizing via NH_3 and NO_x or leaching and runoff during any of the before mentioned steps are taken into account. CO_2-emissions or CO_2-equivalents will be calculated for mineral fertilizer production, on-farm energy use, feed transport and transport of animal products. In the first phase of the project N-emissions and CO_2-

emissions related to crop production, will not be differentiated according to feed and non-feed production. Finally, emissions due to land use changes induced by livestock production will be included in the analysis, but only in the second phase of the project. As far as possible, all relevant parameters will be presented. However, due to the scope and complexity of the model the limit has to be set at the point of manure excretion in case of animal production and N-delivery to fields for animal feed production. For on-farm energy use a detailed description of used parameters would exceed the scope of this study and, therefore, it is kept short. Due to the importance of the applied parameters we decided to pursue a double-checking approach by introducing a second task, asking to scrutinize the emission factors on plausibility and consistency.

Table 1: Emission sources to be reported by the GGELS project

Emission source	Gases
Livestock rearing	
• Enteric fermentation	CH_4
• Livestock excretions	
○ Manure management (housing and storage)	NH_3, N_2O, CH_4
○ Depositions by grazing animals	NH_3, N_2O
○ Application to agricultural soils	NH_3, N_2O
○ Indirect emissions, indirect emissions following N-deposition of volatilized NH3/NOx from agricultural soils and leaching/run-off of nitrate	N_2O
Animal feed production	
• Use of fertilizers for production of crops dedicated to animal feeding crops (directly or as blends or feed concentrates, including imported feed)	
○ Manufacturing of fertilizers	CO_2, N_2O
○ Use of fertilizers, direct emissions from agricultural soils and indirect emissions	NH_3, N_2O
○ Use of fertilizers, indirect emissions following N-deposition of volatilized NH3/NOx from agricultural soils and leaching/run-off of nitrate	N_2O
• Emissions from crop residues (including leguminous feed crops)	N_2O
• Feed transport (including imported feed)	CO_2 equivalents
• On-farm energy use (incl. fossil fuel for forage production and fertilizer application, electricity for buildings)	CO_2 equivalents
• Emissions (or sinks) of land use changes induced by livestock activities (feed production or grazing)	CO_2
• Emissions (or sinks) from pastures	CO_2
Transport of animal products	CO_2 equivalents

Livestock Rearing

The regional database of CAPRI (CAPREG) uses the following categorisation of livestock:

Dairy cows

Cattle: Suckling cows, female calves for fattening, male calves for fattening, female calves for rearing, male calves for rearing, heifers for fattening, heifers for rearing, young bulls

Swine: Pigs for fattening, sows

Poultry: Laying hens, poultry for fattening

Sheep and goats: Sheep and goats for fattening, sheep and goats for milk production

Methane Emissions

Enteric fermentation

Enteric fermentation is a digestive process which, as a by product, produces methane. The rate of methane emissions in first line depends on the type of the digestive system and is much higher in the case of ruminant livestock (e.g. Cattle, Sheep, Goats, Buffalo and Camels) than in the case of Non-ruminant herbivores (Horses, Mules, Asses) or monogastric livestock (Swine). The *2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006)* therefore recommend a more precise approach for the calculation of emissions (Tier 2 or Tier 3) of those ruminant species which play a major role in a country, while for all other species a simplified approach (Tier 1) is considered to be sufficient. The Tier 1 method uses default emission factors which are directly applied to the annual average livestock population. In contrast, the Tier 2 method requires the calculation of regional emission factors, which are derived from the gross energy intake.

The CAPRI-system applies a Tier 2 approach for dairy cows and cattle and a Tier 1 approach for all other animals. The calculation of Tier 2 emission factors is based on the approach suggested by the 2006 IPCC guidelines. Therefore, in a first step, net energy requirements for maintenance, activity, growth, lactation and pregnancy are calculated, while in a second step gross energy intake and emission factors are derived from those values. The calculation steps are shown in the subsequent formulas. If nothing else is mentioned in the text the values for the described variables are usually calculated for each of the above animal activities. This is not explicitly visualized in the expressions in order to reduce the number of subscripts.

$$NE_M = Cf_i * BW^{0.75}$$
$$NE_A = C_a * NE_M$$
$$NE_L = Milk * (1.47 + 0.4 * Fat)$$
$$NE_P = 0.1 * NE_M$$
$$NE_G = 22.02 * \left(\frac{BW}{C * MW}\right)^{0.75} * WG^{1.097}$$
$$GE = \left[\frac{\left(\frac{NE_M + NE_A + NE_L + NE_P}{REM}\right) + \left(\frac{NE_G}{REG}\right)}{\frac{DE\%}{100}}\right]$$
$$EF = \left[\frac{GE * \left(\frac{Y_M}{100}\right) * 365}{55.65}\right]$$

NE_M = net energy requirement for maintenance, MJ per day

NE_A = net energy requirement for animal activity, MJ per day

NE_L = net energy requirement for lactation, MJ per day

NE_P = net energy requirement for pregnancy, MJ per day

NE_G = net energy requirement for growth, MJ per day

GE = gross energy intake, MJ per day

Cf_i = 0.386 (dairy cows, suckling cows), 0.322 (calves, heifers), 0.37 (young bulls)

C_a = coefficient corresponding to animal's feeding situation; 0.00 (Stall), 0.17 (Pasture), 0.36 (Grazing large areas)

C = 0.8 (female calves, heifers), 1.0 (male calves), 1.2 (young bulls)

Milk = amount of milk produced, kg per day

Fat = Fat content of milk, % of weight

BW = average live body weight of the animals in the population, kg

MW = mature live body weight of an adult female in moderate body condition, kg

WG = average daily weight gain of the animals in the population, kg per day

REM = ratio of net energy available in a diet for maintenance to digestible energy consumed

REG = ratio of net energy available in a diet for growth to digestible energy consumed

DE% = digestible energy expressed as a percentage of gross energy

EF = Emission factor, kg CH4 per head and year

Y_M = methane conversion factor, percent of gross energy in feed converted to methane

The net energy requirement for maintenance (NE_M) is the amount of energy needed to keep the animal in equilibrium without gains or losses of body energy. For the average live weight (*BW*) 600 kg are assumed for dairy cows, 550 kg for suckling cows, and the weighted average of both for heifers for rearing. For the fattening categories live weight is derived from the regional stocking density (livestock units per ha of grassland) and the regional production coefficient (kg beef per head), which comes from the CAPREG database. The net energy requirement for activity (NE_A) is the energy needed to obtain their food, water and shelter and is determined by the feeding situation, represented by the coefficient C_a. CAPRI uses country-specific estimates of time shares spent on pastures and in stable, taken from the RAINS database. For the time spent on large grazing areas no data are available. So, it is assumed to be zero. The net energy requirement for lactation (NE_L) is calculated by the daily milk production (*Milk*) and the fat content (*Fat*). The total milk production per head comes from the CAPREG database and is divided by an assumed lactation period of 305 days in order to get the daily milk production. For the fat content a default value of 4% is assumed. The net energy requirement for pregnancy (NE_P) is supposed to be 10% of the net energy requirement for maintenance, while the net energy requirement for growth (NE_G), the net energy required for the weight gain, depends on the daily weight increase and the live body weight of the animal in the population. The mature live body weight of an adult female in moderate body condition (*MW*) is assumed to be 750 kg, while the daily weight gain (*WG*) depends on the age of the animals. In the case of calves for fattening it ranges between 0.8 kg/day and 1.2 kg/day, while calves for rearing gain 0.8 kg/day up to a weight of 150 kg and between 1kg/day and 1.4 kg/day from 151 kg to 335 kg (males) and 330 kg (females). The exact values in the range depend on the relation of the regional to the average EU stocking density. For young bulls daily weight gains range from 0.8 kg/day to 1.4 kg/day, depending on regional stocking densities and final weights, while heifers for fattening are assumed to gain 0.8 kg/day. The digestible energy as a percentage of gross energy (*DE%*) is assumed to be 70% (dairy cows), 65% (calves) and 60% (other cattle), the methane conversion factor (Y_m) is suppose to be 6.5%. The ratio of net energy available to digestible energy consumed (*REM* and *REG*) is derived from *DE%*. For the exact calculation see the 2006 IPCC guidelines (IPCC, 2006: Vol.4, Eq.10.14 and 10.15).

The resulting country specific emission factors for cattle and dairy cows (EU 27) for the year 2002 can be found in Table 2:

Table 2: Emission factors for methane emissions from enteric fermentation in kg per head and year (annual average population for 2002) for dairy and other cattle activities

	Dairy cows		Suckling cows	Male adults for fattening	Heifers for fattening	Heifers for raising	Male calves for fattening	Female calves for fattening	Male calves for raising	Female calves for raising	Other cows	
	CAPRI	NI[2]	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	NI[2]
Belgium[1]	113.10	110.88	76.25	115.85	76.26	61.65	26.08	27.15	30.34	32.61	58.97	43.97
Denmark	158.64	121.46	94.99	109.32	89.98	80.81	26.74	26.07	39.21	41.78	61.36	35.85
Germany	130.73	109.90	83.65	111.17	87.48	72.17	23.84	27.68	34.80	37.15	62.46	37.22
Greece	151.70	81.00	114.70	99.98	99.96	91.59	31.51	22.96	43.91	46.54	69.72	56.00
Spain	132.63	88.13	90.45	97.79	85.20	73.72	30.51	35.63	36.86	38.93	65.59	54.67
France	138.27	103.28	88.81	93.02	91.26	73.81	21.50	22.43	36.01	37.79	63.80	51.53
Ireland	119.89	108.67	89.28	102.31	90.03	73.82	29.05	30.63	36.32	38.62	68.43	52.45
Italy	112.66	109.08	84.83	90.35	76.68	68.42	21.41	22.17	31.92	34.15	55.45	46.52
Netherlands	130.14	119.00	77.36	115.04	77.74	65.97	27.68	29.02	31.81	33.93	47.26	36.77
Austria	120.18	110.47	84.36	93.54	87.50	71.44	22.06	23.59	34.38	36.56	61.85	55.42
Portugal	142.34	115.85	88.95	94.95	90.72	75.94	22.61	21.12	37.23	39.76	66.31	56.85
Sweden	157.03	127.67	92.35	95.88	91.89	76.81	23.25	24.66	37.28	39.64	64.86	53.88
Finland[3]	131.74	114.99	77.57	84.26	75.29	67.13	16.54	15.59	31.56	33.59	51.74	IE
United Kingdom	142.38	100.61	94.85	89.24	90.77	80.20	21.39	31.38	39.32	41.67	65.59	43.00
Cyprus[4]	101.94	0.00	77.53	95.29	77.85	66.45	32.42	15.14	32.12	34.14	44.72	0.00
Czech Republic	137.11	111.42	93.98	97.81	94.99	79.05	19.82	21.12	38.11	40.50	64.53	51.87
Estonia	127.33	113.21	95.12	82.88	85.31	83.47	24.98	16.97	39.48	41.90	51.01	48.36
Hungary	149.28	100.00	98.51	90.80	92.23	84.33	24.79	26.51	40.10	42.57	57.64	48.00
Lithuania	119.72	93.38	93.69	81.76	77.75	84.66	17.60	18.64	39.99	42.49	51.40	43.64
Latvia	122.98	81.00	100.11	85.05	81.83	89.32	23.97	25.69	42.21	44.85	53.74	56.00
Malta	128.04	100.00	85.66	111.22	83.15	76.13	20.03	20.02	36.70	39.13	59.81	48.00
Poland	123.01	92.41	93.40	85.41	81.48	81.38	18.96	18.76	37.78	40.22	50.47	48.49
Slovenia	99.08	94.88	78.81	89.24	87.78	68.73	22.54	25.65	33.14	35.61	59.94	51.90
Slovakia	193.41	98.56	132.71	118.05	122.09	109.95	31.54	40.14	52.68	55.94	82.42	54.50
Bulgaria	111.77	81.00	97.65	91.78	90.91	83.77	27.97	26.93	39.79	42.04	51.84	56.00
Romania	123.31	81.00	107.26	93.57	95.35	91.56	27.95	31.56	43.40	46.08	58.84	56.00

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) “Other cattle” in National Inventories included in “Other animals”, 4) “Other cattle” in National Inventories included in “Dairy cows”

For all other animals a Tier 1 approach was applied. As a first approximation the default emission factors of the *2006 IPCC Guidelines* (IPCC, 2006: Vol.4, Tab.10.10), 1.5 kg per head for pigs and 8 kg per head for sheep and goats[1], were used for all countries, whereas country specific values are partly available from national inventories and could be implemented in the CAPRI-system, if considered to be more reliable and comparable.

Table 3 shows the CAPRI-results for total emissions from enteric fermentation compared to the values reported by the member states (National Inventories of 2007 for 2002). In general the correspondence of inventory data and CAPRI-data seems satisfactory. So, for the EU27 CAPRI reports emissions of 8.049 Mio tons, which is about 13% above the sum of the values reported by the member states. In some countries (i.e.: Denmark, Germany, Italy, Romania and Bulgaria) total

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[1] Since sheep and goats are not separated in CAPRI the emission factor for sheep was applied also to goats.

emissions show stronger deviations, usually reporting higher values in the CAPRI-system than in the National Inventories. Those differences are mainly caused by dairy cows and other cattle, since other animals usually play a less important role with respect to total emissions. For Denmark and Germany the deviation is due to substantially lower emission factors used in the National Inventories, while for Italy the difference comes from deviating numbers for the livestock population and for Bulgaria and Romania both emission factors and livestock population in CAPRI are substantially above those used in the National Inventories.

Table 3: Methane emissions from enteric fermentation in 1000 tons for 2002: CAPRI-Values compared to the values reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		Other animals		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI[2]***
Belgium[1]	72.5	70.9	115.9	107.6	7.8	10.2	1.2	1.5	0.0	0.0	0.0	0.7	***197.4***	***190.9***
Denmark	97.7	74.0	59.8	42.5	11.1	13.9	0.8	1.4	0.0	0.0	0.0	3.3	***169.5***	***135.2***
Germany	579.5	486.6	494.3	355.9	29.4	30.3	15.4	22.6	0.0	0.0	0.0	13.0	***1118.7***	***908.3***
Greece	24.7	17.8	29.5	21.5	0.8	1.4	94.3	95.7	0.0	0.0	0.0	1.4	***149.3***	***137.8***
Spain	153.3	103.4	392.2	292.4	20.0	34.8	195.2	221.3	0.0	0.0	0.0	5.1	***760.7***	***657.0***
France	568.3	432.6	902.9	828.6	14.7	17.7	80.3	81.5	0.0	0.0	0.0	7.9	***1566.2***	***1368.4***
Ireland	135.7	124.7	300.5	275.9	1.5	0.8	38.0	42.2	0.0	0.0	0.0	1.4	***475.7***	***445.0***
Italy	246.4	208.5	321.6	214.0	11.1	13.7	64.6	70.0	0.0	0.0	0.0	19.0	***643.7***	***525.2***
Netherlands	200.7	176.8	68.5	87.3	9.9	17.5	9.7	10.8	0.0	0.0	0.0	2.2	***288.7***	***294.5***
Austria	71.4	65.1	87.0	81.9	3.5	5.0	2.7	2.7	0.0	0.2	0.0	1.8	***164.6***	***156.6***
Portugal	43.1	39.9	67.1	60.3	2.2	3.3	17.4	35.2	0.0	0.0	0.0	2.9	***129.9***	***141.6***
Sweden	65.0	53.2	65.1	65.8	1.8	2.8	1.8	3.4	0.0	0.0	0.0	9.5	***133.7***	***134.7***
Finland[3]	45.5	40.0	30.1	0.0	1.2	2.0	0.4	0.7	0.0	0.0	0.0	35.2	***77.3***	***77.9***
United Kingdom	318.5	224.1	428.7	349.1	4.7	8.4	161.0	172.8	0.0	0.0	0.0	17.0	***912.9***	***771.3***
Cyprus[4]	2.6	4.2	1.3	0.0	0.3	0.7	3.9	4.6	0.0	0.0	0.0	0.0	***8.1***	***9.6***
Czech Republic	60.9	66.4	55.4	47.9	3.6	5.2	0.2	0.8	0.0	0.0	0.0	0.4	***120.0***	***120.7***
Estonia	14.3	13.1	5.0	6.7	0.2	0.3	0.2	0.3	0.0	0.0	0.0	0.1	***19.7***	***20.4***
Hungary	48.6	34.5	17.7	20.7	5.0	7.6	8.3	9.5	0.0	0.8	0.0	1.2	***79.6***	***74.4***
Lithuania	50.9	41.4	16.8	14.7	0.6	1.6	0.3	0.2	0.0	0.0	0.0	1.1	***68.5***	***58.9***
Latvia	21.8	16.6	7.7	10.2	0.2	0.7	0.3	0.3	0.0	0.0	0.0	0.3	***30.0***	***28.2***
Malta	1.0	0.8	0.6	0.5	0.1	0.1	0.1	0.1	0.0	0.2	0.0	0.2	***1.8***	***1.9***
Poland	312.0	265.5	105.0	129.0	13.2	27.9	2.5	3.7	0.0	0.0	0.0	5.9	***432.7***	***432.0***
Slovenia	13.1	13.3	19.3	17.3	0.3	1.1	0.5	1.0	0.0	0.0	0.0	0.3	***33.2***	***32.9***
Slovakia	23.8	25.6	16.2	19.0	1.1	2.3	2.1	2.7	0.0	0.0	0.0	0.1	***43.1***	***49.8***
Bulgaria	47.7	29.4	31.1	16.8	1.3	1.3	26.1	16.8	0.0	0.2	0.0	4.5	***106.2***	***69.0***
Romania	160.1	136.4	116.4	64.6	2.8	5.1	38.2	39.7	0.0	0.0	0.0	18.3	***317.5***	***264.1***
EU27	***3379.1***	***2764.7***	***3755.7***	***3130.1***	***148.4***	***215.8***	***765.5***	***841.8***	***0.0***	***1.3***	***0.0***	***152.8***	***8048.7***	***7106.3***

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

Manure Management

Methane is not only produced during digestion, but also during the treatment and storage of manure, dung and urine, when it is decomposed under anaerobic conditions. This is especially the case when large numbers of animals are managed in a confined area and the manure is treated as a liquid (e.g. in lagoons, tanks or pits). If treated as a solid or directly deposited on pastures manure decomposes under more aerobic conditions and less methane is produced. Therefore, beside the amount of manure produced, the methane emissions depend mainly on the system of storage and treatment of manure, the retention time in the storage facility and the temperature, which affects the process of decomposition.

For a good practice the *2006 IPCC Guidelines* recommend a Tier 2 or Tier 3 approach wherever possible, especially when an animal category plays an important role in a country. A simplified Tier 1 approach is only recommended for the case "if all possible avenues to use the Tier 2 method have been exhausted and/or it is determined that the source is not a key category or subcategory". While for the Tier 1 method information on the livestock population and average annual temperature combined with IPCC default emission factors is sufficient, a Tier 2 method additionally requires detailed information on manure management practices.

CAPRI applies a Tier 2 method for dairy cows and cattle and a Tier 1 approach for all other animal activities. The applied approaches (both Tier 1 and Tier 2) follow the methodology proposed in the *2006 IPCC Guidelines* (IPCC, 2006: Vol.4, Ch.10.4). However, instead of national data CAPRI uses IPCC default values for the shares of management systems (see *IPCC, 2006: Vol.4, Tab.10.A-4-10.A-5*), and so for the moment we cannot speak of a proper Tier 2 approach in terms of data quality[2]. Moreover, for the methane conversion factors (*MCFs*) and the Tier 1 emission factors the rather coarse division into two climate regions is used, and not the exact average temperature as suggested for Dairy cows, other cattle and swine. However, data from the National Inventories are available and could be implemented.

The calculation steps for the Tier 2 method are as follows:

$$VS = GE * \left(1 - \frac{DE\%}{100} + UE\right) * \frac{1 - ASH}{18.45}$$

$$EF = VS * 365 * B_0 * 0.67 * \sum_{s,k} MCF_{s,k} * MS_s * CLIM_k$$

$$\sum_s MS_s = 1$$

$$\sum_k CLIM_k = 1$$

VS = Volatile solid excretion per day on a dry-organic matter basis, kg VS per day

GE = gross energy intake, MJ per day

DE% = digestible energy expressed as a percentage of gross energy

UE = urinary energy expressed as fraction of *GE*

[2] This will be changed as soon as the results of WP2 (manure management systems data on NUTS2 level) are available.

ASH = ash content of manure as a fraction of dry matter feed intake

EF = Emission factor, kg CH4 per head and year intake

B_0 = maximum methane producing capacity for manure produced by the livestock category, m^3 CH_4 per kg *VS* excreted

$MCF_{s,k}$ = methane conversion factors for each manure management system s by climate region k, fraction

MS_s = fraction of manure handled using manure management system s

$CLIM_k$ = fraction of the region in climate region k

The volatile solid excretion per day *(VS)* is the organic material in livestock manure and can be estimated from gross energy intake (*GE*) and digestible energy (*DE%*), which are also the main parameters for the calculation of the enteric fermentation emission factors (see section on enteric fermentation). For the urinary energy fraction (*UE*) and the ash content (*ASH*) the IPCC default values of 0.04 (*UE*) and 0.08 (*ASH* for cattle) are applied (IPCC, 2006: Vol.4, Eq.10.24). The assumed *ASH*-value for swine is 0.02. 18.45 is the conversion factor for Gross energy intake per kg of dry matter (MJ per kg). The emission factors (*EF*) are then calculated in a second step. First, the volatile solid excretion (*VS*) is multiplied by the maximum methane producing capacity (B_0), which is converted from m^3 to kg by the factor 0.67. For B_0 the IPCC default values (0.24 for dairy cows, 0.18 for other cattle and 0.45 for swine) are applied. The second term describes the fraction of the maximum methane producing capacity which is actually emitted with regard to the applied manure management systems and the climate region. $MCF_{s,k}$ is the fraction emitted by management system *s* in climate region *k*, which is multiplied by MS_s, the share of the management systems *s,* and $CLIM_k$, the share of the climate region *k* in the region, and then summarized over all management systems and climate regions. The sum of MS_s over all *s* and the sum of $CLIM_k$ over all *k* must be one, while the values of $MCF_{s,k}$ must be smaller than or equal to one. It is assumed, therefore, that all management systems are equally distributed over the climate regions, and, since for all countries for $MCF_{s,k}$ and MS_s the IPCC default values for Western Europe are used (IPCC, 2006: 10.A-4 – 10A-7), that the shares of management systems are the same in all countries. Two climate regions and 11 management systems are distinguished. The climate regions are defined by the yearly average temperature, cold if it is below and temperate if it is above 15°C. Since warm regions (above 25°C) do not exist in Europe it need not be considered here as proposed by the IPCC. In those cases, where IPCC doesn't propose $MCF_{s,k}$ default values for the climate regions but for a more detailed division according to average temperature steps the values for 10°C were taken for the cold climate region, and those for 17°C for the temperate climate region. The shares of the climate regions on country level ($CLIM_k$) are based on the yearly average temperature on level of NUTS2 regions, which are then weighted by the utilized agricultural area. They are shown in Table 4 (compared to those values, which were used in the National inventories), while the description of the management systems and the applied values for $MCF_{s,k}$ and MS_s are in Table 5.

Table 4: Assumed shares of climate regions for EU countries in CAPRI and in the National Inventories of 2007 for 2002

	CAPRI		National Inventories		
	cold	temperate	cold	temperate	warm
Belgium[1]	1.00	0.00	1.00	0.00	0.00
Denmark	1.00	0.00	1.00	0.00	0.00
Germany	1.00	0.00	1.00	0.00	0.00
Greece	0.51	0.49	0.00	1.00	0.00
Spain[2]	0.65	0.35	>0.20	<0.80	0.00

	CAPRI		National Inventories		
	cold	temperate	cold	temperate	warm
France[2]	0.99	0.01	0.00	>0.90	<0.1
Ireland	1.00	0.00	1.00	0.00	0.00
Italy[2]	0.60	0.40	>0.60	<0.40	0.00
Netherlands	1.00	0.00	NO	NO	NO
Austria	1.00	0.00	1.00	0.00	0.00
Portugal[2]	0.18	0.82	>0.20	<0.80	0.00
Sweden	1.00	0.00	1.00	0.00	0.00
Finland	1.00	0.00	1.00	0.00	0.00
United Kingdom	1.00	0.00	1.00	0.00	0.00
Cyprus	0.00	1.00	0.00	1.00	0.00
Czech Republic	1.00	0.00	NO	NO	NO
Estonia	1.00	0.00	1.00	0.00	0.00
Hungary	1.00	0.00	1.00	0.00	0.00
Lithuania	1.00	0.00	1.00	0.00	0.00
Latvia	1.00	0.00	1.00	0.00	0.00
Malta	0.00	1.00	NO	NO	NO
Poland	1.00	0.00	1.00	0.00	0.00
Slovenia	1.00	0.00	1.00	0.00	0.00
Slovakia	1.00	0.00	1.00	0.00	0.00
Bulgaria	1.00	0.00	0.00	1.00	0.00
Romania	1.00	0.00	0.00	1.00	0.00

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) In national inventories values vary by animal species

Table 5: Manure management systems, their shares MS_s, and fractions of maximum methane producing capacity emitted ($MCF_{s,k}$)

Management system	Description of the management system	*Shares of management systems (MS_s)*		Fraction of maximum methane producing capacity emitted ($MCF_{s,k}$)	
		Dairy cows	Other cows	cold	temperate
Anaerobic Lagoon	Flush systems that use water to transport manure to lagoons	0.00	0.00	0.66	0.76
Liquid/Slurry	Large concrete lined tanks built into the ground	0.357	0.252	0.17	0.32
Solid	Manure is collected in solid form and stored in for a long period (months) before disposal	0.368	0.39	0.02	0.04
Dry lot	Animals are kept on unpaved feedlots where the manure is allowed to dry until it is periodically removed	0.00	0.00	0.01	0.015
Pasture	Manure from pasture and range grazing animals (not managed)	0.20	0.32	0.01	0.015
Pit < 1 month	Swine manure stored in a pit while awaiting disposal (length of storage less than 1 month)	0.00	0.00	0.03	0.03
Pit > 1 month	Swine manure stored in a pit while awaiting disposal (length of storage more than 1 month)	0.00	0.00	0.17	0.32
Daily spread	Manure is collected in solid form and applied to fields regularly	0.07	0.018	0.001	0.005
Anaerobic digester	The manure (liquid or slurry) is anaerobically digested to produce methane gas for energy	0.00	0.00	0.10	0.10

Management system	Description of the management system	*Shares of management systems (MS_s)*		Fraction of maximum methane producing capacity emitted ($MCF_{s,k}$)	
		Dairy cows	Other cows	cold	temperate
Burned for fuel	Manure is collected in dried in cakes and burned for heating and cooking	0.00	0.00	0.10	0.10
Other	Other management systems	0.005	0.02	0.01	0.01

Sources: IPCC, 2006

In some countries the different assumptions with respect to the distribution of manure management systems, shares of climate regions and maximum methane producing capacities $MCF_{s,k}$ lead to considerable deviations in the emission factors compared to those reported by the member states. This can be seen from Table 6, where the resulting emission factors for the dairy and cattle activities are presented. The parameter values used by the national inventories could, in alternative to the IPCC default values, also be implemented into CAPRI. However, for this the comparability and reasonability of the national values first needs to be analysed carefully in order to prevent biased results. So, i.e. it seems hardly arguable, that the national share of the temperate climate region is above 90% in France, while it is generally below 80% in Spain and below 40% in Italy. Similarly, rather surprising assumptions could be found for the case of the shares of management systems, like around 10% of manure on pastures in Austria compared to around 50% in the United Kingdom or in France for dairy cows and cattle. Another alternative would be to replace the climate regions by one degree temperature steps, as proposed by the *2006 IPCC Guidelines.*

Table 6: Emission factors for methane emissions from manure management in kg per head and year (annual average population for 2002) for dairy and other cattle activities

	Dairy cows		Suckling cows	Male adults for fattening	Heifers for fattening	Heifers for raising	Male calves for fattening	Female calves for fattening	Male calves for raising	Female calves for raising	Other cows	
	CAPRI	NI[2]	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	NI[2]
Belgium[1]	18.52	22.55	9.34	14.19	9.34	7.55	2.83	2.95	3.29	3.54	7.05	10.15
Denmark	25.98	17.88	11.63	13.40	11.01	9.90	2.91	2.82	4.25	4.54	7.20	1.78
Germany	21.41	19.67	10.24	13.62	10.71	8.84	2.58	3.02	3.78	4.04	7.40	8.03
Greece	35.63	19.00	20.07	17.48	17.48	16.02	4.88	3.55	6.80	7.22	11.73	13.00
Spain	28.46	13.78	14.47	15.63	13.62	11.79	4.32	5.05	5.22	5.52	10.18	1.19
France	22.85	18.30	10.97	11.50	11.27	9.12	2.35	2.46	3.94	4.13	7.68	18.79
Ireland	19.64	20.72	10.93	12.53	11.03	9.04	3.15	3.33	3.94	4.19	8.16	11.06
Italy	24.99	14.74	14.02	14.93	12.68	11.31	3.13	3.25	4.68	5.01	8.84	7.51
Netherlands	21.31	35.70	9.47	14.10	9.52	8.08	3.01	3.14	3.45	3.68	5.53	7.01
Austria	19.68	20.14	10.33	11.46	10.72	8.75	2.38	2.55	3.73	3.96	7.36	7.32
Portugal	40.25	4.21	18.70	19.97	19.08	15.97	4.22	3.93	6.93	7.42	13.59	1.59
Sweden	25.72	15.68	11.31	11.74	11.25	9.41	2.53	2.68	4.04	4.31	7.69	5.63
Finland[3]	21.58	11.18	9.50	10.33	9.21	8.22	1.80	1.68	3.42	3.64	6.09	IE
United Kingdom	23.32	24.71	11.62	10.93	11.11	9.82	2.33	3.40	4.27	4.53	7.76	4.23
Cyprus[4]	31.49	0.00	17.80	21.86	17.88	15.25	6.59	3.06	6.53	6.94	9.67	0.00
Czech Republic	22.46	14.00	11.51	11.98	11.63	9.68	2.15	2.30	4.13	4.40	7.63	6.00
Estonia	20.85	8.79	11.65	10.15	10.46	10.22	2.72	1.85	4.29	4.55	5.85	3.37

	Dairy cows		Suckling cows	Male adults for fattening	Heifers for fattening	Heifers for raising	Male calves for fattening	Female calves for fattening	Male calves for raising	Female calves for raising	Other cows	
	CAPRI	NI[2]	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	CAPRI	NI[2]
Hungary	24.45	6.00	12.06	11.13	11.29	10.33	2.70	2.87	4.36	4.62	6.73	4.00
Lithuania	19.61	5.06	11.47	9.86	9.49	10.37	1.85	2.07	4.35	4.62	5.87	1.96
Latvia	20.14	6.00	12.26	10.59	10.07	10.94	2.62	2.79	4.59	4.87	6.17	4.00
Malta	39.56	44.00	19.66	25.54	19.09	17.48	4.08	4.08	7.47	7.97	13.18	20.00
Poland	20.15	9.32	11.44	10.45	9.96	9.97	2.05	1.99	4.10	4.37	5.81	6.03
Slovenia	16.23	46.36	9.65	10.93	10.75	8.42	2.45	2.78	3.59	3.86	7.13	20.64
Slovakia	31.68	4.00	16.25	14.47	14.96	13.46	3.42	4.35	5.72	6.07	9.69	3.80
Bulgaria	18.31	18.30	11.96	11.25	11.13	10.26	3.03	2.91	4.32	4.57	5.98	12.21
Romania	20.20	19.00	13.14	11.44	11.68	11.21	3.04	3.42	4.71	5.00	6.76	13.00

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

For swine, sheep, goats and poultry a simplified Tier 1 approach is applied, which does not require detailed information on management systems. It uses emission factors EF_k, which estimate emissions in kg per year and head of the average animal population according to the three climate regions. CAPRI uses the IPCC default emission factors for Western Europe (IPCC, 2006: Tab. 10.14 and 10.15), namely 9 kg/head (cold) and 15 kg/head (temperate) for breeding swine, 6 kg/head (cold) and 10 kg/head (temperate) for market swine, 0.19 kg/head (cold) and 0.28 kg/head (temperate) for sheep and goat, 0.03 kg/head for laying hens and 0.02 kg/head for other poultry. In combination with the above shares of climate regions in the EU countries the country specific Tier 1 emission factors are calculated in the following way:

$$EF = \sum_k EF_k * CLIM_k$$

The estimated emissions from CAPRI compared to those of the National Inventories can be found in Table 8. According to CAPRI, total emissions for the EU27 and for the year 2002 accounts for 1.8 Mio. tons, which is about 30% below the values reported by the member states. In general the observed differences to the results of the National Inventories are significantly higher than those in the case of the emissions from enteric fermentation, which is due to the high number of assumed but critical parameters. Among others, especially the values for swine differ substantially and show a heavy impact on total values. An implementation of a Tier 2 method for the other animal categories should therefore be considered for the second phase of the project. Although the correspondence is generally lower than in the case of enteric fermentation, the overwhelming part of the total deviation comes from two countries, Spain and France. In France an above average share in the use of liquid systems (for swine and other cattle) on the one hand, and the high MCF-values due to the allocation to the temperate climate region on the other hand lead to very high emission levels in the National Inventories. In Spain, in contrast, the deviation is caused by an almost twofold value for the livestock population combined with a higher emission factor in the swine production. Emissions from dairy cows and other cattle, in contrast, are considerably lower than in CAPRI, especially for non-dairy cattle activities, where an extremely low emission factor of 1.19 kg/head is assumed. Since, beside Spain and France, there are also other countries with strong relative deviations between CAPRI and member state values, the used parameters have to be examined carefully in the second phase of the project.

Table 8: Methane emissions from manure management in 1000 tons for 2002: CAPRI-Values compared to the values reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		Other animals		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI[2]***
Belgium[1]	11.9	15.4	13.9	24.8	33.0	59.9	0.0	0.1	0.8	4.3	0.0	0.1	***59.6***	***104.6***
Denmark	16.0	10.9	7.0	2.1	49.0	33.3	0.0	0.0	0.5	0.3	0.0	0.2	***72.5***	***46.8***
Germany	94.9	87.1	58.6	76.7	125.0	74.3	0.4	0.5	3.2	9.5	0.0	1.9	***282.1***	***250.1***
Greece	5.8	4.2	5.0	5.0	5.0	6.6	2.7	3.6	0.7	3.6	0.0	0.2	***19.2***	***23.1***
Spain	32.9	16.2	60.9	6.4	108.4	359.2	5.3	6.0	3.8	15.6	0.0	0.5	***211.3***	***403.8***
France	93.9	76.7	108.7	302.2	63.3	246.3	1.9	2.8	5.5	34.2	0.0	0.9	***273.3***	***663.2***
Ireland	22.2	23.8	35.8	58.2	6.5	22.2	0.9	1.1	0.3	4.7	0.0	0.1	***65.8***	***110.1***
Italy	54.6	28.2	51.3	34.5	58.6	69.9	1.9	1.9	3.7	16.4	0.0	3.0	***170.1***	***153.9***
Netherlands	32.9	53.0	8.0	16.6	43.0	45.7	0.2	0.3	2.2	4.3	0.0	0.4	***86.3***	***120.3***
Austria	11.7	11.9	10.4	10.8	14.9	19.2	0.1	0.1	0.3	1.0	0.0	0.1	***37.4***	***43.0***
Portugal	12.2	1.5	13.8	1.7	15.1	50.0	0.6	1.1	0.8	1.1	0.0	0.2	***42.4***	***55.5***
Sweden	10.6	6.5	7.7	6.9	7.9	5.7	0.0	0.1	0.3	1.3	0.0	0.4	***26.7***	***20.9***
Finland	7.5	3.9	3.5		5.5	4.6	0.0	0.0	0.2	1.8	0.0	0.1	***16.7***	***10.5***
United Kingdom	52.2	55.0	50.7	34.4	20.6	16.8	3.9	4.1	4.0	13.0	0.0	0.4	***131.4***	***123.7***
Cyprus	0.8	0.0	0.3	0.0	2.6	4.9	0.1	0.2	0.1	0.4	0.0	0.0	***3.9***	***5.5***
Czech Republic	10.0	8.3	6.5	5.5	15.8	10.3	0.0	0.0	0.6	2.3	0.0	0.0	***32.9***	***26.6***
Estonia	2.3	1.0	0.6	0.5	1.0	1.1	0.0	0.0	0.0	0.2	0.0	0.0	***4.0***	***2.8***
Hungary	8.0	2.1	2.1	1.7	21.4	15.3	0.2	0.2	1.2	4.0	0.0	0.1	***32.8***	***23.4***
Lithuania	8.3	2.2	1.9	0.7	2.6	4.8	0.0	0.0	0.1	0.5	0.0	0.1	***13.0***	***8.3***
Latvia	3.6	1.2	0.9	0.7	1.0	1.8	0.0	0.0	0.1	0.3	0.0	0.0	***5.5***	***4.1***
Malta	0.3	0.4	0.1	0.2	0.6	0.8	0.0	0.0	0.0	0.2	0.0	0.0	***1.1***	***1.5***
Poland	51.1	26.8	12.1	16.0	58.4	121.8	0.1	0.1	2.8	15.5	0.0	0.5	***124.5***	***180.6***
Slovenia	2.1	6.5	2.3	6.9	1.3	9.6	0.0	0.0	0.1	0.4	0.0	0.0	***5.9***	***23.4***
Slovakia	3.9	1.0	1.9	1.3	4.8	6.2	0.0	0.1	0.3	1.1	0.0	0.0	***10.9***	***9.7***
Bulgaria	7.8	6.6	3.6	3.7	5.5	8.9	0.6	0.6	0.4	2.1	0.0	0.5	***17.9***	***22.4***
Romania	26.2	32.0	13.4	15.0	12.6	35.4	0.9	1.3	1.4	1.4	0.0	1.8	***54.5***	***86.9***
EU27	***583.8***	***482.3***	***480.9***	***632.6***	***683.5***	***1234.5***	***19.9***	***24.2***	***33.7***	***139.5***	***0.0***	***11.7***	**1801.8**	**2524.8**

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

Emissions of N_2O, NH_3 and NO_x

N_2O emissions are produced during the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas. Both processes occur in each of the following stages of manure treatment and application:

1) Directly, during housing and storage of manure (both dung and urine)

2) Directly, in soils (with respect to manure deposited on grassland or arable land)
3) Indirectly, via the volatilisation of NH_3 and NO_x from manure during housing, storage and deposition on grassland and arable land
4) Indirectly, after leaching and runoff of nitrogen during housing, storage, and deposition on grassland and arable land

N_2O emissions due to the application of mineral fertilizers and crop residues, as far as the production of feed stuff is concerned, are considered in the section on animal feed production.

The calculation of the N-cycle CAPRI, as far as possible, follows the methodology developed for the integrated nitrogen model MITERRA-EUROPE (Velthof et al., 2007), which does not only consider N_2O-emissions, but also the emissions of NH_3 and NO_x. The main data-source is the database of the RAINS-model. An important note on the MITERRA-approach is that N_2O-emissions at a certain step of the N-cycle are not calculated on the basis of total N of manure or mineral fertilizer applied at this step, but on the N already diminished by losses of NH_3 and NO_x. Since, however, CAPRI, so far, uses IPCC emission factors, the approach is supposed to underestimate emissions. Moreover, the effects of applied mitigation measures lead to a further reduction of the estimated emissions, compared to what would be the result of the IPCC default method. So, it has to be checked during the second phase of the project, whether and to which extent the emission factors need to be adapted in order to yield reasonable results.

In the subsequent sections the approach and the relevant parameters will be presented for the single emission sources. Provisional numbers for total emissions will only be presented for N_2O, but not for NH_3 and NO_x. This will be an outcome for the second phase of the project.

Direct emissions from deposition during grazing of animals

This section considers all N_2O, NH_3 and NO_x emissions from manure (urine and dung) on pastures, ranges and paddocks, which result from grazing of animals. Therefore, manure deposited on pastures, ranges and paddocks by some kind of managed application is not included here, but in the section on application of manure.

The emissions are calculated in the following way:

$$N_{MAN} = \frac{CRP_{IN}}{6} - RET_N$$

$$S_{GRAZ} = \left(1 - \frac{Day_{ST}}{365}\right) * (1 - T_M)$$

$$EF_{GRAZ}^{NH3} = N_{MAN} * S_{GRAZ} * LF_{GRAZ}^{NH3}$$

$$EF_{GRAZ}^{NOx} = N_{MAN} * S_{GRAZ} * LF_{GRAZ}^{NOx}$$

$$EF_{GRAZ}^{NO2} = N_{MAN} * S_{GRAZ} * \left(1 - LF_{GRAZ}^{NH3} - LF_{GRAZ}^{NOx}\right) * LF_{GRAZ}^{N2O} * \frac{44}{28}$$

CRP_{IN} = Crude protein intake, kg per head

RET_N = Export of N (retention), kg per head

S_{GRAZ} = Share of time per year for grazing

N_{MAN} = N in manure output at tail, kg per head

Day_{ST} = Number of days per year, that the animals normally spend in the stable

T_M = Share of time per day used for melting

EF_{GRAZ}^{NH3} = Emission factor for NH_3 during grazing, kg N per head

EF_{GRAZ}^{NOx} = Emission factor for NO_x during grazing, kg N per head

EF_{GRAZ}^{N2O} = Emission factor for N_2O during grazing, kg N_2O per head

LF_{GRAZ}^{NH3} = Share of N in manure deposited during grazing, volatilising as NH_3

LF_{GRAZ}^{NOx} = Share of N in manure deposited during grazing, volatilising as NO_x

LF_{GRAZ}^{N2O} = Share of N in manure deposited during grazing, volatilising as N_2O

The N-content of animal excretion (N_{MAN}) is calculated by subtracting the exported N in form of animal products from the intake in form of feed. First, the crude protein intake (CRP_{IN}) has to be transformed into its N-content by division by 6, then the retention (RET_N) is subtracted. The crude protein intake (CRP_{IN}) is derived from the same parameters as the net energy intake (*NE*), described in the section on methane emissions from enteric fermentation. So, among others, it depends on live body weight (*BW*), daily weight gain (*WG*), milk yield (*Milk*), fat content of milk (*Fat*) etc. Retention (RET_N) is based on output coefficient, describing the relation between product outputs (milk) and animal activities (like dairy cows). The N output per head in form of manure is shown in Table 9, and compared to the values of the National Inventories (EAA, 2008):

Table 9: N output per head in form of manure for 2002: CAPRI-Values compared to the values reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry[5]	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]
Belgium[1]	90.09	113.23	45.27	59.38	19.02	11.80	5.11	7.69	475.46	487.03
Denmark	179.77	126.71	61.00	37.77	22.88	9.58	9.01	16.87	842.45	586.66
Germany	114.84	111.41	42.80	43.11	19.78	14.40	4.90	7.60	583.85	570.00
Greece	97.88	70.00	45.00	50.00	16.36	16.00	7.07	22.80	581.30	600.00
Spain	116.97	67.42	55.92	52.39	19.09	9.32	7.27	5.77	661.58	669.89
France	107.99	100.00	50.22	58.43	16.55	16.31	6.79	19.17	648.55	600.00
Ireland	109.02	85.00	56.14	65.00	17.43	8.31	5.78	6.39	565.14	336.45
Italy	109.26	116.00	41.87	50.39	22.42	11.47	6.64	16.20	568.66	539.94
Netherlands	132.22	NA	43.53	NA	18.70	NA	5.28	NA	547.69	NA
Austria	103.94	91.88	47.28	45.58	20.72	14.49	6.24	12.97	586.37	550.75
Portugal	141.07	87.60	61.20	46.94	19.93	8.01	7.73	7.58	612.16	758.44
Sweden	152.27	121.68	51.28	185.00	18.77	46.80	6.79	13.00	636.16	1210.00
Finland	114.87	105.18	38.11	44.60	16.34	18.60	5.98	8.58	603.66	746.72

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry[5]	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]
United Kingdom	146.8	112.15	55.38	48.82	18.61	10.11	6.49	5.47	667.15	678.64
Cyprus	119.13	0.00	37.93	0.00	20.46	16.00	8.04	29.07	479.44	600.00
Czech Republic	100.35	100.00	38.43	70.00	17.83	20.00	4.91	20.00	492.46	1000.00
Estonia	110.79	86.50	40.37	31.64	18.89	13.32	7.12	17.04	636.93	600.00
Hungary	112.19	100.00	38.39	70.00	22.20	20.00	6.02	19.84	591.00	600.00
Lithuania	97.77	70.00	40.25	50.00	18.62	20.00	6.93	16.00	657.95	600.00
Latvia	104.76	71.00	46.64	50.00	22.28	10.00	8.47	6.00	765.14	600.00
Malta	123.13	NE	46.90	NE	22.94	NE	7.46	NE	671.97	NE
Poland	94.01	70.00	35.81	50.00	17.87	20.00	6.48	19.23	623.93	600.00
Slovenia	115.07	105.50	52.46	42.10	20.75	11.93	6.25	20.85	570.88	600.00
Slovakia	151.62	100.00	55.16	60.00	21.70	20.25	8.51	16.00	773.46	1133.33
Bulgaria	81.18	70.00	35.39	50.00	16.34	20.00	6.31	16.00	541.12	600.00
Romania	84.73	70.00	35.57	50.00	17.33	20.00	6.22	16.72	533.34	600.00

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows", 5) Values in kg per 1000 heads

The emission factors for grazing, given in kg per head, are calculated by first multiplying the total animal excretion (N_{MAN}) with the share of manure, which is assumed to be deposited by animals during grazing. The days per year spent in the stable (Day_{ST}) and the assumed time for melting (T_M) is taken from the RAINS database. The values are country-specific and, therefore, currently not consistent with the pasture shares used for the calculation of methane emissions from manure management (MS_S), where uniform shares of management systems are used for all member states. In the second phase of the project consistent regional values will be implemented and simultaneously used for the calculation of Methane and N_2O-emissions. It is foreseen to use the results of a questionnaire on manure management systems on NUTS2 level, carried out in WP2. Currently, there are two alternative datasets available, the RAINS values or the numbers of the national inventories. Unfortunately, for some countries they differ considerably, which can be seen from Table 10:

Table 9: Shares of Manure fallen on pastures, ranges and paddocks during grazing: Values of the RAINS database compared to National inventories and the IPCC default values

	Dairy cows			Other cows			Sheep and goats	
	RAINS	NI[2]	IPCC	RAINS	NI[2]	IPCC	RAINS	NI[2]
Belgium[1]	0.39	0.39	0.2	0.46	0.39	0.32	0.73	
Denmark	0.15	0.15	0.2	0.36	0.36	0.32	0.73	
Germany	0.14	0.15	0.2	0.33	0.14	0.32	0.59	
Greece	0.40	0.08	0.2	0.45	0.33	0.32	0.86	0.72-1.00
Spain	0.00	0.07-0.43	0.2	0.83	0.16-0.34	0.32	0.92	0.09-0.41
France	0.28	0.47	0.2	0.62	0.41	0.32	0.70	0.70
Ireland	0.56	0.57	0.2	0.61	0.65	0.32	0.82	0.92
Italy	0.10	0.01-0.04	0.2	0.05	0-0.02	0.32	0.90	0.25-0.65
Netherlands	0.36		0.2	0.36		0.32	0.73	

	Dairy cows			Other cows			Sheep and goats	
	RAINS	NI[2]	IPCC	RAINS	NI[2]	IPCC	RAINS	NI[2]
Austria	0.20	0.11	0.2	0.49	0.1	0.32	0.40	
Portugal	0.30	0.13-0.17	0.2	0.56	0.23-0.56	0.32	0.80	0.25-0.55
Sweden	0.21	0.23	0.2	0.45	0.41	0.32	0.50	
Finland	0.20	0.28	0.2	0.35		0.32	0.51	0.33
United Kingdom	0.38	0.46	0.2	0.50	0.51	0.32	0.96	0.98
Cyprus	0.39		0.2	0.45		0.32	0.86	
Czech Republic	0.36	0.08	0.2	0.30	0.33	0.32	0.73	0.87
Estonia	0.32	0.13	0.2	0.41	0	0.32	0.73	0.73-0.92
Hungary	0.39	0.08	0.2	0.49	0.15	0.32	0.66	0.4
Lithuania	0.40	0.4	0.2	0.45	0.2	0.32	0.73	0.73-0.92
Latvia	0.32	0.4	0.2	0.51	0.45	0.32	0.42	0.43
Malta	0.09		0.2	0.45		0.32	0.32	
Poland	0.19	0.12	0.2	0.19	0.1	0.32	0.73	0.10-0.50
Slovenia	0.12	0.12	0.2	0.15	0.12	0.32	0.64	0.46-0.68
Slovakia	0.40		0.2	0.45		0.32	0.73	
Bulgaria	0.40	0.13	0.2	0.45	0.22	0.32	0.73	
Romania	0.39	0.13	0.2	0.45	0.26	0.32	0.73	0.73-0.92

Sources: EEA, 2008, IPCC, 2006, own calculations; 1) Luxemburg included, 2) NI=National Inventories

In the second step the manure deposited during grazing is multiplied by the respective N-loss factors (LF_{GRAZ}) for N_2O, NH_3 and NO_x. For NH_3 and NO_x emission shares of 8% each, for dairy cows, other cattle, pigs and poultry and 4% for sheep and goats are assumed. The Emission factors (EF_{GRAZ}) are emissions in kg N per head. For N_2O, in contrast to the IPCC 2006 standard approach, the calculation is not based on the whole nitrogen deposition, but just on the share, which has not volatilised in form of NH_3 and NO_x. Therefore, the emissions of NH_3 and NO_x are first subtracted, before the loss factor of N_2O is applied. For N_2O the IPCC default loss factors (see IPCC, 2006: Vol.4, Tab.11.1) are used, which is 2% for dairy cows, cattle, pigs and poultry and 1% for sheep and goats. In order to get values in kg N_2O per head, we finally have to multiply the N-emissions per head by the correction factor 44/28.

The emission factors are presented in Table 11, and compared to those of the National Inventories (EAA, 2008). Differences can be due to assumptions on grazing time (see Table 10) or on manure output per head (see Table 9). The loss factor LF_{GRAZ}, in contrast, is usually the same as in the National Inventories. An exception is Spain, which uses a value of 1% for cattle. Moreover, in general sheep and goats, in contrast to CAPRI, are not distinguished from cattle in the National Inventories.

Table 11: Emission factors for N_2O emissions from grazing in kg per head and year (annual average population for 2002)

	Dairy cows		Other cows		Sheep and goats	
	CAPRI	NI[2]	CAPRI	NI[2]	CAPRI	NI[2]
Belgium[1]	0.92	1.51	0.55	0.83	0.07	0.18
Denmark	0.73	0.60	0.60	0.43	0.11	0.39
Germany	0.42	0.52	0.37	0.24	0.05	0.01

	Dairy cows		Other cows		Sheep and goats	
	CAPRI	NI[2]	CAPRI	NI[2]	CAPRI	NI[2]
Greece	1.03	0.18	0.54	0.52	0.10	0.72
Spain	0.00	0.00	1.23	0.52	0.11	0.08
France	0.81	1.48	0.82	0.95	0.09	0.00
Ireland	1.6	1.54	0.90	1.14	0.08	0.18
Italy	0.28	0.18	0.06	0.04	0.09	0.46
Netherlands	1.29	0.68	0.42	0.46	0.07	0.00
Austria	0.54	0.31	0.61	0.17	0.04	0.36
Portugal	1.12	0.83	0.91	1.14	0.10	0.19
Sweden	0.83	0.70	0.61	0.44	0.07	0.00
Finland[3]	0.62	0.93	0.37	0.00	0.05	0.09
United Kingdom	1.53	1.44	0.84	0.68	0.11	0.13
Cyprus[4]	1.24		0.45		0.11	0.66
Czech Republic	0.96	0.25	0.30	0.73	0.05	0.00
Estonia	0.93	0.35	0.43	0.00	0.08	0.41
Hungary	1.17	0.25	0.50	0.33	0.07	0.25
Lithuania	1.03	0.88	0.48	0.31	0.09	0.43
Latvia	0.87	0.89	0.62	0.71	0.06	0.08
Malta	0.28	0.00	0.56	0.00	0.04	0.00
Poland	0.47	0.27	0.18	0.16	0.14	0.19
Slovenia	0.39	0.39	0.22	0.15	0.06	0.42
Slovakia	1.6	0.63	0.66	0.19	0.10	0.28
Bulgaria	0.85	0.29	0.43	0.35	0.06	0.00
Romania	0.88	0.29	0.43	0.41	0.07	0.40

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

Total emissions are shown in Table 12. For EU27 CAPRI-emissions are about 24% lower than those reported by the member states. However, this is mainly due to sheep and goat activities, where as mentioned above, member states usually do not use the lower emission share of 1%, as proposed by the IPCC. On national level above average deviations can be observed for Belgium, Greece, Spain, Italy, Austria, Cyprus, Bulgaria and Romania. For Belgium, Greece and Cyprus this is caused by different values on N output per head in manure (see Table 9), for Spain, Italy, Austria and Bulgaria by deviations in grazing shares (see Table 10), and in Romania both is the case for some animal activities. For sheep and goat activities deviations are additionally enhanced by the lower emission shares in CAPRI.

Table 12: N_2O emissions from grazing in 1000 tons for 2002: CAPRI-Values compared to the values reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI[2]***
Belgium[1]	0.6	1.0	1.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	***1.7***	***3.0***
Denmark	0.4	0.4	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	***1.1***	***0.9***
Germany	1.9	2.3	2.9	2.3	0.0	0.0	0.1	0.0	0.0	0.0	***4.9***	***4.7***
Greece	0.2	0.0	0.2	0.2	0.0	0.0	1.1	10.6	0.0	0.4	***1.5***	***11.3***

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI***[2]
Spain	0.0	0.0	7.3	2.8	1.2	0.3	2.2	2.1	0.0	0.0	***10.7***	***5.1***
France	3.3	6.2	11.6	15.2	0.0	0.0	0.7	0.0	0.0	0.1	***15.6***	***21.6***
Ireland	1.8	1.8	4.0	6.0	0.0	0.0	0.3	1.3	0.0	0.0	***6.1***	***9.1***
Italy	0.6	0.3	0.3	0.2	0.0	0.0	0.7	4.2	0.0	0.0	***1.7***	***4.7***
Netherlands	2.0	1.0	0.6	1.1	0.0	0.0	0.1	0.0	0.0	0.0	***2.7***	***2.1***
Austria	0.3	0.2	0.9	0.3	0.0	0.0	0.0	0.1	0.0	0.0	***1.2***	***0.6***
Portugal	0.3	0.3	0.9	1.2	0.0	0.0	0.2	0.7	0.0	0.0	***1.5***	***2.3***
Sweden	0.3	0.3	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	***1.0***	***0.8***
Finland	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	***0.4***	***0.3***
United Kingdom	3.4	3.2	5.5	5.5	0.0	0.1	1.8	4.8	0.0	0.2	***10.7***	***13.9***
Cyprus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	***0.1***	***0.5***
Czech Republic	0.4	0.1	0.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	***0.7***	***0.8***
Estonia	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	***0.1***	***0.1***
Hungary	0.4	0.1	0.2	0.1	0.0	0.0	0.1	0.3	0.0	0.0	***0.6***	***0.5***
Lithuania	0.4	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	***0.6***	***0.5***
Latvia	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	***0.2***	***0.3***
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	***0.0***	***0.0***
Poland	1.2	0.8	0.4	0.4	0.0	0.0	0.0	0.1	0.0	0.0	***1.6***	***1.3***
Slovenia	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	***0.1***	***0.2***
Slovakia	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	***0.4***	***0.3***
Bulgaria	0.4	0.1	0.3	0.1	0.0	0.0	0.2	0.0	0.0	0.0	***0.8***	***0.2***
Romania	1.1	0.5	0.8	0.5	0.0	0.0	0.3	3.1	0.0	0.0	***2.3***	***4.1***
EU27	***19.9***	***19.7***	***39.2***	***40.1***	***1.2***	***0.5***	***7.9***	***28.2***	***0.0***	***0.8***	***68.2***	***89.3***

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventories included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

As mentioned in the introduction, due to the combination of IPCC default emission factors with a non IPCC standard approach, CAPRI currently slightly underestimates N_2O emissions, which will be corrected in the second phase of the project, if this is supposed to be reasonable by the subcontractor. Since, according to the definition of IPCC, a Tier 2 method would require country-specific emission factors the CAPRI approach for the calculation of N_2O emissions from grazing can be considered as a Tier 1 method.

Direct emissions from manure management

Direct emissions from manure management include all direct emissions of N_2O, NH_3 and NO_x, which are produced in stable, during storage and treatment of manure before it is applied to soils. Emissions from deposition on pastures, ranges and paddocks are not included here, and have been discussed in the preceding section. Emissions from active application to soils will be the topic of the subsequent section.

According to the *IPCC guidelines,* N_2O emissions from manure management depend in first line on the type of manure management system in use. The default classification suggested is the same as for the calculation of methane emissions from manure management (see Table 5). A method that uses the default emission factors of the IPCC guidelines (see IPCC, 2006: Vol.4, Tab.10.21) is considered as a Tier 1 approach, one which uses country specific values as Tier 2 approach. CAPRI follows the methodology of the MITERRA-EUROPE project, which differentiates between emissions from housing and from storage. The management systems are first divided into liquid and solid systems. Then for each system, according to the country specific estimate of the share of livestock, the assumed N-losses for the case without specific emission reduction measures are calculated. Finally, those basic emissions are reduced according to country specific assumptions on applied emission reduction measures. Currently, data on shares of manure management systems and mitigation measures come from the RAINS database, but as far as reasonable, in the second phase of the project they will be replaced by the results of the manure management study carried out under WP2. Mathematically the calculation can be described in the following way:

$$S_{ST} = 1 - S_{GRAZ}$$

$$EF_{HOUS}^{NH3} = N_{MAN} * S_{ST} * \sum_S MS_S * LF_{HOUS,S}^{NH3} * \left(1 - \sum_A P_{S,A} * R_{S,A}^{NH3}\right)$$

$$EF_{HOUS}^{NOx} = N_{MAN} * S_{ST} * \sum_S MS_S * LF_{HOUS,S}^{NOx} * \left(1 - \sum_A P_{S,A} * R_{S,A}^{NOx}\right)$$

$$EF_{HOUS}^{N2O} = \left(N_{MAN} * S_{ST} - EF_{HOUS}^{NH3} - EF_{HOUS}^{NOx}\right) * \sum_S MS_S * LF_{HOUS,S}^{N2O} * \left(1 - \sum_A P_{S,A} * R_{S,A}^{N2O}\right)$$

$$EF_{STOR}^{NH3} = \left(N_{MAN} * S_{ST} - EF_{HOUS}^{NH3} - EF_{HOUS}^{NOx} - EF_{HOUS}^{N2O}\right) * \sum_S MS_S * LF_{STOR,S}^{NH3} * \left(1 - \sum_B P_{S,B} * R_{S,B}^{NH3}\right) * (1 - C_S * 0.8)$$

$$EF_{STOR}^{NOx} = \left(N_{MAN} * S_{ST} - EF_{HOUS}^{NH3} - EF_{HOUS}^{NOx} - EF_{HOUS}^{N2O}\right) * \sum_S MS_S * LF_{STOR,S}^{NOx} * \left(1 - \sum_B P_{S,B} * R_{S,B}^{NOx}\right)$$

$$EF_{STOR}^{N2} = \left(N_{MAN} * S_{ST} - EF_{HOUS}^{NH3} - EF_{HOUS}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{NH3} - EF_{STOR}^{NOx}\right) * \sum_S MS_S * LF_{STOR,S}^{N2} * \left(1 - \sum_B P_{S,B} * R_{S,B}^{N2}\right)$$

$$EF_{MAN}^{NH3} = EF_{HOUS}^{NH3} + EF_{STOR}^{NH3}$$

$$EF_{MAN}^{NOx} = EF_{HOUS}^{NOx} + EF_{STOR}^{NOx}$$

$$EF_{MAN}^{N2O} = EF_{HOUS}^{N2O} * \frac{44}{28}$$

$$\sum_S MS_S = 1$$

N_{MAN} = N in manure output at tail, kg per head

S_{ST} = Share of time per year the animal spends in the stable

S_{GRAZ} = Share of time per year for grazing

MS_s = fraction of manure handled using housing (storage) system s (s=liquid, solid)

$P_{S,A}$ = fraction of manure handled using housing system s with emission reduction measure A

$P_{S,B}$ = fraction of manure handled using storage system s with coverage types B

C_S = fraction of manure handled using storage systems with stable adaptation measures

$R_{S,A}^{NH3}$ = factor of NH_3 emission reduction using housing system s with emission reduction measure A

$R_{S,A}^{NOx}$ = factor of NOx emission reduction using housing system s with emission reduction measure A

$R_{S,A}^{N2O}$ = factor of N_2O emission reduction using housing system s with emission reduction measure A

$R_{S,B}^{NH3}$ = factor of NH_3 emission reduction using storage system s with emission reduction measure B

$R_{S,B}^{NOx}$ = factor of NOx emission reduction using storage system s with emission reduction measure B

$LF_{HOUS,S}^{NH3}$ = Share of N in manure deposited in housing system s (without reduction measures), lost as NH_3

$LF_{HOUS,S}^{NOx}$ = Share of N in manure deposited in housing system s (without reduction measures), lost as NO_x

$LF_{HOUS,S}^{N2O}$ = Share of N in manure deposited in housing system s (without reduction measures), lost as N_2O

$LF_{STOR,S}^{NH3}$ = Share of N in manure deposited in storage system s (without reduction measures), lost as NH_3

$LF_{STOR,S}^{NOx}$ = Share of N in manure deposited in storage system s (without reduction measures), lost as NO_x

$LF_{STOR,S}^{N2}$ = Share of N in manure deposited in storage system s (without reduction measures), lost as N_2

EF_{HOUS}^{NH3} = Emission factor for NH_3 during housing, kg N per head

EF_{HOUS}^{NOx} = Emission factor for NO_x during housing, kg N per head

EF_{HOUS}^{N2O} = Emission factor for N_2O during housing, kg N per head

EF_{STOR}^{NH3} = Emission factor for NH_3 during storage, kg N per head

EF_{STOR}^{NOx} = Emission factor for NO_x during storage, kg N per head

EF_{STOR}^{N2} = Emission factor for N_2 during storage, kg N per head

EF_{MAN}^{NH3} = Emission factor for NH_3 during housing and storage, kg N per head

EF_{MAN}^{NOx} = Emission factor for NO_x during housing and storage, kg N per head

EF_{MAN}^{N2O} = Emission factor for N_2O during housing and storage, kg N_2O per head

The N of manure entering the management systems is the share S_{ST} of total manure N_{MAN} (see Table 9), which is excreted inside the stable. Then, for each animal category, this is divided into manure in liquid and solid management systems by the shares MS_S. The RAINS values for MS_S are currently not consistent with the values used for the calculation of methane emissions from manure management, which will be changed in phase two of the project. MS_S is shown in table 13 and compared to those values reported by the member states in National Inventories (EAA, 2008). For sheep, goats and poultry no differentiation is applied. For the IPCC default values see Table 5.

Table 13: Shares of Manure management systems (MS_s) for the calculation of N emissions during manure management (Comparison of values from RAINS and National Inventories)

	RAINS						National Inventories								
	Dairy cows		Other cows		Pigs		Dairy cows			Other cows			Pigs		
Country	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Others	Liquid	Solid	Others	Liquid	Solid	Others

	RAINS						National Inventories								
	Dairy cows		Other cows		Pigs		Dairy cows			Other cows			Pigs		
Country	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Others	Liquid	Solid	Others	Liquid	Solid	Others
Belgium	0.48	0.52	0.36	0.64	0.93	0.07	0.50	0.50	0.00	0.50	0.50	0.00	1.00	0.00	0.00
Denmark	0.71	0.29	0.23	0.77	0.87	0.13	0.87	0.13	0.00	0.38	0.62	0.00	0.92	0.08	0.00
Germany	0.83	0.17	0.58	0.42	0.92	0.08	0.82	0.18	0.00	0.63	0.37	0.00	0.91	0.09	0.00
Greece	0.50	0.50	0.50	0.50	0.87	0.13	0.00	0.98	0.02	0.00	0.93	0.07	0.90	0.10	0.00
Spain	0.15	0.85	0.05	0.95	0.63	0.37	0.15	0.60	0.25	0.15	0.60	0.25	1.00	0.00	0.00
France	0.20	0.80	0.37	0.63	0.80	0.20	0.20	0.80	0.00	0.59	0.41	0.00	0.83	0.17	0.00
Ireland	0.93	0.07	0.72	0.28	1.00	0.00	0.94	0.06	0.00	0.67	0.33	0.00	1.00	0.00	0.00
Italy	0.36	0.64	0.36	0.64	1.00	0.00	0.40	0.60	0.00	0.57	0.43	0.00	1.00	0.00	0.00
Netherlands	1.00	0.00	0.94	0.06	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
Austria	0.30	0.70	0.30	0.70	0.80	0.20	0.21	0.79	0.00	0.27	0.73	0.00	0.71	0.29	0.00
Portugal	0.35	0.65	0.00	1.00	0.95	0.05	0.61	0.37	0.02	0.00	1.00	0.00	0.11	0.02	0.86
Sweden	0.57	0.43	0.30	0.70	0.79	0.21	0.58	0.42	0.00	0.26	0.45	0.29	0.70	0.26	0.05
Finland	0.45	0.55	0.25	0.75	0.57	0.43	0.52	0.48	0.00	0.00	0.00	1.00	0.60	0.40	0.00
United Kingdom	0.66	0.34	0.18	0.82	0.50	0.50	0.56	0.18	0.26	0.12	0.42	0.46	0.34	0.60	0.07
Cyprus	0.52	0.48	0.52	0.48	0.70	0.30	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
Czech Republic	0.12	0.88	0.22	0.78	1.00	0.00	0.50	0.23	0.27	0.83	0.03	0.14	0.77	0.23	0.00
Estonia	0.18	0.82	0.42	0.58	0.73	0.27	0.22	0.77	0.01	0.42	0.57	0.01	0.29	0.00	0.71
Hungary	0.02	0.98	0.00	1.00	0.94	0.06	0.04	0.96	0.00	0.02	0.98	0.00	0.73	0.25	0.02
Lithuania	0.52	0.48	0.52	0.48	0.70	0.30	0.20	0.80	0.00	0.20	0.80	0.00	0.00	0.20	0.80
Latvia	0.05	0.95	0.03	0.97	0.47	0.53	0.06	0.89	0.05	0.04	0.93	0.04	0.46	0.51	0.03
Malta	0.00	1.00	0.00	1.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
Poland	0.20	0.80	0.25	0.75	0.30	0.70	0.08	0.92	0.00	0.17	0.83	0.00	0.29	0.71	0.00
Slovenia	0.55	0.45	0.55	0.45	0.77	0.23	0.55	0.45	0.00	0.55	0.45	0.00	0.56	0.36	0.08
Slovakia	0.52	0.48	0.52	0.48	0.70	0.30	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
Bulgaria	0.23	0.77	0.23	0.77	0.50	0.50	0.21	0.77	0.02	0.36	0.63	0.01	0.00	0.53	0.47
Romania	0.23	0.77	0.23	0.77	0.70	0.30	0.21	0.78	0.01	0.38	0.00	0.62	0.00	0.58	0.42

Sources: EEA, 2008

For each animal category, each management system s and both for housing and storage a loss factor *LF* for N losses in form of NH_3, NO_x and N_2O is defined. This loss factor is a default value in case that no specific emission reduction measures are applied and defines the upper limit of emissions of the country. For direct N_2O-emissions during housing and storage the loss factor is assumed to be 0.5% for dairy cows, other cattle and pigs, both for solid and liquid systems. This corresponds to the IPCC 2006 default values (IPCC, 2006: Vol.4, Tab.10.21). Since those default values, however, have been changed since the IPCC 2001 guidelines (IPCC, 2000), and the new values are split up in a more detailed manner, for which CAPRI was not set up, the reasonability of the used values has to be checked in the second phase of the project. For poultry, sheep and goats the values differ between old and new member states. In case of poultry the loss factor is assumed to be 0.46% for old, and 0.37% for new member states, for sheep and goats it is 0.73% for old and 0.5% for new member states respectively.

For NO_x-emissions a general loss factor of 0.3% is applied for all animals, both for solid and liquid systems, once during housing and once during storage (so the total loss via NO_x during management is approximately 0.5-0.6%). N_2-emissions do only occur during storage and are assumed to be 10% for solid and 1% for liquid systems. For poultry, sheep and goats the value for solid systems is applied. Loss factors for volatilisation via NH_3, in contrast to those of N_2O and NO_x, are country-specific and are presented in Table 14:

Table 14: NH_3-Loss factors LF for housing and storage by animal categories and management systems (liquid, solid) in Percent

Country	Housing									Storage								
	Dairy cows		Other cattle		Swine		Sheep and goats	Lay. hens	Poultry for fattening	Dairy cows		Other cattle		Swine		Sheep and goats	Lay. hens	Poultry for fattening
	L[1]	S[1]	L[1]	S[1]	L[1]	S[1]				L[1]	S[1]	L[1]	S[1]	L[1]	S[1]			
Belgium	15.0	14.0	9.0	10.0	17.0	17.0	10.0	14.0	11.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0	4.0	3.0
Denmark	8.0	7.0	8.0	7.0	17.0	18.0	15.0	25.0	20.0	8.0	7.0	6.0	7.0	17.0	18.0	10.0	20.0	20.0
Germany	9.0	9.0	6.2	6.2	25.0	20.0	15.0	22.0	40.0	9.0	9.0	10.5	10.5	25.0	20.0	15.0	25.0	20.0
Greece	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Spain	12.0	12.0	2.6	2.6	17.0	17.0	10.0	20.0	20.0	12.0	12.0	13.5	13.5	17.0	17.0	10.0	20.0	20.0
France	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Ireland	19.0	19.0	19.0	19.0	17.5	17.5	10.0	20.0	20.0	19.0	19.0	4.0	4.0	17.5	17.5	12.0	22.5	20.0
Italy	8.0	8.0	12.0	12.0	17.0	17.0	12.0	22.5	20.0	8.0	8.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0
Netherlands	14.0	14.0	14.0	9.6	18.0	17.9	10.0	20.0	20.0	5.2	4.5	5.2	4.5	10.5	22.0	10.0	20.0	20.0
Austria	11.8	11.8	11.8	11.8	15.0	15.3	10.0	20.0	20.0	7.5	4.5	7.5	4.5	7.8	5.9	0.0	4.4	3.0
Portugal	12.0	12.0	12.0	0.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	17.3	17.0	17.0	10.0	20.0	20.0
Sweden	12.0	13.0	12.0	13.0	17.0	17.0	10.0	20.0	20.0	12.0	13.0	7.5	6.0	17.0	15.0	10.0	36.2	40.0
Finland	12.0	12.0	12.0	12.0	12.8	12.8	10.0	20.0	20.0	12.0	12.0	6.0	4.0	12.8	12.8	10.0	20.0	20.0
United Kingdom	18.6	12.5	18.6	12.5	17.5	22.6	15.0	23.6	14.2	18.6	12.0	10.9	1.1	17.5	17.0	10.0	20.0	20.0
Cyprus	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Czech Republic	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	15.0	22.0	20.0
Estonia	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Hungary	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Lithuania	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Latvia	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0
Malta	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	5.0	10.0	4.0	3.0
Poland	22.0	12.5	18.0	13.0	18.0	22.0	10.0	20.0	20.0	22.0	12.5	10.0	4.0	18.0	17.0	10.0	20.0	20.0
Slovenia	15.4	7.0	15.4	7.0	24.3	15.0	10.0	36.2	40.0	15.4	7.0	6.7	3.9	24.3	17.0	10.0	20.0	20.0
Slovakia	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	22.6	15.0	23.6	14.2
Bulgaria	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	6.0	6.0	6.0	6.0	3.0	6.0	0.0	4.0	3.0
Romania	12.0	12.0	12.0	12.0	17.0	17.0	10.0	20.0	20.0	12.0	12.0	6.0	6.0	17.0	17.0	10.0	20.0	20.0

1) L: Liquid, S: Solid

The emission reduction measures, which are considered in the MITERRA-EUROPE project, are mainly focusing on the reduction of NH_3-emissions, while other emissions may even be increased. For housing those are mainly measures for stable adaptation by improving design and construction of the floor, flushing the floor, climate control (for pigs and poultry) and wet and dry manure systems for poultry. In case of storage two options for manure coverage are considered, a low efficiency option with floating foils or polystyrene and a high efficiency option using tension caps, concrete, corrugated iron or polyester. Moreover, stable adaptation measures, unrelated to coverage, are taken into account for NH_3 (see Velthof et al., 2007). All values with respect to reduction measures are directly taken from MITERRA and, due to a lack of expertise, have not been validated in this project. So, they are just presented here without any detailed comments on their sources and reasonability. The assumed effects on emissions (1-*R*) are presented in Table 15:

Table 15: Effects of NH_3-Emission reduction measures for housing and storage on emissions of NH_3, NO_2, N_2 and NO_x ($R_{S,A/B}$) by animal category and management systems (liquid, solid) in Percent

		Housing			Storage (manure coverage)	
		NH_3	N_2O	NO_x	NH_3, NO_x, N_2	
					High reduction	Low reduction
Dairy cows	Liquid	-25%	+/-0%	+/-0%	-80%	-40%
	Solid	-25%	+/-0%	+/-0%	-80%	-40%
Other cattle	Liquid	-25%	+/-0%	+/-0%	-80%	-40%
	Solid	-25%	+/-0%	+/-0%	-80%	-40%
Pigs	Liquid	-40%	+900%	+/-0%	-80%	-40%
	Solid	-40%	+900%	+/-0%	-80%	-40%
Laying hens		-65%	+900%	+/-0%	-80%	-40%
Other poultry		-85%	+900%	+/-0%	-80%	-40%

The effects are assumed to be equal in all countries, except for NH_3-emission reductions in housing, where for Bulgaria and Netherlands other values are used (Netherlands: -50% for dairy cows, -40% for other cattle and -60% for other poultry; Bulgaria: -70% for other poultry). For stable adaptation measures in storage systems a reduction of NH_3-emission by 80% is assumed.

The national shares of the NH_3-mitigation measures (*P*) are presented in the following tables. For housing, in general, just for a few countries and just for pigs in liquid systems and poultry, mitigation measures are assumed to be present (see Table 16). Coverage measures for storage are confined to liquid systems (see Table 17). For the shares of stable adaptation measures in storage systems (C_s) see Table 18.

Table 16: Shares of NH_3-Emission reduction measures for housing ($P_{S,A}$) by countries, animal categories and management systems (liquid, solid) in Percent

	Dairy cows				Other cows				Pigs				Laying hens		Other poultry	
	Liquid		Solid		Liquid		Solid		Liquid		Solid					
	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red
Belgium	100	0	100	0	100	0	100	0	86	14	100	0	20	80	90	10
Denmark	95	5	100	0	100	0	100	0	72	28	100	0	100	0	100	0
Germany	100	0	100	0	100	0	100	0	85	15	100	0	100	0	100	0
Greece	100	0	100	0	100	0	100	0	95	5	100	0	95	5	90	10
Spain	100	0	100	0	100	0	100	0	90	10	100	0	80	20	95	5
France	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Ireland	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Italy	100	0	100	0	100	0	100	0	100	0	100	0	90	10	100	0
Netherlands	20	80	100	0	100	0	100	0	35	65	100	0	18	82	27	73
Austria	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Portugal	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Sweden	100	0	100	0	100	0	100	0	90	10	100	0	100	0	100	0
Finland	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
United Kingdom	100	0	100	0	100	0	100	0	100	0	100	0	75	25	100	0

	Dairy cows				Other cows				Pigs				Laying hens		Other poultry	
	Liquid		Solid		Liquid		Solid		Liquid		Solid					
	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red	Def	Red
Cyprus	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Czech Republic	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Estonia	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Hungary	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Lithuania	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Latvia	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Malta	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Poland	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Slovenia	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Slovakia	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Bulgaria	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0
Romania	100	0	100	0	100	0	100	0	100	0	100	0	100	0	100	0

Def: Default technology; Red: NH_3-emission reduction measures

Table 17: Shares of NH_3-Emission reduction measures for storage (due to manure coverage) ($P_{S,B}$) by countries and animal categories in Percent

	Dairy cows (Liquid)			Other cows (Liquid)			Pigs (Liquid)			Other Poultry		
	Def	R H	R L	Def	R H	R L	Def	R H	R L	Def	R H	R L
Belgium	30	42.13	27.86	30	41.25	28.75	100	0	0	100	0	0
Denmark	7	93	0	5	95	0	40	60	0	100	0	0
Germany	78	20	2	78	20.7	1.3	100	0	0	100	0	0
Greece	100	0	0	100	0	0	100	0	0	100	0	0
Spain	100	0	0	100	0	0	100	0	0	100	0	0
France	88	2	10	94	2	4	77.65	5	17.35	100	0	0
Ireland	25	0	75	25	0	75	12.9	0	87.1	100	0	0
Italy	67	32	1	80	20	0	82	18	0	100	0	0
Netherlands	80	20	0	0	95	5	90	10	0	82	18	0
Austria	54.3	20	25.6	56.0	10	33.96	57.37	10	32.63	90	10	0
Portugal	100	0	0	100	0	0	100	0	0	100	0	0
Sweden	57	14	29	57	13.5	29.5	100	0	0	80	20	0
Finland	50	0	50	100	0	0	100	0	0	100	0	0
United Kingdom	20	0	80	20	0	80	100	0	0	100	0	0
Cyprus	100	0	0	100	0	0	100	0	0	100	0	0
Czech Republic	100	0	0	100	0	0	100	0	0	100	0	0
Estonia	100	0	0	100	0	0	100	0	0	100	0	0
Hungary	100	0	0	100	0	0	100	0	0	100	0	0
Lithuania	100	0	0	100	0	0	100	0	0	100	0	0
Latvia	100	0	0	100	0	0	100	0	0	100	0	0
Malta	100	0	0	100	0	0	100	0	0	100	0	0
Poland	75	25	0	80	20	0	75	25	0	100	0	0
Slovenia	50	50	0	50	50	0	50.8	49.2	0	100	0	0
Slovakia	100	0	0	100	0	0	100	0	0	100	0	0
Bulgaria	100	0	0	100	0	0	100	0	0	100	0	0
Romania	100	0	0	100	0	0	100	0	0	100	0	0

Def: Default technology; RH: NH_3-emission reduction measures (strong reduction); RL: NH_3-emission reduction measures (low reduction)

Table 18: Shares of stable adaptation measures in storage systems by countries and animal categories (C_s) in Percent

	Dairy cows		Other cows		Pigs		Laying hens	Other poultry	Sheep and goats
Country	Liquid	Solid	Liquid	Solid	Liquid	Solid			
Belgium	0	0	0	0	14	0	80	10	0
Denmark	5	0	0	0	28	0	0	0	0
Germany	0	0	0	0	15	0	0	0	0
Greece	0	0	0	0	5	0	5	10	0
Spain	0	0	0	0	10	0	20	5	0
France	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0
Italy	0	0	0	0	0	0	10	0	0
Netherlands	80	0	0	0	65	0	82	73	0
Austria	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	0	10	0	0	0	0
Finland	0	0	0	0	0	0	0	0	0
United Kingdom	0	0	0	0	0	0	25	0	0
Cyprus	0	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0	0	0
Hungary	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0
Latvia	0	0	0	0	0	0	0	0	0
Poland	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0	0	0	0
Bulgaria	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0

The N_2O-emission factors (*EF)* for manure management (housing and storage) are presented in Table 19, compared to the emission factors reported by the member states. Due to the different approaches deviating results are expectable. Since CAPRI uses the default N_2O-loss factors (0.5% for liquid and solid systems) recommended in the IPCC 2006 guidelines (IPCC, 2006), while the national inventories are mainly based on the higher IPCC 2001 (IPCC, 2000) values (0.1% for liquid and 2% for solid systems), emission factors in CAPRI are generally smaller than in the national inventories. The subtraction of NH_3- and NO_x-emissions before the application of the loss factors leads to a further reduction of emissions compared to the IPCC method. In the second phase of the project it has to be checked whether this should be changed. The high values for pig production, compared to those of the national Inventories, are due to the consideration of NH_3-emission reduction measures in CAPRI, which leads to a boost of N_2O emissions (see table 15) in some countries. National inventories, as the IPCC standard approach, do not specifically take these measures into account.

Table 19: Emission factors for N_2O emissions from manure management (housing and storage) in kg per head and year (annual average population for 2002)

	Dairy cows		Other cows		Swine		Sheep and goats		Poultry[5]	
	CAPRI	NI[2]	CAPRI	NI[2]	CAPRI	NI[2]	CAPRI	NI[2]	CAPRI	NI[2]
Belgium[1]	0.37	0.97	0.17	0.65	0.27	0.05	0.01	0.05	13.30	12.56
Denmark	1.11	0.55	0.28	0.48	0.47	0.04	0.02	0.14	4.84	17.85
Germany	0.71	0.53	0.21	0.32	0.27	0.06	0.02	0.04	2.80	13.67
Greece	0.41	1.98	0.17	0.98	0.15	0.07	0.01	0.00	5.64	1.32
Spain	0.81	1.29	0.05	0.59	0.17	0.01	0.01	0.02	7.20	21.05
France	0.53	1.35	0.13	0.56	0.11	0.11	0.02	0.25	3.74	6.70
Ireland	0.31	0.13	0.14	0.16	0.11	0.01	0.01	0.02	3.24	9.03
Italy	0.71	2.15	0.27	0.70	0.14	0.02	0.01	0.05	4.39	15.67
Netherlands	0.61	0.16	0.19	0.13	0.87	0.01	0.01	0.11	27.94	18.37
Austria	0.58	2.06	0.17	0.94	0.13	0.07	0.04	0.02	3.40	3.92
Portugal	0.68	0.78	0.21	0.34	0.12	0.02	0.02	0.05	3.55	23.59
Sweden	0.83	1.29	0.19	0.54	0.20	0.09	0.03	0.18	3.67	9.20
Finland[3]	0.63	1.22	0.17	0.00	0.12	0.25	0.03	0.18	3.50	16.44
United Kingdom	0.6	0.36	0.19	0.28	0.11	0.17	0.00	0.00	6.15	3.35
Cyprus[4]	0.5		0.14		0.14	0.31	0.01	0.00	2.75	18.91
Czech Republic	0.44	0.74	0.18	0.15	0.11	0.17	0.01	0.03	2.31	4.27
Estonia	0.52	1.85	0.16	0.55	0.12	0.19	0.01	0.12	2.96	13.40
Hungary	0.47	2.78	0.13	1.83	0.14	0.18	0.01	0.37	2.73	14.19
Lithuania	0.4	1.07	0.15	1.02	0.11	0.17	0.01	0.01	3.05	1.35
Latvia	0.49	1.21	0.16	0.81	0.14	0.17	0.03	0.11	3.55	11.87
Malta	0.77	0.00	0.17	0.00	0.15	0.00	0.05	0.00	3.88	0.00
Poland	0.51	1.78	0.20	1.18	0.12	0.46	0.01	0.42	3.19	15.27
Slovenia	0.7	1.41	0.31	0.56	0.13	0.15	0.02	0.24	2.00	14.25
Slovakia	0.63	2.36	0.21	1.61	0.14	0.10	0.02	0.21	3.57	11.73
Bulgaria	0.34	1.50	0.13	0.81	0.09	0.35	0.01	0.01	2.51	3.19
Romania	0.35	1.52	0.13	0.16	0.12	0.38	0.01	0.03	2.49	2.85

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventoires included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows", 5) kg per 1000 heads

The lower emission factors in CAPRI are also reflected in lower total emissions compared to those reported in the national inventories (see Table 20). Total emissions of the EU27, according to CAPRI, amount to 59.000 tons, which is about the half of what is estimated by the member states.

Table 20: N_2O emissions from manure management (housing and storage) in 1000 tons for 2002: CAPRI-Values compared to those reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI[2]***
Belgium[1]	0.2	0.6	0.3	1.6	1.4	0.3	0.0	0.0	0.5	0.5	***2.5***	***3.0***
Denmark	0.7	0.3	0.3	0.6	3.5	0.5	0.0	0.0	0.1	0.4	***4.6***	***1.7***
Germany	3.1	2.3	1.7	3.0	5.2	1.3	0.0	0.1	0.4	1.7	***10.5***	***8.5***

	Dairy cows		Other Cattle		Swine		Sheep and goats		Poultry		***Total emission***	
	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	Capri	NI[2]	***Capri***	***NI[2]***
Greece	0.1	0.4	0.1	0.4	0.1	0.1	0.1	0.0	0.2	0.0	***0.5***	***0.9***
Spain	0.9	1.5	0.3	3.2	2.2	0.3	0.2	0.6	1.2	3.4	***4.9***	***9.0***
France	2.2	5.6	1.9	9.0	1.1	1.3	0.2	2.7	0.9	1.9	***6.3***	***20.6***
Ireland	0.4	0.1	0.6	0.8	0.1	0.0	0.1	0.1	0.0	0.1	***1.2***	***1.3***
Italy	1.6	4.1	1.6	3.2	1.0	0.2	0.1	0.5	0.7	3.2	***4.9***	***11.2***
Netherlands	0.9	0.2	0.3	0.3	5.7	0.2	0.0	0.2	2.5	1.9	***9.5***	***2.8***
Austria	0.3	1.2	0.2	1.4	0.3	0.2	0.0	0.0	0.0	0.0	***1.0***	***2.9***
Portugal	0.2	0.3	0.2	0.4	0.2	0.0	0.0	0.2	0.1	1.0	***0.8***	***1.8***
Sweden	0.3	0.5	0.2	0.7	0.2	0.2	0.0	0.1	0.1	0.2	***0.8***	***1.6***
Finland	0.2	0.4	0.1	0.0	0.1	0.3	0.0	0.0	0.0	0.2	***0.5***	***1.0***
United Kingdom	1.3	0.8	1.2	2.3	0.3	1.0	0.0	0.1	1.1	0.6	***4.0***	***4.7***
Cyprus	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	***0.1***	***0.2***
Czech Republic	0.2	0.4	0.2	0.1	0.3	0.6	0.0	0.0	0.1	0.1	***0.7***	***1.3***
Estonia	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	***0.1***	***0.4***
Hungary	0.2	1.0	0.0	0.8	0.5	0.9	0.0	0.5	0.1	0.7	***0.8***	***3.9***
Lithuania	0.2	0.5	0.1	0.3	0.0	0.2	0.0	0.0	0.0	0.0	***0.3***	***1.0***
Latvia	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	***0.1***	***0.5***
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	***0.0***	***0.0***
Poland	1.3	5.1	0.4	3.1	1.0	8.5	0.0	0.2	0.4	3.0	***3.1***	***20.1***
Slovenia	0.1	0.2	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.1	***0.2***	***0.6***
Slovakia	0.1	0.6	0.0	0.6	0.1	0.2	0.0	0.1	0.0	0.2	***0.3***	***1.6***
Bulgaria	0.1	0.5	0.1	0.2	0.1	0.3	0.0	0.0	0.0	0.1	***0.4***	***1.2***
Romania	0.5	2.6	0.3	0.2	0.2	1.9	0.0	0.2	0.1	0.2	***1.1***	***5.1***
EU27	***15.3***	***30.0***	***10.2***	***32.6***	***23.9***	***18.9***	***0.9***	***5.6***	***8.6***	***19.6***	***59.0***	***106.6***

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories, 3) "Other cattle" in National Inventoiies included in "Other animals", 4) "Other cattle" in National Inventories included in "Dairy cows"

Direct emissions from manure application to agricultural soils

This section includes all emissions of NH_3, NO_x and N_2O, which are induced by the deposition of manure (dung and urine) on agricultural soils except for that part, which has already been considered in the section on grazing. So, direct emissions from application to agricultural soils can be manure deposited on arable land or pastures, however, not directly by the animal, but by farmers using application techniques. In the 2006 IPCC guidelines those emissions are not considered in Chapter 10, like those from manure management, but in Chapter 11 (N_2O emissions from managed soils). IPCC differentiates between Tier 1 and Tier 2 approaches, which, however, are both based on the same calculation structure. The main difference is the use of country specific emission factors in Tier 2 approaches, while Tier 1 methods apply IPCC default values. According to the IPCC classification, the CAPRI approach can be regarded as a Tier 2 approach.

CAPRI calculates the emissions from application to soils based on the total manure output (Table 9) reduced by the share deposited during grazing (Table 11), the share lost via volatilisation during manure management (Table 19), the share lost via runoff during manure management and the share lost via surface-runoff after the application on soils (see section on indirect emissions from runoff and leaching). From the resulting share of the manure, which is assumed to arrive at soil level, in a first step default emissions are calculated by multiplication with the default loss factor (*LF*). In a second step, the application of emission reduction techniques is supposed to reduce emissions by a certain degree (*R*) according to their country-specific frequency of usage (*P*). In contrast to the IPCC guidelines manure used for feed, fuel or construction is not considered in CAPRI, which could be changed in the second phase of the project. The emission factors are calculated according to the following formulas:

$$EF_{AP}^{NH3} = \left(N_{MAN} * S_{ST} - EF_{MAN}^{NH3} - EF_{MAN}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{N2} - N_{RUN}^{MAN} - N_{RUN}^{AP}\right) * \sum_S MS_S * LF_{AP,S}^{NH3} * \left(1 - \sum_C P_{S,C} * R_{S,C}^{NH3}\right)$$

$$EF_{AP}^{NOx} = \left(N_{MAN} * S_{ST} - EF_{MAN}^{NH3} - EF_{MAN}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{N2} - N_{RUN}^{MAN} - N_{RUN}^{AP}\right) * \sum_S MS_S * LF_{AP,S}^{NOx} * \left(1 - \sum_C P_{S,C} * R_{S,C}^{NOx}\right)$$

$$EF_{AP}^{N2O} = \left(N_{MAN} * S_{ST} - EF_{MAN}^{NH3} - EF_{MAN}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{N2} - N_{RUN}^{MAN} - N_{RUN}^{AP} - EF_{AP}^{NH3} - EF_{AP}^{NOx}\right) * \sum_S MS_S * LF_{AP,S}^{N2O} * \left(1 - \sum_C P_{S,C} * R_{S,C}^{N2O}\right) * \frac{44}{28}$$

N_{MAN} = N in manure output at tail, kg per head

S_{ST} = Share of time per year the animal spends in the stable

MS_s = fraction of manure handled using management system s (s=liquid, solid)

$P_{S,C}$ = fraction of manure handled using housing management system s with emission reduction measure C (application)

$R_{S,C}^{NH3}$ = factor of NH_3 emission reduction using management system s with emission reduction measure C (application)

$R_{S,C}^{NOx}$ = factor of NOx emission reduction using management system s with emission reduction measure C (application)

$R_{S,C}^{N2O}$ = factor of N_2O emission reduction using management system s with emission reduction measure C (application)

$LF_{AP,S}^{NH3}$ = Share of N in manure deposited in management system s (without reduction measures), lost as NH_3

$LF_{AP,S}^{NOx}$ = Share of N in manure deposited in management system s (without reduction measures), lost as NO_x

$LF_{AP,S}^{N2O}$ = Share of N in manure deposited in management system s (without reduction measures), lost as N_2O

EF_{HOUS}^{N2O} = Emission factor for N_2O during housing, kg N per head

EF_{STOR}^{N2} = Emission factor for N_2 during storage, kg N per head

EF_{MAN}^{NH3} = Emission factor for NH_3 during housing and storage, kg N per head

EF_{MAN}^{NOx} = Emission factor for NO_x during housing and storage, kg N per head

N_{RUN}^{MAN} = N lost via runoff during housing and storage, kg N per head

N_{RUN}^{AP} = N lost via surface runoff during application, kg N per head

EF_{AP}^{NH3} = Emission factor for NH_3 during application, kg N per head

EF_{AP}^{NOx} = Emission factor for NO_x during application, kg N per head

EF_{AP}^{N2O} = Emission factor for N2O during application, kg N_2O per head

As in the case of manure management and grazing all used parameters and values come from the MITERRA-EUROPE project and, therefore, from the RAINS database. Partly, they will be replaced by regional parameters from WP2 in the second phase of the project. The loss factors (*LF*) for NO_x and N_2O are assumed to be unique for all member states and all management systems. For N_2O the IPCC default value of 1% (IPCC, 2006: Vol 4, Tab. 11.1) is applied, for NO_x a value of 0.03%. The loss factors for NH_3 can be found in Table 21:

Table 21: NH_3-Loss factors LF for application by animal categories and management systems (liquid, solid) in Percent

	Dairy cows		Other cows		Pigs		Laying hens	Other poultry	Sheep and goats
Country	Liquid	Solid	Liquid	Solid	Liquid	Solid			
Belgium	28	8	28	8	30	10	34	6	10
Denmark	19	15	19	15	20	20	16	16	7
Germany	20	20	22	22	16	20	24	27	23
Greece	20	20	20	20	20	20	20	20	10
Spain	20	20	20	20	20	20	20	20	10
France	20	20	20	20	20	20	20	20	10
Ireland	24	8	27	8	9	9	16	10	5
Italy	22	22	24	24	25	25	23	16	22
Netherlands	34	14	34	14	41	17	31	31	32
Austria	30	16	30	16	16	14	20	20	10
Portugal	20	20	20	20	20	20	20	20	10
Sweden	21	16	21	20	18	15	10	12	10
Finland	20	15	20	15	14	14	20	20	10
United Kingdom	22	8	20	9	16	24	36	36	10
Cyprus	20	20	20	20	20	20	20	20	10
Czech Republic	20	20	20	20	20	20	20	20	10
Estonia	20	20	20	20	20	20	20	20	10
Hungary	20	20	20	20	20	20	20	20	10
Lithuania	20	20	20	20	20	20	20	20	10
Latvia	20	20	20	20	20	20	20	20	10
Malta	20	20	20	20	20	20	20	20	10
Poland	20	16	20	16	23	20	20	20	10
Slovenia	24	23	24	23	28	19	23	25	20
Slovakia	20	20	20	20	20	20	20	20	10
Bulgaria	20	20	20	20	20	20	20	20	10
Romania	20	20	20	20	20	20	20	20	10

Among NH_3-emission reduction measures during application high (immediate incorporation, deep and shallow injection of manure) and medium/low efficiency techniques (slit injection, trailing shoe, slurry dilution, band spreading and sprinkling) are distinguished (see Velthof et al., 2007). The emission reduction (R) is supposed to correspond to the values given in Table 22:

Table 22: Effects of NH_3-Emission reduction measures during application on emissions of NH_3, NO_2 and NO_x ($R_{S,C}$) by animal category and management systems (liquid, solid) in Percent

		Medium/low efficiency measures			High efficiency measures		
		NH_3	No_x	N_2O	NH_3	No_x	N_2O
Dairy cows	Liquid	-40%	-40%	+60%	-80%	-80%	+100%
	Solid	-20%	-20%	+60%	-80%	-80%	+100%
Other cattle	Liquid	-40%	-40%	+60%	-80%	-80%	+100%
	Solid	-20%	-20%	+60%	-80%	-80%	+100%
Pigs	Liquid	-40%	-40%	+60%	-80%	-80%	+100%
	Solid	-20%	-20%	+60%	-80%	-80%	+100%
Laying hens		-20%	-20%	+60%	-80%	-80%	+100%
Other poultry		-20%	-20%	+60%	-80%	-80%	+100%
Sheep and goats		-20%	-20%	+60%	-80%	-80%	+100%

While for NH_3 and NO_x the measures lead to a reduction of emissions between 20% and 80%, N_2O-emissions increase by 60%-100%, depending on the type of measure applied. The values are assumed to be unique for all countries, except for some specific values in Belgium (NH_3-reductions of 50% in case of medium/low efficiency measures in liquid systems, and 70%/50% for high efficiency measures in liquid/solid systems).

The presumed shares of emission reduction measures are presented in Table 23a and Table 23b.

Table 23a: Shares of NH_3-Emission reduction measures during application ($P_{S,C}$) by countries, animal categories (dairy cows and other cattle) and management systems (liquid, solid) in Percent

	Dairy cows						Other cattle					
	Liquid			Solid			Liquid			Solid		
	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF
Belgium	12	41	47	0	66	34	9	41	50	0	63	37
Denmark	32	3	65	72	18	10	20	1	79	67	15	18
Germany	2	22	76	4	20	76	3	21	76	4	20	76
Greece	0	0	100	0	0	100	0	0	100	0	0	100
Spain	0	0	100	0	0	100	0	0	100	0	0	100
France	0	0	100	0	0	100	0	0	100	0	0	100
Ireland	0	0	100	0	0	100	0	0	100	0	0	100
Italy	20	10	70	10	30	60	19	1	80	5	15	80
Netherlands	50	50	0	0	80	20	40	40	20	0	80	20
Austria	0	10	90	5	5	90	0	10	90	5	5	90
Portugal	0	0	100	0	0	100	0	0	100	0	0	100
Sweden	8	7	85	20	15	65	8	7	85	20	15	65
Finland	2	47	51	0	47	53	2	47	51	0	47	53
United Kingdom	1	2	97	3	17	80	0	0	100	3	17	80

	Dairy cows						Other cattle					
	Liquid			Solid			Liquid			Solid		
	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF
Cyprus	0	0	100	0	0	100	0	0	100	0	0	100
Czech Republic	3	10	87	5	20	75	3	10	87	5	20	75
Estonia	0	0	100	0	0	100	0	0	100	0	0	100
Hungary	0	100	0	0	0	100	0	0	100	0	0	100
Lithuania	0	0	100	0	0	100	0	0	100	0	0	100
Latvia	0	0	100	0	0	100	0	0	100	0	0	100
Malta	0	0	100	0	0	100	0	0	100	0	0	100
Poland	0	0	100	5	95	0	0	0	100	5	95	0
Slovenia	0	20	80	0	20	80	0	20	80	0	20	80
Slovakia	0	0	100	0	0	100	0	0	100	0	0	100
Bulgaria	0	0	100	0	0	100	0	0	100	0	0	100
Romania	0	0	100	0	0	100	0	0	100	0	0	100

HE: Highly efficient emission reduction measures, LE: Medium/Low efficient emission reduction measures, DEF: No emission reducion measures

Table 23b: Shares of NH_3-Emission reduction measures during application ($P_{S,C}$) by countries, animal categories (sine, poultry, sheep and goats) and management systems (liquid, solid) in Percent

	Swine						Laying hens			Other poultry			Sheep and goats		
	Liquid			Solid											
	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF
Belgium	8	85	7	0	71	29	89	0	11	63	6	31	0	44	56
Denmark	28	0	72	72	18	10	64	18	18	67	15	18	64	18	18
Germany	14	51	35	16	54	30	99	1	0	30	70	0	0	0	100
Greece	5	0	95	0	0	100	5	0	95	10	0	90	0	0	100
Spain	9	1	90	0	0	100	20	0	80	5	0	95	0	0	100
France	12	10	79	0	0	100	0	0	100	0	0	100	0	0	100
Ireland	0	1	99	0	0	100	0	0	100	0	0	100	0	0	100
Italy	10	10	80	0	0	100	34	46	20	12	20	68	0	0	100
Netherlands	90	0	10	0	100	0	82	0	18	73	0	27	0	0	100
Austria	0	10	90	10	10	80	1	10	89	10	10	80	0	100	0
Portugal	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Sweden	5	25	70	30	10	60	0	40	60	0	40	60	0	0	100
Finland	2	68	30	0	68	32	0	47	53	0	47	53	0	0	100
United Kingdom	14	0	87	20	0	80	18	36	46	11	23	65	0	0	100
Cyprus	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Czech Republic	5	20	75	0	0	100	0	0	100	0	0	100	0	0	100
Estonia	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Hungary	0	100	0	0	0	100	0	0	100	0	0	100	0	0	100
Lithuania	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Latvia	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100

	Swine						Laying hens			Other poultry			Sheep and goats		
	Liquid			Solid											
	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF	HE	LE	DEF
Malta	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Poland	0	0	100	6	94	0	4	76	20	5	95	0	0	100	0
Slovenia	8	0	92	8	0	92	0	8	92	0	8	92	0	0	100
Slovakia	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Bulgaria	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100
Romania	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100

HE: Highly efficient emission reduction measures, LE: Medium/Low efficient emission reduction measures, DEF: No emission reducion measures

For the calculation of the runoff during housing and storage (N_{RUN}^{MAN}) and the surface runoff during application (N_{RUN}^{AP}) see the section on indirect emissions from runoff and leaching. The described parameters lead to the following emission factors and total emissions, presented in table 24 and 25. In contrast to preceding section, a comparison between CAPRI-values and values reported by the member states can only be provided for total emissions over all animals, since national inventories do not provide animal specific emissions. Total emissions from manure application on managed soils amount to around 72 thousand tons according to CAPRI, which is 63% of the summed values reported by the member states. On country level the relation of CAPRI values to values from national inventories ranges from 27% in Romania to 139% in Denmark. Generally, the lower CAPRI-values are expected, since most member states use the old N_2O-loss factor of 1.25%, while CAPRI uses the most recent one (1%), presented in the 2006 IPCC guidelines. Moreover, lower values result from the fact, that CAPRI, in contrast to National Inventories, subtracts NH_3- and NO_x-emissions from applied manure before it calculates N_2O-emissions. On the other hand, considering NH_3-emission reduction measures generally leads to higher N_2O-emissions, which is reflected by large values for countries with high frequencies of reduction measures, like Belgium, Denmark, Italy or the Netherlands.

Table 24: Emission factors for N_2O emissions from manure application to managed soils in kg per head and year (annual average population for 2002)

	Dairy cows	Other cows	Swine	Sheep and goats	Poultry[2]
Belgium[1]	0.77	0.36	0.30	0.02	9.17
Denmark	2.67	0.75	0.31	0.04	12.69
Germany	1.15	0.33	0.21	0.02	7.12
Greece	0.52	0.23	0.15	0.01	4.69
Spain	0.99	0.07	0.13	0.01	5.41
France	0.67	0.18	0.15	0.02	4.61
Ireland	0.39	0.20	0.16	0.01	4.42
Italy	1.21	0.39	0.20	0.01	5.96
Netherlands	1.79	0.48	0.38	0.01	10.16
Austria	0.85	0.25	0.22	0.07	5.82
Portugal	0.85	0.25	0.17	0.02	4.38
Sweden	1.39	0.35	0.20	0.03	5.48
Finland[3]	1.19	0.34	0.23	0.03	5.98
United Kingdom	0.85	0.33	0.16	0.00	5.67
Cyprus[4]	0.63	0.19	0.15	0.01	3.41
Czech Republic	0.62	0.28	0.16	0.01	3.29

	Dairy cows	Other cows	Swine	Sheep and goats	Poultry[2]
Estonia	0.64	0.22	0.16	0.02	4.48
Hungary	0.58	0.17	0.29	0.02	4.10
Lithuania	0.49	0.19	0.15	0.02	4.45
Latvia	0.6	0.21	0.17	0.05	5.32
Malta	0.97	0.24	0.18	0.05	5.75
Poland	1.01	0.41	0.20	0.03	7.19
Slovenia	1.01	0.46	0.15	0.02	3.08
Slovakia	0.78	0.27	0.17	0.02	5.49
Bulgaria	0.42	0.16	0.13	0.02	4.26
Romania	0.42	0.17	0.12	0.02	3.63

1) Luxemburg included, 2) kg per 1000 heads

Table 25: N_2O emissions from manure application to managed soils in 1000 tons for 2002: CAPRI-Values compared to those reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows	Other Cattle	Swine	Sheep and goats	Poultry	***Total emission***	
	Capri					***Capri***	***NI***[2]
Belgium[1]	0.5	0.7	1.6	0.0	0.3	***3.1***	***3.3***
Denmark	1.6	0.7	2.3	0.0	0.3	***4.9***	***3.5***
Germany	5.1	2.6	4.2	0.0	1.0	***12.9***	***20.8***
Greece	0.1	0.1	0.1	0.1	0.1	***0.5***	***0.7***
Spain	1.1	0.4	1.7	0.2	0.9	***4.4***	***8.4***
France	2.8	2.5	1.5	0.2	1.1	***8.2***	***17.6***
Ireland	0.4	0.9	0.2	0.1	0.1	***1.6***	***1.6***
Italy	2.6	2.3	1.4	0.1	0.9	***7.4***	***8.9***
Netherlands	2.8	0.7	2.5	0.0	0.9	***6.9***	***9.0***
Austria	0.5	0.3	0.5	0.0	0.1	***1.5***	***2.1***
Portugal	0.3	0.2	0.2	0.0	0.1	***0.9***	***1.2***
Sweden	0.6	0.3	0.2	0.0	0.1	***1.3***	***2.6***
Finland	0.4	0.2	0.2	0.0	0.1	***0.9***	***1.2***
United Kingdom	1.9	2.1	0.5	0.0	1.0	***5.5***	***8.1***
Cyprus	0.0	0.0	0.0	0.0	0.0	***0.1***	***0.1***
Czech Republic	0.3	0.2	0.4	0.0	0.1	***1.0***	***2.8***
Estonia	0.1	0.0	0.0	0.0	0.0	***0.1***	***0.3***
Hungary	0.2	0.1	1.0	0.0	0.2	***1.4***	***3.2***
Lithuania	0.2	0.1	0.1	0.0	0.0	***0.3***	***0.9***
Latvia	0.1	0.0	0.0	0.0	0.0	***0.2***	***0.3***
Malta	0.0	0.0	0.0	0.0	0.0	***0.0***	
Poland	2.6	0.9	1.8	0.0	0.8	***6.1***	***10.1***
Slovenia	0.1	0.1	0.0	0.0	0.0	***0.3***	***0.6***
Slovakia	0.1	0.1	0.1	0.0	0.1	***0.3***	***1.0***
Bulgaria	0.2	0.1	0.1	0.1	0.1	***0.5***	***0.7***
Romania	0.5	0.3	0.2	0.1	0.2	***1.4***	***5.2***
EU27	***25.1***	***16.1***	***20.9***	***1.0***	***8.5***	***71.7***	***114.1***

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories

Until now, emissions from manure application on managed soils have not been differentiated according to whether they are caused by animal or crop production, and so they are all allocated to livestock. This, of course, is not realistic, since a large share of manure applied on arable land is substituting chemical fertilizers, and therefore would not vanish if livestock production was reduced. The exact way of allocation has to be determined in the second phase of the project. The lower limit of the livestock share is what is applied to grassland and crops for feed production. This could eventually be increased by an observed amount of over-fertilization on other crops, assuming that this is mainly caused by the need of dumping excess manure. However, this of course would rather give an upper limit and could not be regarded as correct estimate.

Indirect N_2O-emissions following N-deposition of volatilized NH_3/NO_x

N_2O-emissions do not only occur through a direct but also through indirect pathways. One of them is the volatilisation of N as NH_3 and NO_x and the succeeding deposition as ammonium and nitrate onto soils. Arrived there they increase the total amount of deposited N and, therefore, participate in the same processes (nitrification, denitrification) as directly deposited fertilizers. The fraction that volatilizes as NH_3 and NO_x is explicitly calculated in CAPRI at the different steps of the N-cycle. The applied loss factors are presented in the respective sections. N_2O -emissions are then derived from the total of those emissions. Since for the moment they are not separated according to their sources[3] this section covers both emissions from animal rearing and emissions from crop production (including non-feed production).

The IPCC recommends a default loss factor of 10% (NH_3 and NO_x together) for chemical fertilizers applied to managed soils, 20% for manure applied on managed soils or deposited by grazing animals (see IPCC, 2006: Vol.4, Tab.11.3), and the following values for Manure management (see IPCC, 2006: Vol.4, Tab.10,22):

Table 26: IPCC 2006 default (NH_3+NO_x)-Loss factors (LF) for manure management systems (liquid, solid) in Percent

	Dairy cows	Other cattle	Swine
Liquid/slurry	40		48
Solid storage	30	45	45

Source: IPCC, 2006

National Inventories (EAA, 2008), in contrast, use country-specific loss factors, but based on the whole N manure output at tail. So, in most countries[4] the loss factors are not differentiated by management systems and do not differ between deposition during grazing or application on managed soils. They are shown in Table 27:

Table 27: National Inventories (NH_3+NO_x)-Loss factors (LF) for N manure in Percent

Belgium	22.5

[3] This will be an outcome of the second phase of the project.

[4] Some countries take the NH3 losses from the detailed NH3 inventory. In this case the emission calculations take detailed information on housing and management systems into consideration.

Denmark	22.3
Germany	30.1
Greece	20.0
Spain	33.9
France	20.0
Ireland	19.3
Italy	29.6
Netherlands	No
Austria	21.2
Portugal	21.9
Sweden	33.0
Finland[3]	33.0
United Kingdom	20.0
Cyprus	20.0
Czech Republic	20.0
Estonia	20.0
Hungary	20.0
Lithuania	20.0
Latvia	20.0
Malta	No
Poland	20.0
Slovenia	20.0
Slovakia	24.0
Bulgaria	20.0
Romania	20.0

From the N that volatilizes as NH_3 and NO_x a certain share (LF_{IN}^{N2O}) is deposited again on soils and volatilizes as N_2O. This share is assumed to be 1% in CAPRI, which corresponds to the IPCC 2006 default value (see IPCC, 2006: Vol.4, Tab.11.3) and is also applied by the member states in National Inventories. Formally, the calculation is based on the following formula:

$$EF_{IN}^{N2O} = \left(EF_{GRAZ}^{NH3} + EF_{GRAZ}^{NOx} + EF_{MAN}^{NH3} + EF_{MAN}^{NOx} + EF_{AP}^{NH3} + EF_{AP}^{NOx} + EF_{MIN}^{NH3} + EF_{MIN}^{NOx}\right) * LF_{IN}^{N2O} * \frac{44}{28}$$

LF_{IN}^{N2O} = Share of N volatilizing as NH_3 or NO_x lost as N_2O

EF_{GRAZ}^{NH3} = Emission factor for NH_3 during grazing, kg N per head

EF_{GRAZ}^{NOx} = Emission factor for NO_x during grazing, kg N per head

EF_{MAN}^{NH3} = Emission factor for NH_3 during housing and storage, kg N per head

EF_{MAN}^{NOx} = Emission factor for NO_x during housing and storage, kg N per head

EF_{AP}^{NH3} = Emission factor for NH_3 during manure application on managed soils, kg N per head

EF_{AP}^{NOx} = Emission factor for NO_x during manure application on managed soils, kg N per head

EF_{MIN}^{NH3} = Emission factor for NH_3 during application of chemical fertilizers on managed soils, kg N per head

EF_{MIN}^{NOx} = Emission factor for NO_x during application of chemical fertilizers on managed soils, kg N per head

EF_{IN}^{N2O} = Emission factor for indirect N_2O from N manure volatilizing as NH_3 or NO_x, kg N_2O per head

Emission factors (*EF*) and total N_2O-emissions from N-deposition of volatilized NH_3 and NO_x can be found in tables 28 and 29. Unfortunately, comparative values in the national inventories can just be found for total indirect emissions, including those from mineral fertilizer application (discussed under the chapter on animal feed production). A comparative value for the share, which is caused by manure from livestock, is not available. Moreover, both in CAPRI and the National Inventories, until now, emissions are not differentiated according to whether caused or not caused by livestock production, as required for this study (for CAPRI this will be done in phase II of the project). Total N_2O-emissions from N-deposition of volatilized NH_3 and NO_x for the EU27 amount to 53 thousand tons per year, according to CAPRI calculations, which is 8% more than the sum of the values reported by the member states in national inventories. The correspondence between CAPRI and national inventories is generally satisfactory with a few exceptions like Greece, Spain and Poland. The share of manure (grazing, housing, storage and application to managed soils), which, however, is not equivalent to the share of the livestock sector, amounts to around 80% or 44 thousand tons respectively.

Table 28: Emission factors for N_2O emissions following N-deposition of volatilized NH_3/NO_x in kg per head and year (annual average population for 2002)

	Dairy cows	Other cows	Swine	Sheep and goats	Poultry[2]
Belgium[1]	0.34	0.14	0.11	0.01	1.42
Denmark	0.57	0.17	0.11	0.02	5.48
Germany	0.52	0.18	0.14	0.02	4.96
Greece	0.44	0.18	0.10	0.01	4.19
Spain	0.68	0.19	0.12	0.01	4.68
France	0.53	0.18	0.11	0.01	4.87
Ireland	0.5	0.22	0.10	0.01	3.90
Italy	0.49	0.24	0.16	0.01	3.95
Netherlands	0.4	0.17	0.08	0.01	2.21
Austria	0.46	0.17	0.11	0.01	3.34
Portugal	0.68	0.23	0.12	0.01	4.60
Sweden	0.74	0.20	0.12	0.02	5.14
Finland	0.53	0.14	0.09	0.02	4.50
United Kingdom	0.67	0.12	0.14	0.01	5.28
Cyprus	0.54	0.15	0.14	0.01	3.60
Czech Republic	0.45	0.16	0.11	0.01	3.68
Estonia	0.53	0.16	0.12	0.01	4.79
Hungary	0.5	0.15	0.14	0.01	4.42
Lithuania	0.43	0.16	0.12	0.01	4.90
Latvia	0.5	0.18	0.17	0.02	5.73
Malta	0.68	0.19	0.17	0.02	3.92
Poland	0.47	0.15	0.12	0.01	4.44
Slovenia	0.59	0.24	0.15	0.02	5.59
Slovakia	0.68	0.22	0.14	0.02	5.71
Bulgaria	0.32	0.14	0.09	0.02	3.06
Romania	0.38	0.14	0.12	0.02	3.97

1) Luxemburg included, 2) kg per 1000 heads

Table 29: N_2O emissions following N-deposition of volatilized NH_3/NO_x in 1000 tons for 2002: CAPRI-Values compared to those reported by the member states (National Inventories of 2007 for 2002)

	Dairy cows	Other Cattle	Swine	Sheep and goats	Poultry	***Total Manure***	***Total emissions***	
	Capri							***NI***[2]
Belgium[1]	0.22	0.28	0.55	0.00	0.05	***1.10***	***1.11***	***0.94***
Denmark	0.35	0.17	0.82	0.00	0.12	***1.47***	***1.63***	***1.27***
Germany	2.31	1.40	2.64	0.04	0.67	***7.06***	***8.37***	***7.97***
Greece	0.07	0.08	0.05	0.11	0.12	***0.43***	***0.64***	***1.69***
Spain	0.79	1.12	1.67	0.21	0.77	***4.55***	***5.84***	***3.39***
France	2.18	2.54	1.10	0.14	1.19	***7.16***	***8.94***	***9.85***
Ireland	0.57	0.95	0.10	0.04	0.05	***1.71***	***1.99***	***1.44***
Italy	1.07	1.40	1.14	0.08	0.61	***4.29***	***5.36***	***5.34***
Netherlands	0.62	0.24	0.54	0.02	0.20	***1.61***	***1.71***	***1.64***
Austria	0.27	0.24	0.25	0.00	0.05	***0.82***	***0.86***	***0.58***
Portugal	0.21	0.23	0.18	0.02	0.16	***0.79***	***0.91***	***0.72***
Sweden	0.31	0.20	0.14	0.00	0.07	***0.73***	***0.75***	***0.62***
Finland	0.18	0.08	0.07	0.00	0.05	***0.38***	***0.41***	***0.59***
United Kingdom	1.50	0.79	0.45	0.16	0.93	***3.84***	***4.37***	***5.39***
Cyprus	0.01	0.00	0.03	0.01	0.02	***0.07***	***0.08***	
Czech Republic	0.20	0.14	0.27	0.00	0.10	***0.71***	***0.95***	***1.03***
Estonia	0.06	0.02	0.02	0.00	0.01	***0.10***	***0.11***	***0.09***
Hungary	0.16	0.05	0.48	0.01	0.22	***0.92***	***1.14***	***1.18***
Lithuania	0.18	0.05	0.04	0.00	0.02	***0.30***	***0.43***	***0.42***
Latvia	0.09	0.03	0.02	0.00	0.01	***0.15***	***0.18***	***0.14***
Malta	0.01	0.00	0.01	0.00	0.00	***0.02***	***0.02***	
Poland	1.19	0.31	1.10	0.00	0.52	***3.12***	***4.11***	***1.49***
Slovenia	0.08	0.08	0.03	0.00	0.04	***0.22***	***0.25***	***0.19***
Slovakia	0.08	0.04	0.10	0.01	0.07	***0.31***	***0.37***	***0.40***
Bulgaria	0.14	0.08	0.07	0.07	0.05	***0.41***	***0.51***	***0.63***
Romania	0.49	0.27	0.22	0.09	0.22	***1.29***	***1.57***	***1.89***
EU27	***13.33***	***10.80***	***12.12***	***1.00***	***6.32***	***43.56***	***52.61***	***48.90***

Sources: EEA, 2008, own calculations; 1) Luxemburg included, 2) NI=National Inventories

Indirect N_2O-emissions following from Leaching and Runoff

Beside losses in gaseous form N is lost in form of leaching and runoff, predominantly as nitrate. Leaching is the flow from below soil to the groundwater, runoff the superficial flow into overland water, like lakes and rivers. Some parts of N lost via leaching and runoff is again transformed into N_2O, and, therefore, have to be considered in the N_2O-emissions. Sources of N leaching and runoff, which are relevant for the sake of this study, are the deposition of manure by grazing animals, the treatment of manure during housing and storage, the application of manure upon managed soils, the application of mineral fertilizers and the N delivered by crop residues. As in the case of indirect emissions via volatilisation this section does not differentiate between emission sources, and, therefore, covers both emissions from animal and total crop production (including non-feed crops). In the second phase of the project emissions will be allocated to livestock rearing and feed production.

The calculation in CAPRI is carried out in the following steps. First, the leaching fraction from manure management (N_{RUN}^{MAN}) is figured out after the calculation of gaseous emissions from housing and storage, and then the superficial runoff during the application of manure on managed soils (N_{RUN}^{AP}) is derived. The latter is added to the superficial runoff of manure deposited by grazing animals. After those steps the gaseous emissions from manure application upon managed soils are estimated (see section on manure application on managed soils). The superficial runoff from the application of mineral fertilizers (N_{RUN}^{MIN}) is determined in the same way, using the same loss factor (LF_{RUN}) as for grazing and manure application. The leaching below soils (N_{LEA}) is derived from the N surplus, which is the total of all N delivered to the agricultural system minus the total of N, which leaves the agricultural system in form of animal and crop products, gaseous emissions, superficial runoff or leaching during manure management. The gaseous N_2O-emissions from leaching and runoff are then estimated by the multiplication of N lost by superficial runoff, leaching during manure management and leaching below soils with a unique loss factor ($LF_{LEA+RUN}^{N2O}$). The exact calculation corresponds to the following formulas:

$$N_{RUN}^{GRAZ} = \left(N_{MAN} * S_{GRAZ} - EF_{GRAZ}^{NH3} - EF_{GRAZ}^{NOx} - EF_{GRAZ}^{N2O} * \frac{28}{44} \right) * LF_{RUN}$$

$$N_{RUN}^{MAN} = \left(N_{MAN} * S_{ST} - EF_{MAN}^{NH3} - EF_{MAN}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{N2} \right) * \sum_{S} MS_S * NVZ * \left[LF_{RUN,S,Bas}^{MAN} * (1 - P_{ND}) + LF_{RUN,S,ND}^{MAN} * P_{ND} \right]$$

$$N_{RUN}^{AP} = \left(N_{MAN} * S_{ST} - EF_{MAN}^{NH3} - EF_{MAN}^{NOx} - EF_{HOUS}^{N2O} - EF_{STOR}^{N2} - N_{RUN}^{MAN} \right) * LF_{RUN}$$

$$N_{RUN}^{MIN} = N_{MIN} * \left(1 - EF_{MIN}^{NH3} + EF_{MIN}^{NOx} + EF_{MIN}^{N2O} * \frac{28}{44} \right) * LF_{RUN}$$

$$NT_{RUN}^{GRAZ+MAN+AP} = \sum_{hd,sp} \left(N_{RUN}^{GRAZ} + N_{RUN}^{MAN} + N_{RUN}^{AP} \right)$$

$$NT_{RUN}^{MIN} = \sum_{ha,cp} N_{RUN}^{MIN}$$

$$NT_{GAS}^{MIN} = \sum_{ha,cp} \left(EF_{MIN}^{NH3} + EF_{MIN}^{NOx} + EF_{MIN}^{N2O} * \frac{28}{44} \right)$$

$$NT_{GAS}^{GRAZ+MAN+AP} = \sum_{hd,sp} \left[\begin{array}{l} EF_{GRAZ}^{NH3} + EF_{GRAZ}^{NOx} + EF_{MAN}^{NH3} + EF_{MAN}^{NOx} + EF_{HOUS}^{N2O} + EF_{STOR}^{N2} \\ + EF_{AP}^{NH3} + EF_{AP}^{NOx} + \left(EF_{AP}^{N2O} + EF_{GRAZ}^{N2O} \right) * \frac{28}{44} \end{array} \right]$$

$$NT^{MAN} = \sum_{ha,cp} N^{MAN}$$

$$NT_{MAN} = \sum_{hd,sp} N_{MAN}$$

$$NT_{MIN} = \sum_{ha,cp} N_{MIN}$$

$$NT_{CR} = \sum_{ha,cp} N_{CR}$$

$$N_{LEA} = \frac{\left(\begin{array}{l} NT_{MAN} + NT_{MIN} + NT_{ATD} + NT_{FIX} + NT_{CR} - \\ NT_{EXP} - NT_{RUN}^{MIN} - NT_{RUN}^{GRAZ+MAN+AP} - NT_{GAS}^{MIN} - NT_{GAS}^{GRAZ+MAN+AP} \end{array} \right)}{Area} * LF_{LEA}$$

$$EF_{LEA+RUN}^{N2O} = \left(\frac{NT_{RUN}^{GRAZ+MAN+AP}}{NT^{MAN}} * N^{MAN} + N_{RUN}^{MIN} + N_{LEA} \right) * LF_{LEA+RUN}^{N2O} * \frac{44}{28}$$

Area = Total area of grassland and arable land, in ha

N_{MAN} = N in manure output at tail, kg per head

N_{MIN} = N in chemical fertilizers applied to pastures and crops, kg per ha

N_{CR} = N delivery from crop residues, kg per ha

S_{GRAZ} = Share of time per year for grazing

S_{ST} = Share of time per year the animal spends in the stable

MS_s = fraction of manure handled using housing (storage) system s (s=liquid, solid)

NVZ = Share of region being a Nitrate Vulnerable Zone (NVZ)

N_{LEA} = N leaching below soils, kg N per ha

N^{MAN} = N from manure deposited on fields or pastures (cop specific), kg N per ha

N_{RUN}^{GRAZ} = Surface runoff of N manure deposited by grazing animals, kg N per head

N_{RUN}^{MAN} = N manure leaching during housing and storage, kg N per head

N_{RUN}^{AP} = N manure superficial runoff during application upon managed soils, kg N per head

N_{RUN}^{MIN} = N surface runoff from application of mineral fertilizers, kg N per ha

NT_{MAN} = Total N from manure excreted by animals (sum over all animal species sp and heads hd), kg N

NT_{MIN} = Total N from chemical fertilizers (sum over all crops cp and crop areas ha), kg N

NT_{FIX} = Total N from biological fixation (sum over all crops cp and crop areas ha), kg N

NT_{ATD} = Total N from atmospheric deposition (sum over all crops cp and crop areas ha), kg N

NT_{CR} = Total N from crop residues (sum over all crops cp and crop areas ha), kg N

NT_{EXP} = Total N retention in crop products, crop residues and animals

NT^{MAN} = Total N from manure deposited on fields or pastures (sum over all crops cp and crop areas ha), kg N

NT_{RUN}^{MIN} = Total losses of organic N from chemical fertilizers (sum over all crops cp and crop areas ha) by superficial runoff, in kg N

$NT_{RUN}^{GRAZ+MAN+AP}$ = Total losses of organic N (sum over all animal species sp and heads hd) by leaching during housing and storage or superficial runoff during grazing and application, in kg N

NT_{GAS}^{MIN} = Total gaseous losses of organic N from chemical fertilizers (sum over all crops cp and crop areas ha) as NH_3, NO_x or N_2O, in kg N

$NT_{GAS}^{GRAZ+MAN+AP}$ = Total gaseous losses of N manure (sum over all animal species sp and heads hd) as NH_3, NO_x or N_2O, in kg N

$LF_{LEA+RUN}^{N2O}$ = Share of N from leaching and runoff, lost as N_2O

$LF_{RUN,S,BAS}^{MAN}$ = Share of N manure lost by leaching and runoff during housing and storage in manure management system s without Nitrate directive measures

$LF_{RUN,S,ND}^{MAN}$ = Share of N manure lost by leaching and runoff during housing and storage in manure management system s with Nitrate directive measures

P_{ND}= National penetration rate for Nitrate directive measures

LF_{RUN}= Share of N deposited on fields or pastures lost by surface runoff

LF_{LEA}= Share of N deposited on fields or pastures lost by leaching below soils

EF_{GRAZ}^{NH3} = Emission factor for NH_3 during grazing, kg N per head

EF_{GRAZ}^{NOx} = Emission factor for NO_x during grazing, kg N per head

EF_{GRAZ}^{N2O} = Emission factor for N_2O during grazing, kg N_2O per head

EF_{MAN}^{NH3} = Emission factor for NH_3 during housing and storage, kg N per head

EF_{MAN}^{NOx} = Emission factor for NO_x during housing and storage, kg N per head

EF_{HOUS}^{N2O} = Emission factor for N_2O during housing, kg N per head

EF_{STOR}^{N2} = Emission factor for N_2 during storage, kg N per head

EF_{AP}^{NH3} = Emission factor for NH_3 during application, kg N per head

EF_{AP}^{NOx} = Emission factor for NO_x during application, kg N per head

EF_{AP}^{N2O} = Emission factor for N_2O during application, kg N_2O per head

EF_{MIN}^{NH3} = Emission factor for NH_3 during application of chemical fertilizers on managed soils, kg N per ha

EF_{MIN}^{NOx} = Emission factor for NO_x during application of chemical fertilizers on managed soils, kg N per ha

EF_{MIN}^{N2O} = Emission factor for N_2O during application of chemical fertilizers on managed soils, kg N_2O per ha

$EF_{LEA+RUN}^{N2O}$ = Emission factor for indirect N_2O-emissions from leaching and runoff, kg N_2O per ha

The loss factor for superficial runoff (LF_{RUN}), which is used for the calculation of surface runoff from grazing animals, manure application upon managed soils and application of mineral fertilizers (see corresponding section under Animal feed production), is differentiated by NUTS2 regions and ranges from 14.67% in Severoiztochen (Bulgaria) to 0.17% in Oevre Norrland (Sweden). The complete list for all NUTS2 regions is presented in Table A1 in the appendix. The loss factor for leaching during housing and storage ($LF_{RUN,S}^{MAN}$) depends on the management system *s* (Liquid/Solid) and the national penetration rate of the nitrate directive (P_{ND}). Without the implementation of the nitrate directive measures a general loss factor of 7.18% for solid systems is assumed. For liquid systems CAPRI uses a loss factor of 2% for Belgium, Denmark, Germany, France, Ireland, Netherlands, Sweden, Finland, United Kingdom and Luxemburg, and 5% for all other countries. Where, in contrast, the nitrate directive measures are already implemented, a general loss factor of 3.23% for solid systems and zero losses for liquid systems are applied. For those animal categories, for which solid and liquid systems are not differentiated (poultry, sheep and goats), the values of solid systems are in use. The penetration rates of nitrate directive measures are supposed to be 100% for Denmark, Finland and the Netherlands, 50% for Germany, and zero for all other member states. In the current version of CAPRI the calculation of losses for leaching during housing and storage is confined to nitrate vulnerable zones. Therefore, the loss factors are multiplied with the regional shares of nitrate vulnerable zones (*NVZ*).

The loss factor for leaching below soils (LF_{LEA}) is applied to the total N surplus of the agricultural system, as mentioned above. The N-surplus is calculated by summing up all N-imports to the agricultural system and subtracting all N-exports via products, gaseous losses or losses from superficial runoff and leaching during manure management. A certain share of the surplus is assumed to volatilize as N_2 (denitrification) or contribute to N-accumulation in soils and the zone between soils and groundwater. The rest (NT_{LEA}) is supposed to be leached into the groundwater. It is achieved by multiplying the surplus by the loss factor (LF_{LEA}), which is specific to regions. LF_{LEA} for all regions can be found in Table A1.

In order to get estimates for the N_2O-emissions from leaching and runoff, NT_{LEA} is first added to NT_{RUN}^{MIN} and $NT_{RUN}^{GRAZ+MAN+AP}$, and then the loss factor $LF_{LEA+RUN}^{N2O}$ is applied. $LF_{LEA+RUN}^{N2O}$ is assumed to be 0.75% in correspondence to the emission factor EF_5, recommended by the IPCC guidelines (see IPCC, 2006: Vol.4, Tab.11.3).

Unfortunately, until now CAPRI does not yield reasonable and consistent results due to unsolved problems in the Code. Those problems will be removed during the second phase of the project, but for the moment a meaningful presentation of values for N runoff, leaching and N_2O-emissions, and a comparison with National Inventory results is not possible. The National Inventories still apply the old N_2O-emission factor of 2.5% (compared to 0.75% in CAPRI), and a general loss factor for leaching and runoff of 30% of all N-inputs. The 30% are recommended by the IPCC guidelines (see $Frac_{Leach-(H)}$, IPCC, 2006: Vol.4, Tab.11.3), but only for regions, where the soil water-holding capacity is exceeded. For other regions a zero value should be applied, which is not implemented in the National inventories. Therefore, National Inventory data are expected to overestimate emissions with respect to IPCC recommendation, which has to be considered for a future comparison of results. The reasonability of the parameters used in CAPRI need to be checked carefully before and during the second phase of the project, since the CAPRI-approach deviates considerably from the IPCC standard method, and, therefore, the comparison is not straightforward.

Animal feed Production

CAPRI distinguishes marketable and not marketable feeds. Not marketable feeds are those coming from pure fodder activities like grass, straw, fodder maize, root crops, silage, and milk from suckling cows, mother goats or sheep. They are not traded between regions and, therefore, have to be used within the region where they are produced. Marketable feeds, in contrast, are usually products with alternative uses (e.g. soft wheat is also used for human consumption and industrial production). They are not necessarily consumed within the region, but sold on the market for a fixed price. For non marketable feeds the allocation to the livestock sector is straightforward, since production activities are exclusively devoted to feed production. Marketable feeds, however, are at the one hand used for various purposes, and at the other hand can be imported or exported among EU-countries and from/to the world market. Emissions of production activities, therefore, have to be split up according to usage for the sake of this study, which has not been done yet. So, emission factors and emissions presented in this interim report will include all emissions from arable land, which is also reasonable for comparison to the results of national inventories, where this distinction isn't done either.

Emissions of N_2O, NH_3 and NO_x

Emissions sources of N_2O, NH_3 and NO_x, which have not been discussed in the chapter on livestock rearing, are the application of mineral fertilizers and crop residues upon managed soils. The chemical processes are the same as those mentioned above. N_2O -Emissions are produced during the following stages of the N-cycle:

1) Directly, in soils (with respect to mineral fertilizers and crop residues deposited on grassland or arable land)
2) Indirectly, via the volatilisation of NH_3 and NO_x from deposition of mineral fertilizers on grassland and arable land
3) Indirectly, after leaching and runoff of nitrogen during N deposition of mineral fertilizers on grassland and arable land

In this chapter only direct emissions are discussed, since indirect emissions have been treated in the chapter on livestock rearing.

Direct emissions from the use of mineral fertilizers for the production of feed crops

This section includes all emissions of NH_3, NO_x and N_2O, which are induced by the deposition of mineral fertilizers on agricultural soils (including grassland). The calculation in CAPRI follows the approach of the MITERRA-EUROPE project, and, therefore, the methodology is similar as in proceeding section on animal rearing. Mineral fertilizers are differentiated by ureum and other fertilizers. The calculation is based on the following formulas:

$$EF_{MIN}^{NH3} = N_{MIN} * \sum_K FS_K * LF_{MIN,K}^{NH3}$$

$$EF_{MIN}^{NOx} = N_{MIN} * \sum_K FS_K * LF_{MIN,K}^{NOx}$$

$$EF_{MIN}^{N2O} = \left(N_{MIN} - EF_{MIN}^{NH3} - EF_{MIN}^{NOx}\right) * \sum_K FS_K * LF_{MIN,K}^{N2O} * \frac{44}{28}$$

N_{MIN} = N in chemical fertilizers applied to pastures and crops, kg per ha

FS_K = fraction of applied fertilizer type k (k=ureum, other fertilizers) in total chemical fertilizer applied

$LF_{MIN,K}^{NH3}$ = Share of N in fertilizer type k, lost as NH_3

$LF_{MIN,K}^{NOx}$ = Share of N in fertilizer type k, lost as NO_x

$LF_{MIN,K}^{N2O}$ = Share of N in fertilizer type k, lost as N_2O

EF_{MIN}^{NH3} = Emission factor for NH_3 during application of chemical fertilizers on managed soils, kg N per ha

EF_{MIN}^{NOx} = Emission factor for NO_x during application of chemical fertilizers on managed soils, kg N per ha

EF_{MIN}^{N2O} = Emission factor for N_2O during application of chemical fertilizers on managed soils, kg N_2O per ha

The total amount of N applied as mineral fertilizers (N_{MIN}) in 1000 tons is presented in Table 30. It is based on member state data of the European Fertilizer Manufacturer's Association as published by FAOSTAT and expert questionnaire data from EFMA reporting average mineral fertilizer application rates per crop and Member States, but the exact allocation to crops in CAPRI is done by an algorithm for input allocation. This algorithm estimates the most probable organic and inorganic rates which at the one hand exhaust the available organic and inorganic nutrient at Member State level, and on the other hand cover crop needs plus losses from Ammonia emission. However, it has to be emphasized, that there is no evidence, that the allocation of mineral fertilizers to crops corresponds to the real values, and so also crop specific emissions can only be seen as a rough estimate. For EU27 CAPRI calculates a total amount of around 11.1 Mio tons of N, which is 5% more than reported by the member states. Except for a few countries, like Portugal, Cyprus, Czech Republic, Hungary, Latvia and Malta, the correspondence between CAPRI and National Inventories is good. Most of chemical fertilizers are used for the production of cereals and grass.

Table 30: Application of chemical fertilizers in CAPRI compared to those reported by the member states (National Inventories of 2007 for 2002) in 1000 t

	CAPRI			***NI[1]***
	Non marketable feeds	***Marketable crops (total)***	***Total***	***Total***

	Fodder maize	Fodder root crops	Other fodder on arable land	Grassland	Cereals	Oilseeds	Other crops		
Belgium	12.34	0.78	0.00	57.61	58.78	1.05	33.76	***164.32***	***171.17***
Denmark	2.71	1.55	0.00	13.33	160.65	7.08	22.42	***207.74***	***206.17***
Germany	95.34	1.81	30.69	314.17	997.32	145.70	214.11	***1799.13***	***1791.69***
Greece	0.51	0.02	0.68	38.23	107.64	62.73	48.64	***258.46***	***227.70***
Spain	7.28	1.72	2.89	257.01	533.09	97.31	186.18	***1085.48***	***1004.53***
France	63.12	2.35	0.00	417.62	1419.13	212.98	201.15	***2316.35***	***2157.72***
Ireland	3.17	1.07	111.78	193.74	40.87	0.38	13.34	***364.33***	***357.49***
Italy	25.00	0.78	0.00	98.27	469.50	34.71	160.24	***788.49***	***745.29***
Netherlands	17.85	0.18	0.00	134.69	46.31	0.38	90.67	***290.07***	***282.52***
Austria	7.01	0.04	0.00	23.35	71.85	6.15	10.24	***118.65***	***119.03***
Portugal	6.77	0.19	0.00	36.54	34.09	7.04	18.43	***103.06***	***154.53***
Sweden	0.00	0.00	57.09	12.89	105.88	2.70	10.89	***189.44***	***184.80***
Finland	0.00	0.01	1.62	40.42	106.24	6.54	8.67	***163.50***	***159.44***
United Kingdom	6.26	0.32	25.30	517.44	460.44	70.97	76.17	***1156.89***	***1172.14***
Cyprus	0.00	0.00	1.13	0.03	3.24	0.23	3.48	***8.12***	***10.72***
Czech Republic	10.16	0.31	31.91	25.38	160.86	37.34	23.25	***289.21***	***204.50***
Estonia	0.00	0.00	0.00	1.71	11.98	2.09	2.08	***17.87***	***16.70***
Hungary	0.00	0.01	11.22	19.38	271.80	32.57	18.58	***353.57***	***272.70***
Lithuania	0.14	4.26	18.14	26.58	44.79	1.07	15.13	***110.11***	***115.00***
Latvia	0.01	0.29	0.65	7.72	17.68	1.45	7.27	***35.08***	***24.84***
Malta	0.00	0.01	0.00	0.00	0.01	0.00	0.31	***0.32***	***0.73***
Poland	15.91	8.42	10.50	69.43	560.11	46.69	133.15	***844.21***	***775.80***
Slovenia	2.06	0.14	1.26	11.43	14.36	0.35	4.19	***33.78***	***30.07***
Slovakia	5.55	0.00	6.60	8.51	45.25	14.08	5.70	***85.69***	***79.43***
Bulgaria	0.00	0.01	2.00	14.37	108.45	26.43	3.54	***154.82***	***139.87***
Romania	0.00	0.00	0.00	17.77	191.78	34.35	0.30	***244.20***	***215.10***
EU27	***281.21***	***24.28***	***313.46***	***2357.60***	***6042.08***	***852.37***	***1311.88***	***11182.89***	***10619.68***

Sources: EEA, 2008, own calculations; 1) NI=National Inventories

The applied N_2O-loss factor (*LF*) corresponds to the default emission factor of 1%, recommended in the 2006 IPCC guidelines (IPCC, 2006: Vol.4, Tab.11.1). In contrast, the national inventories use the old emission factor of 1.25%. For volatilisation as NH_3 and NO_x the IPCC guidelines recommend cumulative losses of 10% (IPCC, 2006: Vol.4, Tab.11.3). The CAPRI-loss factors for NH_3+NO_x, those used in the National inventories, and the assumed fractions of applied fertilizer types (ureum and other fertilizers) are presented in Table 31:

Table 31: Shares of fertilizer type (ureum, other fertilizers) use and NH_3+NO_x-loss factors in CAPRI compared to those reported by the member states (National Inventories of 2007 for 2002) in Percent

	CAPRI							***NI***[1]
	Shares of fertilizer types		NH3-loss factors		NH3+NOx loss factors			
	Ureum	Others	Ureum	Others	Ureum	Others	***Total***	***Total***
Belgium	1	99	15	2	15.3	2.3	***2.43***	***4.3***
Denmark	1	99	15	2	15.3	2.3	***2.43***	***2.2***
Germany	16	84	15	1	15.3	1.3	***3.54***	***4.7***

	CAPRI							NI[1]
	Shares of fertilizer types		NH3-loss factors		NH3+NOx loss factors			
	Ureum	Others	Ureum	Others	Ureum	Others	***Total***	***Total***
Greece	2	98	20	4	20.3	4.3	***4.62***	***10.0***
Spain	26	74	16	4	16.3	4.3	***7.42***	***6.3***
France	10	90	15	4	15.3	4.3	***5.4***	***10.0***
Ireland	14	86	18	2	18.3	2.3	***4.54***	***1.7***
Italy	44	56	15	3	15.3	3.3	***8.58***	***9.0***
Netherlands	0	100	15	2	15.3	2.3	***2.3***	
Austria	3	97	15	2	15.3	2.3	***2.69***	***2.7***
Portugal	18	82	15	3	15.3	3.3	***5.46***	***5.7***
Sweden	0	100	15	1	15.3	1.3	***1.3***	***1.4***
Finland	1	99	15	1	15.3	1.3	***1.44***	***0.6***
United Kingdom	7	93	15	2	15.3	2.3	***3.21***	***10.0***
Cyprus	8	92	15	3	15.3	3.3	***4.26***	***10.0***
Czech Republic	12	88	15	3	15.3	3.3	***4.74***	***10.0***
Estonia	4	96	15	2	15.3	2.3	***2.82***	***10.0***
Hungary	12	88	15	3	15.3	3.3	***4.74***	***10.0***
Lithuania	0	100	15	7	15.3	7.3	***7.3***	***10.0***
Latvia	32	68	15	2	15.3	2.3	***6.46***	***10.0***
Malta	0	100	15	2	15.3	2.3	***2.3***	
Poland	25	75	15	4	15.3	4.3	***7.05***	***10.0***
Slovenia	15	85	15	2	15.3	2.3	***4.25***	***10.0***
Slovakia	16	84	15	2	15.3	2.3	***4.38***	***10.0***
Bulgaria	11	89	15	3	15.3	3.3	***4.62***	***10.0***
Romania	34	66	15	3	15.3	3.3	***7.38***	***10.0***

Sources: EEA, 2008, own calculations; 1) NI=National Inventories

Tables 32 and 33 show the N_2O-emission factors (*EF*) and total direct N_2O-emissions from application of chemical fertilizers. For the EU27 CAPRI estimates total emissions of 167 thousand tons, which are 84% of the emissions reported by the member states. The difference mainly accrues from a 25% higher loss factor in National Inventories, while, apart from that, emissions correspond very well. For a few countries deviations are higher, which is due to the different values on chemical fertilizer-application, shown in Table 30. 45 thousand tons of emissions are due to the production of non marketable feeds, the share coming from marketable feeds will be quantified in the second phase of the project.

Table 32: CAPRI-Emission factors for N_2O emissions from application of chemical fertilizers in kg per ha and year

	Non marketable feeds				***Marketable crops (total)***			***Total***
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
Belgium	1.04	2.07	0	1.51	2.75	0.72	1.71	1.65
Denmark	0.44	2.3	0	1.13	1.66	1.71	0.91	1.14
Germany	1.26	2.31	1.04	0.95	2.17	2.31	1.30	1.60
Greece	1.14	0.91	0.03	0.32	1.23	0.86	0.47	0.64
Spain	1.25	0.48	0.04	0.52	1.17	0.46	0.37	0.62

	Non marketable feeds				Marketable crops (total)			Total
	Fodder maize	Fodder root crops	Other fodder on arable land	Grassland	Cereals	Oilseeds	Other crops	
France	0.63	0.78	0	0.62	2.33	2.13	0.65	1.15
Ireland	2.6	2.48	2.15	0.9	2.07	2.88	2.16	1.24
Italy	1.27	1.01	0	0.32	1.61	0.36	0.72	0.74
Netherlands	1.29	3.62	0	2.41	3.06	1.07	3.07	2.33
Austria	1.47	0.73	0	0.19	1.34	0.97	0.47	0.54
Portugal	0.89	0.31	0	0.37	1.04	0.26	0.25	0.39
Sweden	0	0	0.92	0.45	1.44	1.09	0.40	0.98
Finland	0	1.11	1.44	1	1.40	1.40	0.45	1.15
United Kingdom	0.78	0.12	0.32	0.7	2.27	2.67	1.01	1.02
Cyprus	0	0.85	0.74	0.52	0.89	0.49	1.54	1.02
Czech Republic	0.7	1.55	1.3	0.43	1.55	1.32	0.79	1.11
Estonia	0.14	0.02	0	0.21	0.69	0.90	0.47	0.36
Hungary	0	0.12	0.71	0.27	1.38	0.84	0.41	0.94
Lithuania	0.15	1.89	1.25	0.34	0.72	0.25	0.53	0.58
Latvia	0.15	0.53	0.03	0.19	0.60	1.12	0.53	0.33
Malta	0	2.5	0	0	0.14		0.89	0.46
Poland	1.13	1.66	0.36	0.28	0.97	1.48	0.49	0.72
Slovenia	1.4	0.54	0.75	0.56	2.14	0.83	1.59	1.01
Slovakia	0.84	0	0.61	0.16	0.83	1.06	0.53	0.57
Bulgaria	0	0.22	0.3	0.12	0.83	0.75	0.06	0.43
Romania	0	0	0	0.05	0.47	0.44	0.00	0.24

Table 33: N_2O emissions from application of mineral fertilizers for 2002: CAPRI-Values compared to those reported by the member states (National Inventories of 2007 for 2002) in 1000 t

	CAPRI								NI[1]
	Non marketable feeds				Marketable crops (total)			Total	Total
	Fodder maize	Fodder root crops	Other fodder on arable land	Grassland	Cereals	Oilseeds	Other crops		
Belgium	0.19	0.01	0.00	0.89	0.90	0.02	0.52	***2.53***	***3.36***
Denmark	0.04	0.02	0.00	0.21	2.46	0.11	0.34	***3.18***	***4.05***
Germany	1.44	0.03	0.46	4.73	15.07	2.20	3.23	***27.17***	***33.56***
Greece	0.01	0.00	0.01	0.57	1.62	0.94	0.73	***3.88***	***4.47***
Spain	0.11	0.03	0.04	3.73	7.74	1.41	2.70	***15.74***	***18.49***
France	0.94	0.04	0.00	6.19	21.14	3.18	3.00	***34.48***	***42.38***
Ireland	0.05	0.02	1.67	2.88	0.61	0.01	0.20	***5.43***	***7.02***
Italy	0.36	0.01	0.00	1.40	6.74	0.50	2.30	***11.30***	***14.64***
Netherlands	0.27	0.00	0.00	2.06	0.71	0.01	1.39	***4.44***	***4.65***
Austria	0.11	0.00	0.00	0.36	1.10	0.09	0.16	***1.82***	***2.34***
Portugal	0.10	0.00	0.00	0.54	0.51	0.10	0.27	***1.52***	***3.04***
Sweden	0.00	0.00	0.89	0.20	1.65	0.04	0.17	***2.95***	***2.29***
Finland	0.00	0.00	0.03	0.63	1.65	0.10	0.13	***2.54***	***3.13***
United Kingdom	0.10	0.00	0.39	7.86	7.03	1.08	1.16	***17.63***	***23.02***
Cyprus	0.00	0.00	0.02	0.00	0.05	0.00	0.05	***0.12***	***0.19***
Czech Republic	0.15	0.00	0.48	0.38	2.40	0.56	0.35	***4.32***	***4.02***
Estonia	0.00	0.00	0.00	0.03	0.18	0.03	0.03	***0.27***	***0.30***

	CAPRI								*NI*[1]
	Non marketable feeds				*Marketable crops (total)*			*Total*	*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*		
Hungary	0.00	0.00	0.17	0.29	4.10	0.49	0.28	***5.32***	***5.36***
Lithuania	0.00	0.06	0.27	0.39	0.65	0.02	0.22	***1.61***	***2.03***
Latvia	0.00	0.00	0.01	0.12	0.26	0.02	0.11	***0.52***	***0.49***
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***	***0.01***
Poland	0.23	0.12	0.15	1.00	8.16	0.68	1.93	***12.28***	***10.84***
Slovenia	0.03	0.00	0.02	0.17	0.22	0.01	0.06	***0.51***	***0.59***
Slovakia	0.08	0.00	0.10	0.13	0.68	0.21	0.09	***1.29***	***1.56***
Bulgaria	0.00	0.00	0.03	0.21	1.62	0.40	0.05	***2.32***	***2.20***
Romania	0.00	0.00	0.00	0.25	2.79	0.50	0.00	***3.54***	***4.23***
EU27	***4.20***	***0.36***	***4.72***	***35.20***	***90.04***	***12.70***	***19.49***	***166.71***	***198.26***

Sources: EEA, 2008, own calculations; 1) NI=National Inventories

Direct emissions from crop residues of feed crops

Crop residues, if left on the field, serve as a supplier of nutrients, like manure or chemical fertilizers, and are, therefore, sources of N-emissions. In contrast to manure and chemical fertilizers, CAPRI, until now, calculates only direct N_2O-emissions for N of crop residues, but not emissions of NH_3 and NO_x. As a consequence, crop residues do not contribute to indirect N_2O-emissions via volatilisation of NH_3 and NO_x. This has to be changed during the second phase of the project. CAPRI estimates the emissions according to the following formulas:

$$N_{CR} = N_{PLANT} * F_{CR}$$

$$EF_{CR}^{N2O} = N_{CR} * (1 - CRBU - CRFU - CRFE) * LF_{CR}^{N2O} * \frac{44}{28}$$

N_{CR} = N delivery from crop residues, kg per ha

N_{PLANT} = N uptake of the plant (harvested product + residues), kg N per ha

F_{CR} = relation of N in crop residues to N uptake by plants (crop specific)

$CRBU$ = share of crop residues burned on the field

$CRFU$ = share of crop residues used as fuel

$CRFE$ = share of crop residues used as animal feed

LF_{CR}^{N2O} = Share of N of crop residues, lost as N_2O

EF_{CR}^{N2O} = Emission factor for N_2O for N from crop residues, kg N_2O per ha

The delivery of N (N_{CR}) is calculated for each crop by the multiplication of the N uptake of the grown pants (N_{PLANT}) with a crop-specific factor (F_{CR}). N_{PLANT} depends on the country-specific yield, while the factor F_{CR} describes the assumed relation of N in crop residues to the N uptake by the whole plant. F_{CR} is assumed to be crop specific but not country specific. The shares of crop residues, which are burned at the field (*CRBU*) or used as fuel (*CRFU*) or feed (*CRFE*) do not contribute to N delivery and are therefore subtracted. Due to a lack of meaningful estimations

CRFU and *CRFE* are currently assumed to be zero. *CRBU* is supposed to be 10% for Greece, Spain, Italy, Portugal and the new member states, while the other countries are not supposed to practise the burning of crop residues.

The resulting amounts of N delivery for the member states and various groups of crops is presented in Table 34, and compared to the assumed values of the National inventories. Therefore, 4.7 Mio tons of N are supposed to come from crop residues, which is about 80% more than what the member states report. The CAPRI-values on country level deviate even stronger from the National Inventory data for some member states, especially Ireland, Lithuania and Greece. The reasonability of the used numbers has to be examined during the second phase of the project.

Table 34: N-delivery from crop residues in CAPRI compared to those reported by the member states (National Inventories of 2007 for 2002) in 1000 t

	CAPRI								***NI[1]***
	Non marketable feeds				***Marketable crops (total)***			***Total***	***Total***
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***		
Belgium	5.55	0.53	3.03	8.22	10.44	0.62	26.09	***54.49***	***57.90***
Denmark	2.35	0.79	49.85	9.47	34.00	3.47	14.59	***114.53***	***53.42***
Germany	32.68	0.66	25.57	180.74	194.08	54.67	123.61	***612.01***	***274.36***
Greece	0.13	0.01	3.01	9.11	27.88	29.00	19.98	***89.11***	***25.10***
Spain	2.41	0.70	15.00	54.76	103.24	33.45	62.94	***272.50***	***125.43***
France	39.70	2.56	162.93	273.13	334.85	79.38	150.79	***1043.34***	***490.85***
Ireland	0.80	0.35	68.66	144.56	8.17	0.11	5.94	***228.59***	***17.76***
Italy	7.93	0.58	30.83	30.61	134.65	27.82	64.96	***297.39***	***142.46***
Netherlands	6.47	0.05	6.97	25.01	7.89	0.14	37.12	***83.65***	***35.38***
Austria	2.08	0.04	3.22	26.84	30.14	4.17	11.67	***78.16***	***36.40***
Portugal	1.51	0.05	10.04	18.45	10.93	1.91	6.03	***48.91***	***24.13***
Sweden	0.10	0.00	52.34	11.92	21.83	1.67	10.30	***98.16***	***54.09***
Finland	0.00	0.00	0.28	6.41	16.50	1.83	4.30	***29.33***	***27.88***
United Kingdom	2.80	0.48	81.67	407.40	78.53	23.73	47.70	***642.30***	***441.53***
Cyprus	0.00	0.00	0.23	0.01	0.47	0.07	1.01	***1.79***	
Czech Republic	4.00	0.09	12.85	17.45	25.87	13.97	15.74	***89.98***	***85.46***
Estonia	0.01	0.02	10.04	2.94	2.04	0.97	0.63	***16.64***	***8.02***
Hungary	1.62	0.02	8.91	19.61	79.85	16.03	12.23	***138.27***	***96.72***
Lithuania	0.20	1.05	8.92	28.83	9.52	1.65	6.81	***56.98***	***11.31***
Latvia	0.02	0.15	11.27	14.01	3.54	0.47	2.75	***32.21***	***20.81***
Malta	0.00	0.00	0.04	0.00	0.01	0.00	0.15	***0.20***	***0.00***
Poland	5.34	2.39	13.87	72.58	113.08	16.03	61.43	***284.73***	***161.04***
Slovenia	0.40	0.03	0.22	1.37	3.61	0.12	1.31	***7.06***	***5.45***
Slovakia	1.46	0.06	5.43	13.11	13.95	5.82	5.35	***45.18***	***66.68***
Bulgaria	0.35	0.01	1.42	12.41	26.08	9.18	6.89	***56.35***	
Romania	0.33	0.91	35.05	110.26	112.18	20.81	16.30	***295.84***	***346.98***
EU27	***118.25***	***11.54***	***621.65***	***1499.22***	***1403.34***	***347.09***	***716.60***	***4717.69***	***2609.16***

Sources: EEA, 2008, own calculations; 1) NI=National Inventories

The applied loss factor (*LF*) corresponds to the value of 1%, recommended in the IPCC 2006 guidelines (IPCC, 2006: Vol.4, Tab.11.1), while in National Inventories most countries still use the old value of 1.25%. Therefore, the deviations between CAPRI and inventory data for N-deliveries are to some extent balanced out in emission values, shown in Table 35 and 36. CAPRI estimates N_2O-emissions from crop residues of 74 thousand tons for EU27, about 50% more than to what the numbers of the inventories add up. Almost half of those emissions (35 thousand tons) come from the production of non marketable feeds, while the share of marketable crops, which is related to livestock production in Europe, will be quantified in the second phase of the project. The highest shares of emissions are those of grassland and cereals. However, this is not caused by above average per hectare values but by the large amount of land in use for those groups (see Table 35).

Table 35: CAPRI-Emission factors (EF) for N_2O emissions from crop residues in kg per ha and year

	Non marketable feeds				***Marketable crops (total)***			***Total***
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
Belgium	0.48	1.45	0.47	0.22	0.50	0.44	1.35	0.56
Denmark	0.39	1.2	1.36	0.82	0.36	0.86	0.61	0.65
Germany	0.45	0.88	0.9	0.57	0.44	0.90	0.78	0.57
Greece	0.3	0.3	0.16	0.08	0.33	0.42	0.20	0.23
Spain	0.45	0.21	0.25	0.12	0.25	0.17	0.14	0.17
France	0.42	0.89	0.77	0.43	0.58	0.84	0.51	0.55
Ireland	0.69	0.86	1.39	0.71	0.44	0.89	1.01	0.82
Italy	0.44	0.82	0.26	0.11	0.51	0.31	0.32	0.31
Netherlands	0.48	1.14	0.75	0.46	0.54	0.39	1.29	0.69
Austria	0.45	0.79	0.35	0.22	0.58	0.68	0.55	0.36
Portugal	0.21	0.08	0.4	0.2	0.35	0.08	0.09	0.20
Sweden	0.42	0	0.85	0.42	0.30	0.68	0.38	0.51
Finland	0	0.32	0.25	0.16	0.22	0.40	0.22	0.21
United Kingdom	0.36	0.19	1.06	0.57	0.40	0.92	0.65	0.58
Cyprus	0	0.43	0.16	0.09	0.14	0.15	0.47	0.24
Czech Republic	0.29	0.48	0.55	0.31	0.26	0.52	0.57	0.36
Estonia	0.23	0.35	0.59	0.37	0.12	0.43	0.15	0.34
Hungary	0.2	0.18	0.59	0.29	0.42	0.43	0.28	0.38
Lithuania	0.24	0.5	0.66	0.4	0.17	0.41	0.25	0.32
Latvia	0.23	0.3	0.56	0.36	0.13	0.38	0.21	0.32
Malta	0	1.06	0.15	0	0.08		0.44	0.29
Poland	0.41	0.51	0.51	0.32	0.21	0.55	0.24	0.26
Slovenia	0.28	0.14	0.14	0.07	0.56	0.30	0.52	0.22
Slovakia	0.23	0.32	0.52	0.26	0.27	0.46	0.52	0.32
Bulgaria	0.11	0.12	0.22	0.11	0.21	0.27	0.12	0.17
Romania	0.2	0.41	0.54	0.35	0.30	0.29	0.15	0.31

Table 36: N_2O emissions from crop residues for 2002: CAPRI-Values compared to those reported by the member states (National Inventories of 2007 for 2002) in 1000 t

	CAPRI			***NI***[1]
	Non marketable feeds	***Marketable crops (total)***	***Total***	***Total***

	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*		
Belgium	0.09	0.01	0.05	0.13	0.16	0.01	0.41	***0.86***	***1.14***
Denmark	0.04	0.01	0.78	0.15	0.53	0.05	0.23	***1.80***	***1.05***
Germany	0.51	0.01	0.40	2.84	3.05	0.86	1.94	***9.62***	***4.31***
Greece	0.00	0.00	0.05	0.14	0.44	0.46	0.31	***1.40***	***0.49***
Spain	0.04	0.01	0.24	0.86	1.62	0.53	0.99	***4.28***	***2.46***
France	0.62	0.04	2.56	4.29	5.26	1.25	2.37	***16.40***	***9.64***
Ireland	0.01	0.01	1.08	2.27	0.13	0.00	0.09	***3.59***	***0.35***
Italy	0.12	0.01	0.48	0.48	2.12	0.44	1.02	***4.67***	***2.80***
Netherlands	0.10	0.00	0.11	0.39	0.12	0.00	0.58	***1.31***	***0.56***
Austria	0.03	0.00	0.05	0.42	0.47	0.07	0.18	***1.23***	***0.71***
Portugal	0.02	0.00	0.16	0.29	0.17	0.03	0.09	***0.77***	***0.47***
Sweden	0.00	0.00	0.82	0.19	0.34	0.03	0.16	***1.54***	***1.06***
Finland	0.00	0.00	0.00	0.10	0.26	0.03	0.07	***0.46***	***0.55***
United Kingdom	0.04	0.01	1.28	6.40	1.23	0.37	0.75	***10.09***	***8.67***
Cyprus	0.00	0.00	0.00	0.00	0.01	0.00	0.02	***0.03***	***0.03***
Czech Republic	0.06	0.00	0.20	0.27	0.41	0.22	0.25	***1.41***	***1.68***
Estonia	0.00	0.00	0.16	0.05	0.03	0.02	0.01	***0.26***	***0.16***
Hungary	0.03	0.00	0.14	0.31	1.25	0.25	0.19	***2.17***	***1.90***
Lithuania	0.00	0.02	0.14	0.45	0.15	0.03	0.11	***0.90***	***0.22***
Latvia	0.00	0.00	0.18	0.22	0.06	0.01	0.04	***0.51***	***0.41***
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***	
Poland	0.08	0.04	0.22	1.14	1.78	0.25	0.97	***4.47***	***2.53***
Slovenia	0.01	0.00	0.00	0.02	0.06	0.00	0.02	***0.11***	***0.11***
Slovakia	0.02	0.00	0.09	0.21	0.22	0.09	0.08	***0.71***	***1.31***
Bulgaria	0.01	0.00	0.02	0.19	0.41	0.14	0.11	***0.89***	***0.62***
Romania	0.01	0.01	0.55	1.73	1.76	0.33	0.26	***4.65***	***6.82***
EU27	***1.86***	***0.18***	***9.77***	***23.56***	***22.05***	***5.45***	***11.26***	***74.14***	***50.05***

Sources: EEA, 2008, own calculations; 1) NI=National Inventories

Other direct and indirect sources of greenhouse gas emissions

Manufacturing of fertilizers

Mineral fertilizers do not only contribute to GHG emissions when applied to fields or pastures, but also during the production process. Emissions occur in form of CO_2 and N_2O. CAPRI uses a simplistic approach with a unique factor for each nutrient (N, P_2O_5, K_2O) and the two greenhouse gases, not differentiating between various fertilizer types. For the second phase of the project country-specific factors with respect to the observed regional distribution of fertilizer types will be implemented. The factors include both emissions from N-losses and energy usage in the production process. The calculation corresponds to the following formulas:

$$EF_N^x = N_{MIN} * LF_N^x$$
$$EF_P^x = P_{MIN} * LF_P^x$$
$$EF_K^x = K_{MIN} * LF_K^x$$

N_{MIN} = N in chemical fertilizers applied to pastures and crops, kg per ha

P_{MIN} = P_2O_5 in chemical fertilizers applied to pastures and crops, kg per ha

K_{MIN} = K_2O in chemical fertilizers applied to pastures and crops, kg per ha

x = N_2O, CO_2

LF_N^x = x-factors during Production of N-fertilizers, kg x per kg N

LF_P^x = x- factors during Production of P_2O_5-fertilizers, kg x per kg N

LF_N^x = x- factors during Production of K_2O -fertilizers, kg x per kg N

EF_N^x = Emission factor for x-Losses during Production of N-fertilizers, kg x per ha

EF_P^x = Emission factor for x-Losses during Production of P_2O_5-fertilizers, kg x per ha

EF_K^x = Emission factor for x-Losses during Production of K_2O -fertilizers, kg x per ha

The applied N_2O- and CO_2-factors (*LF*) are presented in Table 37, the emission factors (*EF*) and total emissions for crop groups in tables 38 to 41. As already mentioned in the section on mineral fertilizer application the statistical knowledge on the allocation of mineral fertilizers to crops is very poor, and so the estimates in CAPRI are the outcome of an optimization procedure, which tries to use the available information in the most efficient way, but above all serves to satisfy the nutrient requirement functions of the model. So, the results on crop level should be used with precaution. The distribution of emissions is similar to what has already been discussed in the section on mineral fertilizer application. N_2O-Emissions from fertilizer production for EU27 amount to 144 thousand tons, which is about 70% of the emissions from fertilizer application. CO_2-emissions, according to CAPRI, are quantified at 32 Mio tons, which, in terms of GHG-potential, corresponds to 75% of N_2O-Emissions from fertilizer application. 26% of emissions come from non marketable feeds and are, therefore, directly due to livestock production. The feed share of marketable crops will be quantified in the second phase of the project. The countries with the highest per hectare emissions are the Netherlands, Belgium and Germany, while the lowest ones can be found in Romania, Latvia and Estonia.

Table 37: LF for the N_2O- and CO_2-emissions during the production of mineral fertilizers, in kg gas per ton of nutrient (N, P_2O_5, K_2O)

	CO_2	**N_2O**
N	2543.6	11.3
P_2O_5	972.7	4.3
K_2O	140	0.6

Table 38: CAPRI-Emission factors (EF) for N_2O emissions from mineral fertilizer production in kg per ha and year

	Non marketable feeds	*Marketable crops (total)*	*Total*

	Fodder maize	Fodder root crops	Other fodder on arable land	Grassland	Cereals	Oilseeds	Other crops	
Belgium	0.91	1.79	0	1.29	2.14	0.60	1.48	***1.37***
Denmark	0.44	1.84	0.02	0.83	1.31	1.34	0.74	***0.91***
Germany	1.05	1.92	0.78	0.76	1.73	1.94	1.14	***1.30***
Greece	1.08	0.86	0.12	0.25	1.03	0.81	0.43	***0.56***
Spain	1.23	0.49	0.2	0.48	1.11	0.45	0.36	***0.60***
France	0.57	0.78	0.01	0.52	2.02	1.88	0.61	***1.00***
Ireland	1.97	1.95	2.01	0.71	1.87	2.45	1.99	***1.05***
Italy	1.02	0.99	0.01	0.33	1.49	0.38	0.69	***0.70***
Netherlands	1.07	2.92	0	1.87	2.34	0.86	2.58	***1.86***
Austria	1.37	0.71	0.04	0.14	1.18	0.89	0.44	***0.47***
Portugal	0.82	0.34	0.12	0.31	0.96	0.28	0.25	***0.37***
Sweden	0	0	0.75	0.37	1.09	0.91	0.36	***0.77***
Finland	0	1.01	1.19	0.86	1.14	1.21	0.41	***0.96***
United Kingdom	0.82	0.09	0.24	0.54	1.97	2.20	0.96	***0.84***
Cyprus	0	1.09	0.65	0.39	0.87	0.52	1.48	***0.98***
Czech Republic	0.53	1.21	0.98	0.33	1.26	1.08	0.73	***0.90***
Estonia	0.11	0.14	0	0.15	0.57	0.76	0.39	***0.29***
Hungary	0.02	0.09	0.53	0.21	1.11	0.70	0.36	***0.76***
Lithuania	0.12	1.8	1	0.31	0.62	0.25	0.48	***0.50***
Latvia	0.11	0.49	0.02	0.14	0.52	1.03	0.47	***0.27***
Malta	0	2.51	0	0	0.13		0.83	***0.43***
Poland	1.02	1.54	0.29	0.27	0.87	1.33	0.44	***0.65***
Slovenia	1.52	0.56	0.67	0.49	1.96	0.76	1.51	***0.92***
Slovakia	0.66	0.01	0.51	0.12	0.69	0.86	0.46	***0.47***
Bulgaria	0	0.16	0.22	0.09	0.66	0.57	0.05	***0.34***
Romania	0.01	0.03	0	0.04	0.40	0.45	0.00	***0.21***

Table 39: CAPRI-Emission factors (EF) for CO_2 emissions from mineral fertilizer production in kg per ha and year

	Non marketable feeds				Marketable crops (total)			Total
	Fodder maize	Fodder root crops	Other fodder on arable land	Grassland	Cereals	Oilseeds	Other crops	
Belgium	204.19	403.3	0	291.12	481.78	134.14	333.94	***309.06***
Denmark	98.34	414.53	4.06	186.83	295.37	301.67	167.61	***204.73***
Germany	236.85	432.01	174.85	170.89	389.62	436.84	256.95	***292.68***
Greece	242.54	194.72	27.37	57.06	233.45	183.33	97.40	***127.47***
Spain	278.39	111.29	44.58	108.39	251.15	102.64	81.66	***135.46***
France	128.95	176.97	2.32	116.83	454.30	425.28	136.29	***225.10***
Ireland	442.36	439.13	454.5	159.38	420.67	554.06	448.34	***236.93***
Italy	230.22	222.98	1.2	75.06	335.49	87.19	155.11	***158.10***
Netherlands	241.46	659.03	0	421.36	526.55	192.47	583.19	***419.72***
Austria	308.88	159.54	9.14	31.27	266.92	200.92	99.13	***104.72***
Portugal	185.8	75.95	27.96	69.86	217.60	63.29	57.30	***83.19***
Sweden	0.04	0	169.69	83.54	245.42	205.41	82.06	***173.64***
Finland	0	227.86	267.25	194.96	256.13	272.59	93.34	***216.91***
United Kingdom	184.74	20.66	53.15	120.83	444.36	495.15	215.70	***189.57***

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*	
Cyprus	0	246.1	145.94	88.88	196.55	117.41	333.15	***220.12***
Czech Republic	119.3	273.37	221.07	73.75	284.40	242.73	165.26	***203.16***
Estonia	23.8	33.18	0.01	34.84	127.93	172.02	87.98	***66.15***
Hungary	5.1	20.51	120.28	46.4	250.47	158.06	82.43	***171.56***
Lithuania	27.49	406.12	225.35	69.16	139.30	55.00	108.40	***113.35***
Latvia	25.11	110.73	5.26	32.1	117.58	232.34	105.16	***61.94***
Malta	0	567.53	0	0	31.02		187.15	***96.24***
Poland	229.69	346.82	66.14	61.08	195.81	299.34	99.83	***146.17***
Slovenia	342.82	125.59	151.92	109.91	441.25	170.68	339.92	***207.33***
Slovakia	148.28	1.3	114.72	27.32	155.11	194.52	104.20	***106.36***
Bulgaria	0	36.83	50.19	20.62	148.23	128.89	11.51	***76.65***
Romania	1.83	6.92	0.25	9.13	89.91	101.44	0.85	***46.96***

Table 40: Total N_2O emissions from mineral fertilizer production in 1000 tons

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*	
Belgium	0.17	0.01	0.00	0.76	0.70	0.01	0.45	***2.10***
Denmark	0.04	0.02	0.01	0.15	1.95	0.09	0.28	***2.53***
Germany	1.20	0.02	0.35	3.79	12.00	1.85	2.84	***22.05***
Greece	0.01	0.00	0.04	0.45	1.36	0.89	0.66	***3.41***
Spain	0.10	0.03	0.19	3.44	7.34	1.39	2.65	***15.13***
France	0.85	0.04	0.03	5.19	18.30	2.81	2.80	***30.01***
Ireland	0.04	0.01	1.56	2.27	0.55	0.00	0.18	***4.62***
Italy	0.29	0.01	0.02	1.44	6.24	0.54	2.20	***10.73***
Netherlands	0.23	0.00	0.00	1.60	0.54	0.00	1.17	***3.54***
Austria	0.10	0.00	0.01	0.27	0.97	0.09	0.15	***1.57***
Portugal	0.09	0.00	0.05	0.45	0.47	0.11	0.27	***1.45***
Sweden	0.00	0.00	0.73	0.17	1.25	0.03	0.15	***2.33***
Finland	0.00	0.00	0.02	0.54	1.34	0.09	0.13	***2.12***
United Kingdom	0.10	0.00	0.29	6.07	6.11	0.89	1.10	***14.56***
Cyprus	0.00	0.00	0.01	0.00	0.05	0.00	0.05	***0.12***
Czech Republic	0.11	0.00	0.36	0.29	1.96	0.45	0.32	***3.50***
Estonia	0.00	0.00	0.00	0.02	0.15	0.03	0.03	***0.22***
Hungary	0.00	0.00	0.13	0.22	3.30	0.41	0.25	***4.31***
Lithuania	0.00	0.06	0.21	0.35	0.56	0.02	0.20	***1.40***
Latvia	0.00	0.00	0.01	0.09	0.22	0.02	0.09	***0.43***
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Poland	0.21	0.11	0.12	0.96	7.31	0.61	1.74	***11.07***
Slovenia	0.03	0.00	0.02	0.15	0.20	0.00	0.06	***0.47***
Slovakia	0.07	0.00	0.08	0.10	0.57	0.17	0.07	***1.06***
Bulgaria	0.00	0.00	0.02	0.16	1.28	0.30	0.05	***1.81***
Romania	0.00	0.00	0.00	0.20	2.37	0.51	0.01	***3.08***
EU27	***3.63***	***0.33***	***4.25***	***29.11***	***77.09***	***11.31***	***17.90***	***143.63***

Table 41: Total CO_2 emissions from mineral fertilizer production in 1000 tons

	Non marketable feeds				***Marketable crops (total)***			***Total***
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
Belgium	37.08	2.34	0.00	170.98	158.22	2.99	101.44	***473.04***
Denmark	9.33	4.29	2.34	33.90	438.40	19.15	62.96	***570.37***
Germany	270.31	5.13	78.06	851.52	2704.39	416.91	639.67	***4965.99***
Greece	1.64	0.05	8.08	102.08	307.78	201.04	149.83	***770.51***
Spain	23.43	5.81	42.04	777.27	1655.08	312.73	597.10	***3413.47***
France	191.56	8.00	7.71	1166.12	4120.28	634.67	630.89	***6759.24***
Ireland	8.07	2.82	352.80	509.95	123.88	1.09	41.31	***1039.91***
Italy	65.21	2.48	2.24	328.27	1405.11	121.71	496.13	***2421.14***
Netherlands	51.12	0.49	0.00	360.03	121.85	1.05	263.90	***798.44***
Austria	22.47	0.12	1.32	59.96	217.83	19.33	33.05	***354.07***
Portugal	20.97	0.71	11.03	101.29	105.83	25.11	61.71	***326.65***
Sweden	0.00	0.00	164.20	37.27	280.33	7.87	34.54	***524.22***
Finland	0.00	0.03	4.68	122.83	302.07	19.79	28.22	***477.60***
United Kingdom	22.59	0.81	64.35	1357.11	1378.88	200.57	247.78	***3272.09***
Cyprus	0.00	0.02	3.33	0.08	10.73	0.84	11.30	***26.31***
Czech Republic	25.85	0.83	81.16	65.24	440.39	101.98	72.21	***787.67***
Estonia	0.01	0.02	0.00	4.35	33.96	6.12	5.93	***50.39***
Hungary	0.65	0.03	28.55	49.30	744.84	92.14	55.63	***971.13***
Lithuania	0.36	13.42	47.85	78.33	126.24	3.52	45.62	***315.33***
Latvia	0.03	0.89	1.66	19.63	50.45	4.45	21.14	***98.26***
Malta	0.00	0.02	0.00	0.00	0.03	0.00	0.98	***1.04***
Poland	47.05	25.58	28.26	217.70	1649.69	137.25	393.81	***2499.35***
Slovenia	7.62	0.48	3.82	33.74	44.46	1.10	13.51	***104.73***
Slovakia	14.79	0.00	18.81	21.65	127.77	38.77	16.69	***238.49***
Bulgaria	0.00	0.03	5.10	36.55	288.15	67.71	10.72	***408.26***
Romania	0.05	0.24	0.25	45.20	533.40	114.70	1.45	***695.29***
EU27	***820.19***	***74.66***	***957.65***	***6550.33***	***17370.04***	***2552.60***	***4037.51***	***32362.98***

GHG-emissions from On-farm energy use

This section is devoted to the use of energy on the farm-level, which is above all the direct use of fuels and electricity, but also the indirect energy consumption via the construction of buildings or machineries. On-farm energy use has been implemented in CAPRI in form of a sub-module. However, currently the sub-module is not integrated in the standard CAPRI-version, and, therefore, for the moment only results from past runs can be presented. Since the energy-module is quite comprehensive and uses a large number of input parameters, for which a transparent documentation is still missing, its presentation at this point of the project will be kept short and be confined to the basic principles. A more thorough description can be found in Kempen and Kraenzlein (2008) and Kraenzlein (2008).

The energy module uses a life-cycle approach, which matches the need of this study. It considers direct energy usage in form of fuels and electricity and indirect energy usage from the production of mineral fertilizers, pesticides, buildings and machinery. Mineral fertilizer has been considered in the previous section and will therefore not be included in the analysis of on-farm energy usage. The results of the energy-module are differentiated by production activities, as it was the case in the previous sections. The greenhouse gas emissions are calculated as CO_2-equivalents, a differentiation by GHG-types, therefore, is not possible. The consistency of parameters used in the energy-module with parameters used for the calculation of N_2O- and CH_4-emissions is for the moment not guaranteed, since partly completely different data sources are in use. Improving consistency between the various modules used for the calculation of environmental indicators is one of the objectives for the second phase of the project.

The methodology for the calculation of energy use is presented in the following sub-sections:

Direct energy use in form of diesel fuel

The calculation of diesel fuel use is based on the KTBL model (KTBL, 2004), taking into account soil quality (light/medium/heavy), work-process steps (soil preparation/seed and seedbed preparation/fertilizer application/plant protection/harvesting/transport), and plot size (1/2/5/10/20/40/80 ha) on a regional basis. For grassland diesel fuel use is calculated as a function of regional grass yield, cutting behaviour and pasture share. The resulting amount of diesel fuel is then multiplied with the factor 3.08 kg CO_2–equivalent per litre. Emission factors and total emissions are presented in the tables 42 and 43. Therefore, total CO_2-emissions from diesel fuel use in agriculture amount to 56 Mio tons per year, from which 22% can be connected to non marketable feeds. The highest emissions per hectare can be found in southern European countries like Greece, Spain, Italy and Portugal.

Table 42 CAPRI-Emission factors for CO_2 emissions from diesel fuel usage in kg per ha and year

	Non marketable feeds				***Marketable crops (total)***			***Total***
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
Belgium	311.7	330.55	81.78	176.88	274.32	259.27	594.58	***291.77***
Denmark	314.5	339.51	83.68	224.37	241.76	233.19	208.23	***206.07***
Germany	312.7	325.36	81.81	160.31	250.41	244.25	320.83	***233.95***
Greece	1063.22	711.03	270.4	271.13	564.92	833.58	1190.33	***710.42***
Spain	1280.59	366.72	397.46	114.16	402.02	533.21	895.12	***514.02***
France	451.19	359.94	84.2	130.76	292.73	289.06	393.41	***239.14***
Ireland	327.73	403.96	81.78	195.66	252.31	253.91	359.72	***183.64***
Italy	693.49	391.13	123.64	99.92	370.35	380.68	1024.57	***452.28***
Netherlands	305.03	358.11	88.8	241.07	274.87	244.92	621.73	***336.28***
Austria	320.51	337.05	81.78	100.89	268.43	253.34	333.49	***172.29***
Portugal	714.25	537.81	138.38	142.51	502.62	464.67	785.66	***442.39***
Sweden	332.33	341.27	81.83	122.85	262.56	259.42	170.35	***171.16***
Finland	0	346.83	91.21	113.03	279.6	288.44	228.56	***223.80***
United Kingdom	330.31	327.17	81.61	151.75	269.65	275.31	372.63	***187.31***
Cyprus	0	30.99	193.82	3552.37	79.4	71.95	831.54	***421.60***

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*	
Czech Republic	326.62	321.31	81.6	104.8	288.83	263.77	333.51	***231.67***
Estonia	330.35	324.25	81.78	105.42	291.7	276.61	284.18	***186.24***
Hungary	358.61	413.8	81.52	107.23	302.05	296.84	519.81	***289.63***
Lithuania	324.13	324.15	81.78	105.39	286.59	267.9	321.50	***202.66***
Latvia	316.9	340.15	81.78	105.18	304.82	312.85	327.99	***186.62***
Malta	0	25.24	61.79	76.12	31.87	0	464.76	***254.74***
Poland	318.99	317.7	81.78	112.49	274.96	270.33	337.48	***251.28***
Slovenia	375.43	424.31	85.25	117.02	306.71	304.39	730.18	***221.20***
Slovakia	348.77	341.46	82.06	104.39	272.16	256.36	499.32	***217.31***
Bulgaria	352.14	336.24	81.77	103.32	320.89	285.4	519.78	***278.09***
Romania	348.86	342.2	81.75	103.26	307.85	282.82	590.04	***254.73***

Table 43: Total CO_2 emissions from diesel fuel usage in 1000 tons

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*	
Belgium	56.60	1.91	8.29	103.89	90.09	5.78	180.61	***447.17***
Denmark	29.83	3.52	48.20	40.71	358.83	14.81	78.22	***574.12***
Germany	356.87	3.86	36.52	798.80	1738.14	233.11	798.67	***3965.98***
Greece	7.20	0.19	79.85	485.06	744.78	914.10	1831.13	***4062.31***
Spain	107.79	19.15	374.83	818.64	2649.32	1624.57	6544.94	***12139.25***
France	670.27	16.27	279.98	1305.16	2654.91	431.38	1821.11	***7179.08***
Ireland	5.98	2.59	63.48	626.03	74.30	0.50	33.14	***806.02***
Italy	196.44	4.35	230.40	436.99	1551.10	531.41	3277.17	***6227.86***
Netherlands	64.58	0.27	12.97	205.98	63.61	1.33	281.34	***630.08***
Austria	23.31	0.26	11.81	193.45	219.06	24.37	111.17	***583.44***
Portugal	80.60	5.04	54.58	206.62	244.45	184.38	846.12	***1621.79***
Sweden	1.21	0.00	79.18	54.80	299.91	9.94	71.71	***516.76***
Finland	0.00	0.04	1.60	71.21	329.75	20.94	69.10	***492.63***
United Kingdom	40.39	12.86	98.81	1704.39	836.75	111.52	428.04	***3232.76***
Cyprus	0.00	0.00	4.43	3.13	4.34	0.52	28.20	***40.61***
Czech Republic	70.78	0.97	29.96	92.71	447.26	110.83	145.74	***898.24***
Estonia	0.17	0.24	21.87	13.15	77.44	9.83	19.14	***141.84***
Hungary	45.75	0.69	19.35	113.93	898.21	173.05	350.79	***1601.76***
Lithuania	4.20	10.71	17.37	119.36	259.70	17.14	135.29	***563.78***
Latvia	0.42	2.75	25.86	64.32	130.79	6.00	65.92	***296.07***
Malta	0.00	0.00	0.27	0.00	0.03	0.00	2.44	***2.75***
Poland	65.34	23.43	34.94	400.94	2316.51	123.95	1331.34	***4296.45***
Slovenia	8.34	1.63	2.14	35.92	30.90	1.97	29.01	***109.92***
Slovakia	34.79	1.00	13.46	82.72	224.20	51.10	79.96	***487.23***
Bulgaria	17.78	0.32	8.30	183.13	623.78	149.93	484.20	***1467.44***
Romania	9.13	11.92	83.37	511.21	1826.34	319.77	1009.70	***3771.44***
EU27	***1897.78***	***123.98***	***1641.82***	***8672.25***	***18694.51***	***5072.22***	***20054.22***	***56156.78***

Direct Electricity and heating gas energy usage

Electricity is used in many steps of agricultural production. CAPRI calculates emissions from animal production, feedstuff production, greenhouses, irrigation and grain drying. Heating gas usage is considered for animal production, feedstuff production and greenhouses. Electricity usage in animal production is based on coefficients from Boxberger et al. (1997). It takes account of herd size, building type, manure management system (manure storage/daily spread) and space requirement per animal unit. Moreover, for some specific processes (e.g. milk cooling) yield-based or feed-specific parameters are applied. Heating gas requirements are calculated in a similar way but need not account for manure management systems. The preparation of feedstuffs (e.g. drying) is differentiated by feed components (cereals/oilseeds/energy-rich and protein-rich feeds) and the moisture content. Data sources are Bockisch (2000), Sauer (1992), Moerschner (2000) and Keiser (1999). Greenhouses require energy heating and lightening, and are divided in heated and non-heated ones. Energy need from irrigation is based on a method presented in Nemecek et al. (2003) and considers standardized irrigation systems (mobile/fixed), water sources (surface water/reservoir water) and the water quantity. Finally, electricity usage for grain drying is derived by a formula described in Nemecek et al. (2003). In order to get estimates for GHG-emissions the energy usage is multiplied by a factor of 0.54 kg CO_2-equicalent per kWh for electricity, and 2.46 kg CO_2-equicalent per Nm^3 for heating gas. Emission factors and total emissions from electricity usage are shown in the tables 44 and 45. According to current CAPRI calculations, therefore, 41 Mio tons of CO_2-equivalents are due to electricity usage in agriculture. At least 70% is directly caused by animal production (not marketable feeds included), and another considerable share of the remaining part is due to marketable feed production, to be quantified in the second phase of the project.

Table 44: CAPRI-Emission factors for CO_2 emissions from electricity usage in kg per ha/head and year

	Non marketable feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*[1]	*Sheep and goats*
Belgium	3.02	196.01	2.27	107.10	381.49	76.95	84.96	2293.35	6.31
Denmark	11.82	37.77	4.11	31.37	494.12	53.05	94.91	2180.26	7.44
Germany	3.22	83.23	2.91	44.50	442.58	62.09	86.79	2324.00	5.90
Greece	164.79	237.87	510.38	291.97	387.68	49.65	104.90	2423.48	6.51
Spain	53.71	97.44	235.57	252.64	424.21	62.15	94.37	2275.58	6.97
France	13.75	260.67	16.07	68.52	436.62	79.96	84.95	2191.53	7.47
Ireland	1.51	2.19	2.04	19.93	350.23	64.18	95.84	2136.07	6.49
Italy	40.61	83.76	111.31	138.62	378.02	60.41	81.51	2316.98	3.47
Netherlands	12.52	205.84	2.53	355.74	444.27	90.98	90.49	2444.80	5.55
Austria	2.13	304.86	3.65	34.68	422.82	63.41	88.45	2319.11	6.71
Portugal	59.65	193.59	116.44	115.36	469.64	83.92	99.14	2117.34	7.36
Sweden	2.6	36.29	3.55	22.61	507.48	68.91	92.32	2375.66	8.74
Finland	2.42	16.01	3.88	34.47	490.86	51.27	99.87	2233.57	9.10
United Kingdom	0.68	46.74	1.11	46.16	432.71	56.32	93.88	2180.26	6.59
Cyprus	277.78	56.51	49.49	768.63	435.74	29.59	102.13	2200.79	7.37
Czech Republic	0.8	48.82	1.04	16.13	420.04	72.86	94.89	2248.97	10.48
Estonia	0.48	32.86	1.01	35.68	400.64	13.22	109.73	2822.32	9.21
Hungary	1.45	279.43	1.76	31.22	454.28	48.53	91.54	2346.13	8.22
Lithuania	0.51	2.43	0.96	25.56	388.63	5.74	106.01	2874.10	17.90
Latvia	0.41	53.03	0.96	32.22	398.63	8.16	122.90	3076.28	18.38

	Non marketable feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*[1]	*Sheep and goats*
Malta	39.45	11.68	0	422.86	409.88	56.08	88.96	2384.09	8.39
Poland	1.27	73.55	0.97	41.39	408.76	29.71	97.29	2581.36	22.26
Slovenia	3.99	68.29	4.32	54.21	411.37	76.19	115.18	2169.58	3.98
Slovakia	4.44	110.1	5.95	66.50	500.42	73.74	101.93	2548.61	11.67
Bulgaria	0.07	40.09	0.21	1.13	169.57	23.03	80.43	2312.32	7.29
Romania	0.23	2.33	0.35	3.95	199.26	23.31	102.12	2643.90	8.49

1) Values in kg per 1000 heads

Table 45: Total CO_2 emissions from electricity usage in 1000 tons

	Non market feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*	*Sheep and goats*	*Total*
Belgium	2.65	64.37	0.05	32.53	244.52	188.78	438.86	78.59	0.98	***1051.34***
Denmark	10.20	56.06	0.26	11.79	304.40	62.95	709.48	48.54	0.78	***1204.46***
Germany	21.20	577.71	2.78	110.77	1961.90	593.60	1695.88	314.14	11.37	***5289.35***
Greece	344.63	313.61	559.68	449.15	63.13	19.02	59.01	67.85	76.67	***1952.75***
Spain	443.13	642.13	717.73	1847.27	490.20	332.47	1261.44	373.79	169.91	***6278.09***
France	204.01	2364.14	23.98	317.19	1794.56	1285.70	832.08	535.88	74.95	***7432.50***
Ireland	6.04	0.64	0.00	1.84	396.44	337.58	94.80	29.91	30.86	***898.11***
Italy	265.23	350.80	155.38	443.40	826.62	277.83	598.07	354.91	28.06	***3300.31***
Netherlands	15.19	47.63	0.01	160.98	685.02	215.88	596.85	221.72	6.70	***1949.99***
Austria	4.55	248.79	0.35	11.56	251.17	93.71	205.78	33.46	2.29	***851.65***
Portugal	117.30	94.15	46.20	124.24	142.35	88.95	146.28	71.58	16.00	***847.06***
Sweden	3.69	41.45	0.14	9.52	210.05	84.14	112.04	34.21	1.94	***497.17***
Finland	1.57	18.88	0.28	10.42	169.63	34.74	82.28	22.59	0.51	***340.91***
United Kingdom	8.57	145.04	0.45	53.03	968.02	457.19	295.72	384.39	132.51	***2444.92***
Cyprus	6.61	3.09	0.36	26.06	11.16	0.00	23.58	9.48	3.57	***83.91***
Czech Republic	1.18	75.60	0.44	7.05	186.48	67.32	228.79	62.45	0.24	***629.55***
Estonia	0.19	8.72	0.04	2.40	44.87	1.83	17.04	4.87	0.24	***80.21***
Hungary	2.07	830.95	1.03	21.07	147.98	20.93	304.85	118.33	8.51	***1455.72***
Lithuania	0.71	2.20	0.06	10.76	165.22	1.93	40.63	13.63	0.57	***235.72***
Latvia	0.38	22.75	0.02	6.48	70.72	1.49	16.89	6.25	0.63	***125.62***
Malta	0.18	0.01	0.00	2.22	3.17	0.60	4.94	2.40	0.10	***13.62***
Poland	5.42	619.65	0.44	163.28	1036.77	79.03	861.00	301.56	7.04	***3074.20***
Slovenia	1.43	6.88	0.03	2.15	54.37	25.39	22.25	14.57	0.25	***127.31***
Slovakia	4.70	90.70	1.19	10.65	61.52	25.66	73.21	32.46	3.03	***303.11***
Bulgaria	0.13	77.93	0.11	1.06	72.38	6.91	68.89	37.63	23.77	***288.81***
Romania	1.39	13.82	0.40	6.77	258.74	26.91	191.42	146.23	40.55	***686.22***
EU27	***1472.35***	***6717.73***	***1511.40***	***3843.63***	***10621.39***	***4330.55***	***8982.08***	***3321.43***	***642.03***	***41442.58***

Indirect energy usage by machinery and buildings

Energy is not only used directly during the agricultural production process but also indirectly by the production of inputs. The most important long-term inputs are machinery and buildings. Data on machinery stocks come from different sources (see Kraenzlein, 2008) and are allocated to activities by the KTBL-approach (see KTBL, 2004). For tractors, as an example, the energy use is a function of machinery stock, engine power class (<40/40-60/61-100/>100 kW), average service life, hours of machinery use, machinery weight, all specific for different plot sizes and soil qualities. For a more detailed description see Kraenzlein (2008). Energy-use assessment of buildings follows the methodology described in Lalive d'Epinay (2000). It differentiates operations and building materials. In order to guarantee comparability, buildings were categorized according to a standardized approach based on SALCA061 (2006). In general, energy usage is derived from three components, construction energy, disposal energy use and maintenance energy use, all in numbers per m^3. In case of buildings in animal production, for example, those values are calculated for each manure management system (manure storage/daily spread), and then the sum of those components is divided by an average service life, depending on the building type (northern/central/southern European type). In a second step those standardized yearly values are allocated to the different activities by the average space requirement per head, depending on regional herd size, building type and manure management system.

Tables 46 to 49 contain the emission factors and total indirect GHG emissions from machinery and building usage. Therefore, another 33 Mio tons of CO_2-equivalents per year are due to indirect emissions from machinery usage, 50 Mio tons come from the usage of buildings. 60% of those emissions are directly related to animal production activities, the overwhelming part to dairy and beef activities, and non marketable feed production. The share of marketable feeds will be quantified at a later stage of the project.

Table 46: CAPRI-Emission factors for indirect CO_2 emissions from machinery usage in kg per ha/head and year

	Non marketable feeds	***Cereals***	***Oilseeds***	***Other crops***	***Dairy cows***
Belgium	167.61	217.98	143.81	444.35	7.47
Denmark	165.39	174.35	147.61	161.19	10.26
Germany	197.76	258.85	192.69	397.43	8.96
Greece	231.14	376.27	712.16	503.75	6.83
Spain	97.38	173.70	344.83	410.41	7.83
France	77.06	145.70	117.77	320.71	8.51
Ireland	96.87	143.56	136.09	294.57	6.43
Italy	93.17	213.83	242.68	537.46	7.04
Netherlands	181.98	241.50	156.69	469.55	9.78
Austria	106.84	286.48	215.26	551.38	7.57
Portugal	134.90	349.91	229.81	438.23	9.11
Sweden	113.67	256.31	206.55	185.84	10.96
Finland	81.37	245.10	209.30	909.05	9.98
United Kingdom	40.50	87.63	75.24	177.23	9.16
Cyprus	378.05	114.82	111.80	1147.06	8.27
Czech Republic	54.07	102.68	78.73	165.36	8.24
Estonia	34.86	135.65	90.76	748.59	7.39
Hungary	22.60	54.21	41.37	189.22	8.64
Lithuania	38.97	115.21	88.38	691.08	5.62
Latvia	35.34	122.21	88.60	799.02	5.91
Malta	79.42	67.03	0.00	805.88	7.43
Poland	43.78	123.15	89.21	723.42	6.09

	Non marketable feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*
Slovenia	225.74	417.88	308.99	1485.94	6.93
Slovakia	33.69	64.92	55.49	209.84	9.34
Bulgaria	7.50	31.20	22.09	97.63	4.53
Romania	23.52	66.35	36.62	407.64	4.79

1) Values in kg per 1000 heads

Table 47: Total indirect CO_2 emissions from machinery usage in 1000 tons

	Non market feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Total*
Belgium	146.84	71.58	3.21	134.98	4.78	***361.40***
Denmark	142.67	258.78	9.37	60.55	6.32	***477.70***
Germany	1301.74	1796.72	183.90	989.37	39.73	***4311.46***
Greece	483.39	496.07	780.95	774.94	1.11	***2536.47***
Spain	803.43	1144.69	1050.62	3000.84	9.04	***6008.62***
France	1143.36	1321.42	175.76	1484.59	34.97	***4160.09***
Ireland	387.53	42.27	0.27	27.14	7.28	***464.49***
Italy	608.52	895.56	338.77	1719.11	15.39	***3577.35***
Netherlands	220.73	55.89	0.85	212.48	15.07	***505.02***
Austria	228.15	233.79	20.71	183.81	4.50	***670.95***
Portugal	265.28	170.18	91.19	471.95	2.76	***1001.36***
Sweden	161.11	292.77	7.92	78.24	4.54	***544.57***
Finland	52.70	289.06	15.20	274.82	3.45	***635.22***
United Kingdom	510.46	271.92	30.48	203.59	20.48	***1036.93***
Cyprus	9.00	6.27	0.80	38.90	0.21	***55.18***
Czech Republic	79.56	159.00	33.08	72.26	3.66	***347.56***
Estonia	13.71	36.01	3.23	50.42	0.83	***104.20***
Hungary	32.30	161.21	24.12	127.69	2.81	***348.12***
Lithuania	54.20	104.40	5.65	290.82	2.39	***457.47***
Latvia	33.12	52.44	1.70	160.60	1.05	***248.90***
Malta	0.36	0.07	0.00	4.23	0.06	***4.72***
Poland	186.94	1037.52	40.90	2853.90	15.44	***4134.71***
Slovenia	80.86	42.11	2.00	59.04	0.92	***184.91***
Slovakia	35.68	53.48	11.06	33.60	1.15	***134.97***
Bulgaria	14.44	60.65	11.60	90.94	1.93	***179.57***
Romania	141.86	393.63	41.40	697.57	6.23	***1280.69***
EU27	***7137.95***	***9447.50***	***2884.73***	***14096.36***	***206.10***	***33772.64***

Table 48: CAPRI-Emission factors for indirect CO_2 emissions from building usage in kg per ha/head and year

	Non marketable feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry[1]*	*Sheep and goats*
Belgium	23.23	31.01	18.73	500.11	449.74	327.42	45.50	3288.12	16.92
Denmark	21.67	23.8	19.47	95.16	479.38	310.59	62.64	5046.69	23.98
Germany	27.9	36.48	25.84	166.08	465.53	286.69	45.76	4064.57	15.20

	Non marketable feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*[1]	*Sheep and goats*
Greece	0.77	3.47	2.61	98.52	254.99	250.46	47.26	2346.08	12.91
Spain	1.66	2.83	1.67	237.61	255.51	226.43	35.38	2350.41	13.30
France	8.09	17.85	12.74	239.94	456.42	347.86	50.62	3696.01	21.21
Ireland	13.83	19.97	18.44	106.24	520.44	337.50	64.90	6452.66	18.82
Italy	2.85	7.3	6.88	244.44	233.13	161.05	21.51	2233.92	10.36
Netherlands	23.74	33.66	20.58	1592.51	494.23	415.07	57.67	4246.67	17.80
Austria	15.47	42.83	29.73	132.73	497.81	319.77	50.65	4087.35	17.16
Portugal	1.65	2.31	1.45	101.95	271.55	247.14	41.25	3777.63	13.69
Sweden	16.12	35.89	27.83	88.30	504.76	295.82	57.70	4880.72	16.41
Finland	3.18	9.61	7.79	114.19	378.76	197.83	69.77	4614.05	6.32
United Kingdom	5.32	11.89	9.87	120.12	461.85	311.05	63.20	4277.13	15.62
Cyprus	0.56	0.86	0.91	4.62	153.87	144.38	40.65	2413.00	3.12
Czech Republic	3.12	6.26	4.36	55.93	453.03	306.51	51.23	5683.87	16.07
Estonia	1.02	4.15	2.51	146.08	451.64	239.53	73.18	4022.99	7.30
Hungary	2.21	7.47	4.1	125.07	464.90	329.72	45.73	3725.56	20.96
Lithuania	1.14	3.31	2.44	101.19	485.40	300.62	76.89	3820.64	9.72
Latvia	1.03	3.93	2.45	130.11	504.15	273.53	94.56	3441.31	11.27
Malta	0.6	1.04	0	5.64	142.65	136.30	27.99	2617.02	9.30
Poland	1.25	4.13	2.47	163.94	480.68	299.05	68.00	4181.52	10.98
Slovenia	27.61	51.4	35.44	307.16	444.72	223.06	85.46	3654.15	10.10
Slovakia	2.9	6.84	4.85	69.76	485.64	326.02	63.87	5954.59	25.77
Bulgaria	0.19	1.09	0.54	7.04	111.90	57.14	58.68	4488.73	5.95
Romania	0.59	1.65	0.9	12.36	67.05	58.03	72.32	4549.55	9.12

1) Values in kg per 1000 heads

Table 49: Total indirect CO_2 emissions from building usage in 1000 tons

	Non market feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*	*Sheep and goats*	*Total*
Belgium	20.35	10.18	0.42	151.92	288.27	803.28	235.02	112.69	2.64	***1624.76***
Denmark	18.69	35.33	1.24	35.75	295.32	368.52	468.25	112.36	2.52	***1337.98***
Germany	183.65	253.21	24.66	413.44	2063.65	2740.81	894.23	549.41	29.30	***7152.37***
Greece	1.61	4.57	2.86	151.56	41.52	95.94	26.59	65.68	152.14	***542.47***
Spain	13.70	18.65	5.09	1737.33	295.26	1211.30	472.91	386.09	324.28	***4464.60***
France	120.03	161.89	19.01	1110.69	1875.95	5593.62	495.84	903.76	212.82	***10493.61***
Ireland	55.33	5.88	0.04	9.79	589.12	1775.28	64.19	90.35	89.43	***2679.40***
Italy	18.61	30.57	9.60	781.85	509.77	740.71	157.79	342.19	83.70	***2674.80***
Netherlands	28.80	7.79	0.11	720.64	762.06	984.89	380.38	385.14	21.48	***3291.29***
Austria	33.03	34.95	2.86	44.25	295.71	472.61	117.84	58.96	5.85	***1066.07***
Portugal	3.24	1.12	0.58	109.79	82.31	261.96	60.87	127.71	29.78	***677.37***
Sweden	22.85	40.99	1.07	37.17	208.92	361.19	70.03	70.28	3.64	***816.15***
Finland	2.06	11.33	0.57	34.52	130.89	134.05	57.48	46.66	0.36	***417.92***
United Kingdom	67.05	36.90	4.00	137.98	1033.21	2525.08	199.09	754.08	314.34	***5071.74***
Cyprus	0.01	0.05	0.01	0.16	3.94	0.00	9.39	10.39	1.51	***25.45***
Czech Republic	4.59	9.69	1.83	24.44	201.12	283.21	123.52	157.84	0.37	***806.62***
Estonia	0.40	1.10	0.09	9.84	50.58	33.13	11.36	6.95	0.19	***113.64***

	Non market feeds	*Cereals*	*Oilseeds*	*Other crops*	*Dairy cows*	*Other cows*	*Swine*	*Poultry*	*Sheep and goats*	*Total*
Hungary	3.16	22.21	2.39	84.40	151.44	142.21	152.29	187.91	21.70	***767.71***
Lithuania	1.59	3.00	0.16	42.58	206.36	100.95	29.47	18.13	0.31	***402.54***
Latvia	0.97	1.69	0.05	26.15	89.45	50.06	12.99	7.00	0.39	***188.73***
Malta	0.00	0.00	0.00	0.03	1.10	1.46	1.55	2.63	0.11	***6.89***
Poland	5.34	34.79	1.13	646.75	1219.19	795.48	601.79	488.50	3.47	***3796.45***
Slovenia	9.89	5.18	0.23	12.20	58.78	74.34	16.50	24.53	0.62	***202.28***
Slovakia	3.07	5.63	0.97	11.17	59.70	113.44	45.88	75.84	6.69	***322.38***
Bulgaria	0.37	2.12	0.28	6.56	47.76	17.15	50.26	73.05	19.40	***216.94***
Romania	3.56	9.79	1.02	21.16	87.06	66.98	135.57	251.62	43.56	***620.32***
EU27	***621.95***	***748.64***	***80.25***	***6362.11***	***10648.46***	***19747.66***	***4891.09***	***5309.73***	***1370.59***	***49780.47***

Pesticide usage

Energy consumption for Pesticide usage is a rather small part of total plant production energy usage, and an even smaller share is devoted to the production of feedstuffs. In CAPRI it is estimated on the basis of pesticide costs. Those cost terms are based on FADN and EUROSTAT data. In order to achieve a distribution of substances and energy values per substance, data from the FAO statistics (FAO, 2005) are combined with coefficients from SALCAo61 (2006). Finally, CAPRI derives GHG-emissions wit the following coefficients: 7.07 kg CO_2 per kg herbicide, 10.99 kg CO_2 per kg insecticide and 4.31 kg CO_2 per kg fungicide (herbicides, insecticides and fungicides as active substances). Emission factors and total emissions from pesticide usage can be found in the tables 50 and 51. Therefore, around 2 Mio tons of CO_2-equivaltens are due to pesticide usage in the EU27, 6% of it being caused by the production of non-marketable feeds. The major part of the emissions comes from crops with high pesticide usage, like fruits, vegetables, flowers and wine. The highest per hectare emissions can be found in Belgium, Netherlands and Italy, the lowest ones in scandinavian countries, most Eastern European countries and Austria. For Bulgaria, Latvia, Malta and Cyprus, due to a lack of data, no values are available.

Table 50: CAPRI-Emission factors for CO_2 emissions from pesticide usage in kg per ha and year

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	*Fodder root crops*	*Other fodder on arable land*	*Grassland*	*Cereals*	*Oilseeds*	*Other crops*	
Belgium	4.27	20.40	16.37	3.70	43.88	8.70	142.53	***41.14***
Denmark	9.63	3.70	2.47	1.58	8.36	9.35	11.14	***7.15***
Germany	3.44	12.50	6.40	1.26	15.98	12.90	20.59	***11.18***
Greece	19.16	3.36	0.89	1.47	8.31	0.20	26.95	***12.16***
Spain	24.67	1.32	1.29	0.27	7.67	3.73	22.84	***11.00***
France	10.00	5.02	2.48	0.73	25.87	24.63	52.88	***18.28***
Ireland	23.40	1.97	3.43	0.26	17.18	15.79	36.59	***2.87***
Italy	33.22	129.70	3.14	0.55	15.94	41.57	81.66	***29.37***
Netherlands	15.41	8.43	4.81	2.16	26.53	3.45	78.49	***26.13***
Austria	12.14	5.55	1.82	1.45	8.43	8.33	27.09	***6.28***
Portugal	3.47	1.60	2.94	0.77	17.09	12.95	48.83	***20.86***
Sweden	29.51	0.00	2.09	0.14	4.87	6.51	6.12	***3.59***
Finland	0.00	3.80	2.64	0.73	4.00	4.26	6.57	***3.51***

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
United Kingdom	10.10	0.31	1.03	0.30	42.97	35.25	61.68	***13.06***
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Czech Republic	7.98	1.28	1.94	1.58	7.90	9.31	18.12	***7.29***
Estonia	8.85	3.30	0.56	0.73	1.63	6.28	18.12	***2.83***
Hungary	3.87	2.07	0.54	0.32	3.20	4.25	16.11	***4.56***
Lithuania	1.62	1.58	0.30	0.25	1.32	2.44	5.67	***1.52***
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Poland	3.55	1.74	0.96	0.59	1.57	3.86	9.94	***3.40***
Slovenia	22.98	4.13	6.45	3.28	16.33	84.55	100.82	***16.67***
Slovakia	1.41	4.80	1.37	0.99	10.84	12.31	44.52	***8.87***
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Romania	3.04	4.20	1.33	1.09	3.07	1.06	18.58	***4.02***

Table 51: Total CO_2 emissions from pesticide usage in 1000 tons

	Non marketable feeds				*Marketable crops (total)*			*Total*
	Fodder maize	***Fodder root crops***	***Other fodder on arable land***	***Grassland***	***Cereals***	***Oilseeds***	***Other crops***	
Belgium	0.78	0.12	1.66	2.17	14.41	0.19	43.30	***62.63***
Denmark	0.91	0.04	1.42	0.29	12.41	0.59	4.19	***19.85***
Germany	3.93	0.15	2.86	6.28	110.92	12.31	51.25	***187.69***
Greece	0.13	0.00	0.26	2.63	10.96	0.22	41.46	***55.66***
Spain	2.08	0.07	1.22	1.94	50.55	11.36	167.04	***234.24***
France	14.86	0.23	8.25	7.29	234.63	36.76	244.78	***546.78***
Ireland	0.43	0.01	2.66	0.83	5.06	0.03	3.37	***12.40***
Italy	9.41	1.44	5.85	2.41	66.76	58.03	261.19	***405.09***
Netherlands	3.26	0.01	0.70	1.85	6.14	0.02	35.52	***47.49***
Austria	0.88	0.00	0.26	2.78	6.88	0.80	9.03	***20.64***
Portugal	0.39	0.01	1.16	1.12	8.31	5.14	52.58	***68.72***
Sweden	0.11	0.00	2.02	0.06	5.56	0.25	2.58	***10.58***
Finland	0.00	0.00	0.05	0.46	4.72	0.31	1.98	***7.52***
United Kingdom	1.23	0.01	1.25	3.37	133.34	14.28	70.85	***224.34***
Cyprus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Czech Republic	1.73	0.00	0.71	1.40	12.23	3.91	7.92	***27.90***
Estonia	0.00	0.00	0.15	0.09	0.43	0.22	1.22	***2.12***
Hungary	0.49	0.00	0.13	0.34	9.52	2.48	10.87	***23.83***
Lithuania	0.02	0.05	0.06	0.28	1.20	0.16	2.38	***4.16***
Latvia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Malta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Poland	0.73	0.13	0.41	2.10	13.23	1.77	39.22	***57.58***
Slovenia	0.51	0.02	0.16	1.01	1.65	0.55	4.01	***7.89***
Slovakia	0.14	0.01	0.22	0.78	8.93	2.45	7.13	***19.68***
Bulgaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	***0.00***
Romania	0.08	0.15	1.36	5.40	18.21	1.20	31.79	***58.18***
EU27	***42.10***	***2.46***	***32.83***	***44.86***	***736.03***	***153.03***	***1093.66***	***2104.97***

Transport of feed and animal products

An indication of live transport during animal production will hopefully be obtained from EU databases. Milk transport to dairies is the sole other transport considered at EU level, in accordance with the terms of reference of the AA. Here an indication will be obtained through a case study in dairy region of a member state with statistical information on dairy farm as well as dairy plant density. Feed and selected animal import transport will only cover sea transport emissions. For the calculation the following emission factors (see Kraenzlein, 2008) will be used: 10.57 kg (CO_2-equivalent per 1000 tons and km) for shipping overseas, 37.48 kg for rail transport, 45.83 kg for barge transport, 166.43 kg for transport in big lorries and 370.40 kg for transport in small lorries.

Land use change

Emissions of both CO_2 and N_2O due to the mineralization of organic carbon, induced to changes in land use are calculated according to the IPCC methodology, by determining the default *equilibrium* organic matter contents of the land uses:

$$SOC = \sum_{c,s,i} \left(SOC_{REF_{c,s,i}} \cdot F_{LU_{c,s,i}} \cdot F_{MG_{c,s,i}} \cdot F_{I_{c,s,i}} \cdot A_{c,s,i} \right),$$

Whereby the inidices *c,s*, and *i* indicate the dependency of the soil organic carbon (SOC) content on climate, soil, and management system. The dimensionless factors F_{LU}, F_{MG}, and F_{I} are used to consider different land use (sub-)systems, management regimes, and input of organic matter, respectively. The SOC content is determined for a base line (T0) and the actual year (T1); land use combination of relevance for the present AA include the conversion of forests or cropland to grassland, forests or grassland to cropland, or the change in the management regime for cropland or grassland.

The change in SOC for a single year depends on the assumed time period for transition between the equilibrium SOC values, whereby commonly 20 years are used. For estimating N_2O fluxes from mineralization of organic matter, a C:N ratio of 15 (original land use: forest or grassland) or 12 (original land use: cropland) is applied.

Even though there is some evidence that grasslands in Europe represent a carbon sink by sequestering CO_2 (Soussana et al., 2007a,b) even under constant management regime, we regard the data as not sufficiently robust to differentiate the sink strength by grassland management. Thus whether the carbon sequestration rate is changed if previously unmanaged grassland is included in the grazed land or the management of the land changes, remains unclear. Thus, for the first phase of the current project, possible reduced carbon sink strength due to, for example, the intensification of livestock rearing activities, which are not yet considered in the IPCC management factors, were not considered.

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Appendix

Table A1: Regional Loss factors for the calculation of superficial runoff and leaching below soil in Percent

NUTS code	LF_{RUN}*100	LF_{LEA}*100
LU000	6.85	29.0
AT110	2.15	9.0
AT120	1.91	7.0
AT210	2.99	10.0
AT220	1.91	7.0
AT310	5.5	17.0
AT320	3.49	10.0
AT330	1.93	6.0
AT340	1.77	7.0

NUTS code	LF_{RUN}*100	LF_{LEA}*100
BL210	2.04	43.0
BL220	2.16	25.0
BL230	3.7	49.0
BL240	5.96	39.0
BL250	2.4	31.0
BL310	6.6	40.0
BL320	5.9	32.0
BL330	5.65	26.0
BL340	3.68	24.0
BL350	7.11	29.0
DE110	3.65	11.0
DE120	3.39	13.0
DE130	7.89	30.0
DE140	8.94	44.0
DE210	6.23	37.0
DE220	2.93	22.0
DE230	2.21	7.0
DE240	2.88	8.0
DE250	3.63	11.0
DE260	3.41	12.0
DE270	5.46	37.0
DE400	2.38	18.0
DE710	2.73	12.0
DE720	2.57	11.0
DE730	3.51	13.0
DE800	2.56	14.0
DE910	2.78	12.0
DE920	2.47	15.0
DE930	1.68	23.0
DE940	2.12	31.0
DEA10	4.26	30.0
DEA20	4.8	22.0
DEA30	4.45	35.0
DEA40	5.78	29.0
DEA50	5.02	23.0
DEB10	3.69	12.0
DEB20	8.35	30.0
DEB30	3.48	13.0
DEC00	9.58	24.0
DED00	2.45	14.0
DEE10	2.04	15.0
DEE20	2.47	13.0
DEE30	2.13	13.0
DEF00	4.92	34.0
DEG00	3.21	11.0
DK000	3.16	30.0
ES110	7.18	27.0
ES130	7.5	55.0
ES210	5.02	20.0
ES220	3.91	17.0
ES230	3.49	18.0
ES240	3.66	15.0

NUTS code	LF_{RUN}*100	LF_{LEA}*100
ES300	3.14	18.0
ES410	3.3	16.0
ES420	3.37	14.0
ES430	1.28	8.0
ES510	3.81	17.0
ES520	3.7	16.0
ES530	4.08	14.0
ES610	2.99	12.0
ES620	3.67	16.0
EL110	2.51	11.0
EL120	1.85	10.0
EL130	1.63	6.0
EL140	1.83	9.0
EL210	1.49	7.0
EL220	2.2	7.0
EL230	1.1	5.0
EL240	1.88	8.0
EL250	1.77	7.0
EL300	2.36	11.0
EL410	0.92	3.0
EL420	1.55	5.0
EL430	2.53	9.0
FR100	2.63	13.0
FR210	3.98	23.0
FR220	3.15	17.0
FR230	4.3	20.0
FR240	2.46	13.0
FR250	2.84	13.0
FR260	2.17	11.0
FR300	3.09	16.0
FR410	5.4	29.0
FR420	2.09	11.0
FR430	5.18	27.0
FR510	2.51	14.0
FR520	4.57	22.0
FR530	2.59	16.0
FR610	4.38	27.0
FR620	3.38	20.0
FR630	5.54	38.0
FR710	3.76	22.0
FR720	2.56	17.0
FR810	2.32	15.0
FR820	1.42	9.0
FR830	2.04	14.0
FI200	0.37	2.0
FI130	2.14	6.0
FI180	1.25	4.0
FI190	0.96	4.0
FI1A0	2.52	10.0
IT110	3.05	19.0
IT120	6.32	18.0
IT130	2.25	7.0

NUTS code	LF_{RUN}*100	LF_{LEA}*100
IT200	2.98	18.0
IT310	5	15.0
IT320	4.26	21.0
IT330	8.68	40.0
IT400	2.64	19.0
IT510	3.57	17.0
IT520	3.34	16.0
IT530	4.11	13.0
IT600	3.87	19.0
IT710	4.01	12.0
IT720	3.39	14.0
IT800	4.05	21.0
IT910	3.28	18.0
IT920	4.33	14.0
IT930	3.53	16.0
ITA00	4.42	14.0
ITB00	3.33	15.0
IR010	2.1	19.0
IR020	2.69	17.0
NL110	2.69	24.0
NL120	2.58	26.0
NL130	0.64	21.0
NL210	1.15	25.0
NL220	3.15	34.0
NL230	7.47	53.0
NL310	2.4	24.0
NL320	4.64	35.0
NL330	4.8	34.0
NL340	5.93	45.0
NL410	1.79	30.0
NL420	2.65	24.0
PT110	6.6	21.0
PT150	2.72	7.0
PT160	3.38	12.0
PT170	2.74	8.0
PT180	2.35	10.0
SE010	0.88	7.0
SE020	0.76	6.0
SE040	0.95	6.0
SE060	0.38	3.0
SE070	0.25	2.0
SE080	0.17	1.0
SE090	0.63	5.0
SE0A0	0.99	8.0
UKC00	1.83	17.0
UKD00	2.31	28.0
UKE00	1.84	14.0
UKF00	2.09	15.0
UKG00	1.98	14.0
UKH00	2.35	17.0
UKJ00	2.44	19.0
UKK00	4.31	28.0

NUTS code	LF_{RUN}*100	LF_{LEA}*100
UKL00	3.16	19.0
UKM00	5.08	36.0
UKN00	2.84	24.0
CZ010	9.81	35.0
CZ020	8.75	36.0
CZ030	8.43	30.0
CZ040	6.06	19.0
CZ050	7.9	31.0
CZ060	9.99	37.0
CZ070	9.78	34.0
CZ080	9.62	32.0
HU100	8.53	23.0
HU210	5.75	19.0
HU220	4.12	13.0
HU230	7.5	23.0
HU310	8.98	18.0
HU320	5.34	24.0
HU330	5.44	21.0
PL110	3.24	24.0
PL120	3.18	23.0
PL210	8.6	16.0
PL220	4.66	20.0
PL310	6.95	19.0
PL320	5.85	15.0
PL330	9.81	23.0
PL340	2.75	18.0
PL410	3.26	25.0
PL420	4.04	21.0
PL430	3.15	21.0
PL510	6.26	20.0
PL520	6.28	23.0
PL610	3.8	24.0
PL620	5.49	19.0
PL630	4.7	19.0
BG010	13.14	28.0
BG020	13.2	29.0
BG030	14.67	29.0
BG040	7.7	23.0
BG050	7.6	22.0
BG060	7.99	23.0
RO010	8.44	25.0
RO020	7.69	25.0
RO030	7.95	26.0
RO040	8.2	28.0
RO050	6.41	24.0
RO060	8	25.0
RO070	7.38	25.0
RO080	7.77	25.0
SK010	6.09	34.0
SK020	6.16	30.0
SK030	4.63	17.0
SK040	4.11	16.0

NUTS code	LF_{RUN}*100	LF_{LEA}*100
SI000	3.4	14.0
EE000	4.54	27.0
LV000	5.47	28.0
LT000	8.13	38.0
CY000	3.4	14.0
MT000	3.4	14.0

LU: Luxembourg, AT: Austria, BL: Belgium, DE: Germany, DK: Denmark, ES: Spain, EL: Greece, FR: France, FI: Finland, IT: Italy,IR: Ireland, NL: Netherlands, PT: Portugal, SE: Sweden, UK: United Kingdom, CZ: Czech Republic, HU: Hungary, PL: Poland, BG: Bulgaria, RO: Romania, SK: Slovakia, SI: Slovenia, EE: Estonia, LV: Latvia, LT: Lithuania, CY: Cyprus, MT: Malta.

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Abstract

This interim report constitutes the third and final deliverable of the study "Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions - Phase 1 (GGELS)", in accordance with the terms of reference of the Administrative Arrangement (AA) No. AGRI-2008-0245. It reports on Work Packages 2, 3 and 4. A report on Work package 1 constituted the project’s first deliverable, which was accepted in October 2008. It is thus not covered in this report.
This report aims to provide DG AGRI, as well as other possible users of the GGELS project results, with a clear though exhaustive insight in the work preformed during GGELS Phase 1 and the intermediate results produced. GGELS being a multi-disciplinary research project spanning across three JRC institutes and 5 actions, this GGELS Phase 1 report is largely a collection of output produced by the different partners. Each of these contributions constitutes a separate section in this report.

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