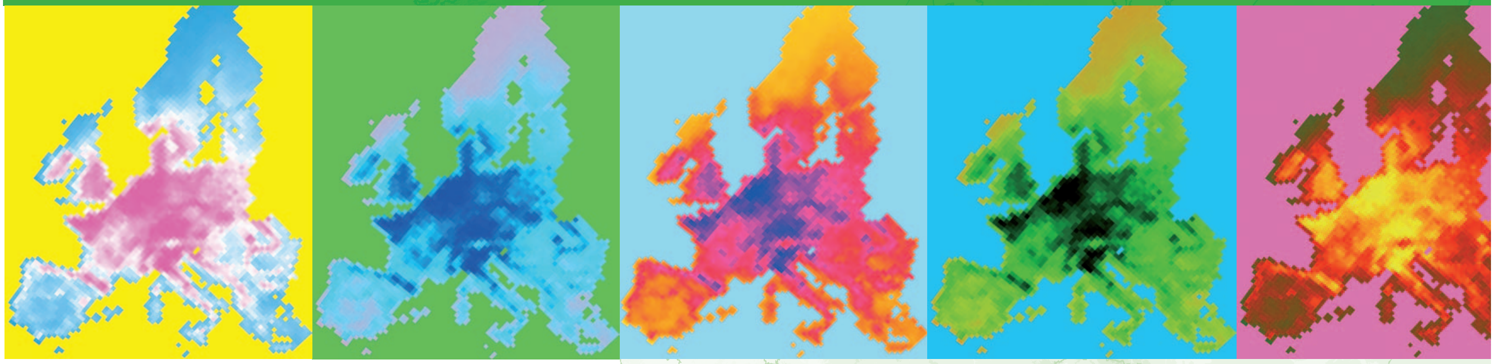
Spatialised European Nutrient Balance

Bruna Grizzetti, Fayçal Bouraoui and Alberto Aloe



Institute for Environment and Sustainability

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1 Introduction

1.1 Background

The Agenda 2000 introduced the need for the integration of environmental concerns into the agricultural policy. The CAP reform (Council Regulation 1782/2003) links the farmer's eligibility for agricultural subsidies to the respect of environment Community legislation (Cross-compliance), such as the Nitrate Directive (676/1991/EEC), and the maintenance of lands in good agricultural and environmental conditions. Improving the environment is among the main objectives of the Rural Development policy (Council Regulation 1698/2005), and the Community strategic guidelines for rural development for 2007-2013 identify water, together with biodiversity and climate change, as priority areas of action, stressing the importance of integrating rural development with the objectives laid down in Water Framework Directive (Council decision 144/2006).

Assessing the pressures originating from agriculture on water allows to evaluate the relationship between the environment status and past and current agricultural policies. In addition it constitutes a preliminary step to perform risk and scenarios analysis, both essential for effective water resource management planning. The assessment of water pollution caused by nitrates from agriculture is important for monitoring the designation of Nitrogen Vulnerable Zones and to adopt or revise appropriate Action Programs under the Nitrate Directive (676/1991/EEC). The WFD requires Member States to develop plan of measures based on the assessment of pressure and impact, to be integrated in the river management plans, whose implementation is foreseen for 2009. Similarly, the Groundwater Directive (2006/118/EC) imposes Member States to perform an analysis of groundwater chemical status to be reported in the river basin management plans according with the Water Framework Directive. Therefore the assessment of nutrient pressures could contribute to implement the European legislation.

The need for assessment of agricultural pressures on environment was stressed by Commission communication COM(2000)20, which defined objectives for developing indicators of integration of environmental concerns into the CAP, called IRENA indicators. Concerning nutrients, gross nitrogen balance was designated as the indicator of agricultural pressures on water quality, as it allows identifying areas where nitrogen surplus or deficit may be cause of concern for natural resources and indirectly for human health. Moreover, nitrogen balance at farm level has been suggested as a tool to monitor the effects of agri-environmental policy (Brouwer, 1998).

The final report on IRENA indicators (EEA, 2005) emphasised that the calculation of national gross nitrogen balance can mask important regional differences, while regional gross nitrogen balances (i.e. gross nitrogen balance computed at finer spatial resolution) would provide a better indication of nutrient losses to water bodies. However, the estimation of regional gross nitrogen balance is accompanies by certain difficulties due to the lack of important data at regional level (such as manure, fertiliser application, crop yield coefficients) and the uncertainty in agronomic coefficients (EEA, 2005; Campling, 2005). Furthermore, these data, when available, refer to national or administrative territorial unit, which are less suitable for environmental studies, the appropriate study unit being a river basin.

Several studies have contributed to develop methodologies to estimated regional nitrogen balance, using the CORINE land cover to spatialise the statistical data at catchment scale, such as Crouzet (in EEA, 2001) for the basins of the Elbe and the Loire and Campling et al. (2005) for EU-15. So far, the phosphorus balance has not been studied with the same interest.

Rae data available for administrative regions (economic data) are inappropriate for analysis for geographical and spatial reasons. The task is to redistribute the statistical data collected and aggregated in administrative units, into the relevant zones, that are catchment units (EEA, 2001), as they constitute the natural frame for studying and managing water resources efficiently. The spatialisation of administrative data constitutes therefore the first step for the integration between the economic and the environmental systems.

The assessment of spatial nutrient pressures together with information on farm management practices, soil and climatic conditions, would allow to estimate risk of nutrient losses in water bodies, providing support to European environmental policy.

1.2 Purpose

The general objective of this research is to contribute to the estimation at European scale of nutrient pressures originating from agriculture, in particular those threatening the water quality.
This work focused on the development of European maps of nutrient inputs from agriculture and nutrient surplus at the soil surface. The maps were developed in the framework of the FATE project (Fate of Agrochemicals in Terrestrial Ecosystems, Bouraoui et al., 2006), with the double objective to offer a direct assessment of actual nutrient pressures and provide a reliable data layer for risk analysis and for more complex process models, addressing water and soil quality. The study included both nitrogen and phosphorus elements.

The idea is to spatialise the official European statistics on agriculture provided at administrative units, to relevant geographical units, in order to analyse the nutrient pressures caused by agriculture on the environment, especially on water quality.
In this study, the statistics on agriculture available from the Farm Structure Survey (FSS) database of year 2000 were spatialised using the geographical information of the Corine land cover 2000 database, providing as major outputs:

- a European land-use map including crop distribution consistent with FSS data;
- European maps of spatialised nitrogen and phosphorus mineral fertiliser input;
- European maps of spatialised nitrogen and phosphorus manure input;
- European maps of spatialised nitrogen and phosphorus balance in soils.

The report is organised along three main tasks:

- Comparison of FSS crop data and CLC 2000 land cover areas, investigating the causes of discrepancies (Chapter 2);
- Development of a land-use map spatialising the FSS crop data on the basis of the CLC 2000 information, being consistent with the FSS agricultural areas (Chapter 3);
- Estimation of the nutrient input and output from agricultural sector (mineral fertiliser, manure and crop yield) and the nitrogen and phosphorus gross balance at a fine spatial resolution for EU-15 (Chapter 4).

2 Data

Evaluating the impact of agriculture on water quality requires a spatial analysis of agricultural pressures. The Farm Structure Survey data (FSS) describe the European agricultural status, while the CORINE Land Cover 2000 (CLC) embodies the spatial distribution of land cover types in Europe. Combining these two layers of data may provide relevant information to assess the impact of agriculture and in particular land use on the environment, strengthening the spatial dimension of the analysis. The link is only possible if the agricultural data contained in the two databases are consistent. However some discrepancies exist when comparing the two databases.

This chapter illustrates the information available in the two databases and the results of the analysis of their comparison.

2.1 Farm Structure Survey data (FSS)

Data on the structure of agricultural holdings are available from Eurostat, the Statistical Office of the European Community. Data are collected by the statistical services of the Member States through Farm Structure Survey (FSS) and then sent to Eurostat, which checks the data and once aggregated disseminates them at Community level.

The Farm Structure Survey consists of an agricultural census carried out every ten years to which intermediate random sample based surveys, organised every two or three years, are added. In order to provide harmonised information at European level, the surveys are carried out according to a methodological framework and within an agreed time frame established by community legislation. The last basic surveys took place in 1990 (EU-12) and 2000 (EU-15), while intermediate surveys were performed in 1993, 1995, 1997 and 2003. The actual survey of year 2000 took place in the period from 01/12/1998 to 01/03/2001.
The FSS database contains data on land use, livestock, management and farm labour input, using the agricultural holding as survey unit.

According to the Council Regulation (EEC) No 571/88 (Art.5 and 6) an agricultural holding is a single unit, both technically and economically, which has a single management and which produces agricultural products; and the agricultural area utilised for farming means the total area taken up by arable land, permanent pasture and meadow, permanent crops and kitchen gardens.
The survey covers agricultural holdings where:

- the agricultural area utilised for farming is 1ha or more;
- the agricultural area utilised for farming is less than 1 ha but they produce a certain proportion for sale or their production unit exceeds certain physical thresholds.
- in any case the threshold is set at a level excluding only the smallest holdings which together contribute 1 % or less to the total standard gross margin (SGM).

Data on land-use concerns areas of different covers, grouped in: arable land (class D), set-aside (class I08), kitchen garden (class E), permanent grass and meadow (class F), permanent crops (class G) and other land (class H) (Table 2.1). Total utilised agricultural area (UAA) is the sum of D + F + G + E + I08AD22. (Note that arable land is D + I08AD22 - D15_17_G07 and the surface occupied by permanent crops is G +D15_17_G07). Livestock data include information on heads for animal type.

Data collected by the survey are subject to statistical confidentiality; therefore Eurostat follows detailed rules for receiving, processing and disseminating theses data. In order to avoid any derivation (indirect calculation) of data, only aggregated data are disseminated and some filtering processes are used, such as rounding the values to the closer multiple of 10.

The data are available on three geographical levels: countries, regions and districts, according to the NUTS nomenclature of European territorial units (EUROSTAT, 2006a). The holding agricultural statistics are attributed to the territorial unit where the holding has is legal seat whatever the actual location of the holding parcels is.

For this study, data of FSS 2000 covering EU-15 were available at NUTS3 level.

Table 2.1 Description of FSS data classes considered in the study.

AGRAREA: Utilised agricultural area (UAA)
D - Arable land
D01 - Common wheat and spelt
D02 - Durum wheat
D03 - Rye
D04 - Barley
D05 - Oats
D06 - Grain maize
D07 - Rice
D08 - Other cereals
D09 - Pulses - total
D09C - Pulses - fodder peas
D09D - Pulses - fodder field beans
D10 - Potatoes
D11 - Sugar beet
D12 - Fodder roots and brassicas
D13 - Industrial plants
D13A - Tobacco
D13B - Hops
D13C - Cotton
D13D - Other industrial plants
D13D1 - Total:Other oil-seed or fibre plants
D13D1A - Rape and turnip:Other oil-seed or fibre plants
D13D1B - Sunflower:Other oil-seed or fibre plants
D13D1C - Soya:Other oil-seed or fibre plants
D13D1D - Others:Other oil-seed or fibre plants
D13D2 - Aromatic-; medicinal and culinary plants
D13D3 - Industrial plants - Others
D14 - Outdoor:Fresh vegetables; melons; strawberries
D14A - Open field:Outdoor:Fresh vegetables; melons; strawberries
D14B - Market gardening:Outdoor:Fresh vegetables; melons; strawberries
D15_17_G07 - Under glass:Vegetables; flowers and permanent crops
D15 - Under glass:Fresh vegetables; melons; strawberries
D16 - Outdoor:Flowers and ornemental plants
D17 - Under glass:Flowers and ornemental plants
D18 - Forage plants - total
D18A - Forage plants - temporary grass
D18B - Total:Other green fodder:Forage plants
D18B1 - Green maize:Other green fodder:Forage plants
D18B2 - Leguminous plants:Other green fodder:Forage plants
D18B3_2000 - age plants - other green fodder - others
D19 - Seeds and seedlings
D20 - Other crops
D21 - Fallow land without subsidies
I08 - Set-aside areas under incentive schemes
I08AD22 - Fallow land with no economic use:Set-aside areas under incentive schemes
E - Kitchen gardens

Table 2.1 (continue) Description of FSS data classes considered in the study.

- F - Total:Permanent grassland and meadow
    - F01 - Pasture and meadow:Permanent grassland and meadow
    - F02 - Rough grazings:Permanent grassland and meadow
- G - Permanent crops
    - G01 - Fruit and berry plantations - total
        - G01A - Temperate climate:Fruit and berry plantations
        - G01B - Subtropical climate:Fruit and berry plantations
        - G01C - Nuts:Fruit and berry plantations
    - G02 - Citrus plantations
    - G03 - Olive plantations - total
        - G03A - Olive plantations - table olives
        - G03B - Olive plantations - oil production
    - G04 - Vineyards - total
        - G04A - Vineyards - quality wine
        - G04B - Vineyards - other wines
        - G04C - Vineyards - table grapes
        - G04D - Vineyards - raisins
    - G05 - Nurseries
    - G06 - Other permanent crops
    - G07 - Permanent crops under glass
- H - Other land

- J - Livestock
    - J01 - Equidae
    - J02 - Bovine <1 year old - total
        - J02A - Bovine <1 year old - males
        - J02B - Bovine <1 year old - females
    - J03 - Bovine 1-<2 years - males
    - J04 - Bovine 1-<2 years - females
    - J05 - Bovine 2 years and older - males
    - J06 - Heifers; 2 years and older
    - J07 - Dairy cows
    - J08 - Other cows; bovine 2 years old and over
    - J09 - Sheep - total
        - J09A - Sheep - breeding ewes
        - J09B - Sheep - others
    - J10 - Goats
        - J10A - Goats - breeding females
        - J10B - Goats - others
    - J11 - Pigs - piglets under 20 kg
    - J12 - Pigs - breeding sows over 50 kg
    - J13 - Pigs - others
    - J14 - Poultry - broilers
    - J15 - Laying hens
    - J16 - Poultry - others

2.2 CORINE Land Cover 2000 map (CLC2000)

The CORINE Land Cover (CLC) database contains geo-referenced land cover information for Europe (Figure 2.1). It was initiated by the Commission in 1985 and then regularly updated. The CLC database is now maintained by the European Topic Centre on Terrestrial Environment on behalf of the European Environment Agency (ETC, 2005). In 1999 the EEA and the JRC launched the IMAGE2000 and the CLC2000 Project (I&CLC2000) to produce the CLC database for the reference year 2000 and the land cover changes database between 1990 and 2000 (Büttner et al., 2002). The Corine Land Cover 2000 was performed in a 3 years period from 1999 to 2001, by interpretation of satellite images (Landsat TM IMAGE 2000).

The main characteristics of the CLC 2000 are:
- the mapping scale is 1:100 000, which means a mapping accuracy of 100 m.
- the mapping unit is 25 ha, with minimum width of unit of 100 m, which means that polygons of 25 ha are the smallest surface mapped and linear features with width lower than 100 m are not considered.

The CLC nomenclature is hierarchical and distinguishes 5 classes at the first level, 15 classes at the second level and 44 classes at the third level (Table 2.2).
The CLC 2000 is available in both vector and raster based format. In this project CLC raster database 2000 with 100 m grid cell size was used (ETC, 2005).

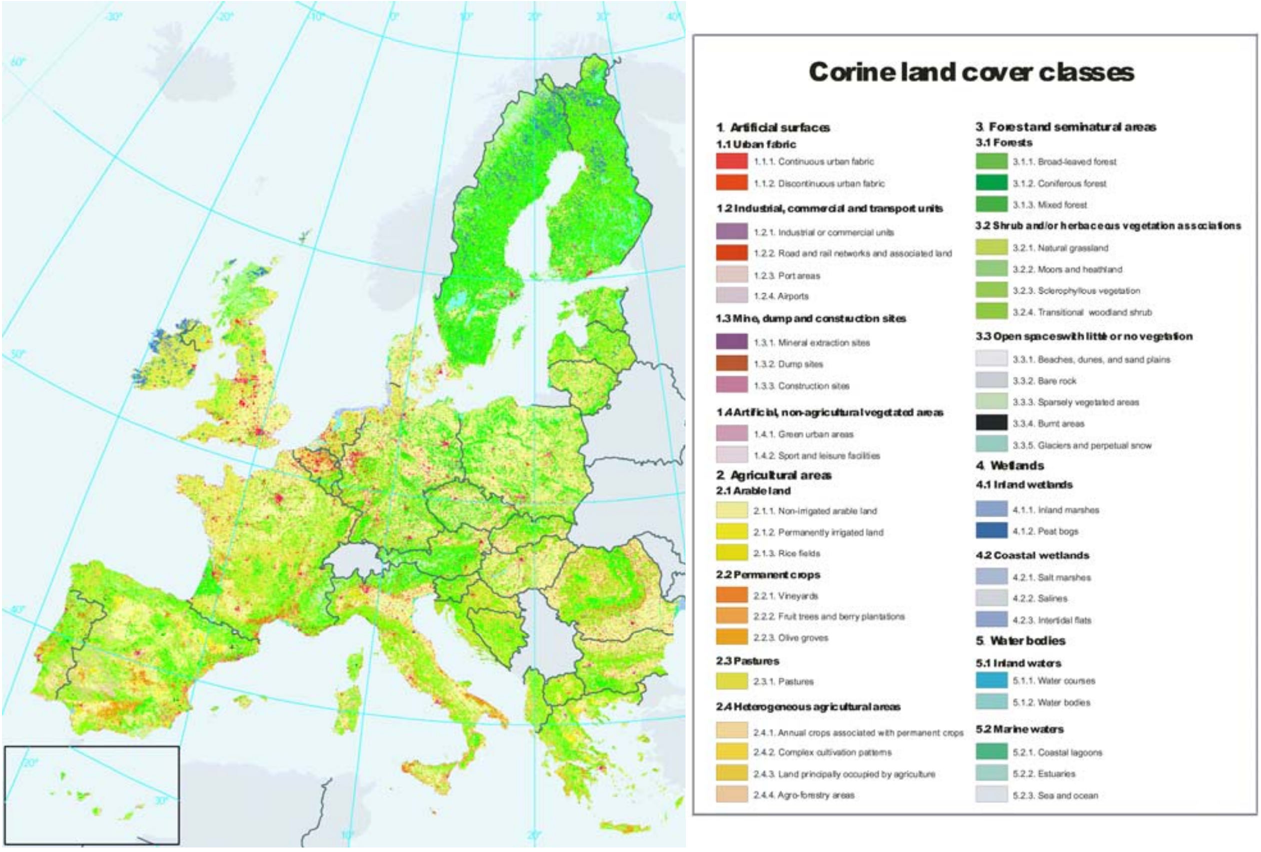


Figure 2.1 CORINE Land Cover map.
(http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=1270).

Table 2.2 CORINE Land Cover classes.

Level 1	Level 2	Level 3	ID
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric	1
		1.1.2 Discontinuous urban fabric	2
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units	3
		1.2.2 Road and rail networks and associated land	4
		1.2.3 Port areas	5
		1.2.4 Airports	6
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites	7
		1.3.2 Dump sites	8
		1.3.3 Construction sites	9
	1.4 Artificial, non-agricultural vegetated areas	1.4.1Green urban areas	10
		1.4.2 Sport and leisure facilities	11
2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land	12
		2.1.2 Permanently irrigated land	13
		2.1.3 Rice fields	14
	2.2 Permanent crops	2.2.1 Vineyards	15
		2.2.2 Fruit trees and berry plantations	16
		2.2.3 Olive groves	17
	2.3 Pastures	2.3.1 Pastures	18
	2.4 Heterogeneous agricultural areas	2.4.1 Annual crops associated with permanent crops	19
		2.4.2 Complex cultivation patterns	20
		2.4.3 Land principally occupied by agriculture with significant areas of natural vegetation	21
		2.4.4 Agro-forestry areas	22
3. Forest and semi natural areas	3.1 Forests	3.1.1 Broad-leaved forest	23
		3.1.2 Coniferous forest	24
		3.1.3 Mixed forest	25
	3.2 Scrub and/or herbaceous vegetation associations	3.2.1 Natural grasslands	26
		3.2.2 Moors and heathland	27
		3.2.3 Sclerophyllous vegetation	28
		3.2.4Transitional woodland-shrub	29
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sands	30
		3.3.2 Bare rocks	31
		3.3.3 Sparsely vegetated areas	32
		3.3.4 Burnt areas	33
		3.3.5 Glaciers and perpetual snow	34
4. Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes	35
		4.1.2 Peat bogs	36
	4.2 Maritime wetlands	4.2.1 Salt marshes	37
		4.2.2 Salines	38
		4.2.3 Intertidal flats	39
5. Water bodies	5.1 Inland waters	5.1.1 Water courses	40
		5.1.2 Water bodies	41
	5.2 Marine waters	5.2.1 Coastal lagoons	42
		5.2.2 Estuaries	43
		5.2.3 Sea and ocean	44

2.3 Comparison between FSS and CLC 2000 databases

The link between FSS and CLC data is possible if the agricultural information contained in the two databases is consistent. For this reason, the information of the two databases was compared.

The Utilised Agricultural Area (UAA) reported in FSS database and in CLC2000 are not in agreement (Figure 2.2). This discrepancy may lead to different nutrient balance estimations at local and regional scale, as nutrient inputs are directly related to crops extension.

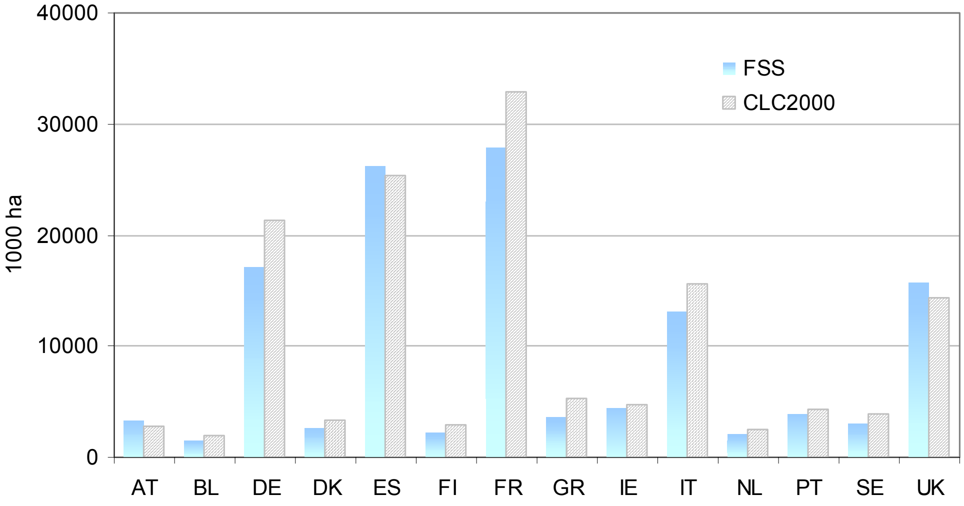


Figure 2.2 Utilised Agricultural Area (UAA) reported in FSS database and in CLC2000 (Corine class 2: Agricultural Areas).

The discrepancies in reported surfaces increase when considering the different types of agricultural areas (class correspondence is shown in Table 2.3): arable land (Figure 2.3), pasture (Figure 2.4) and permanent crops (Figure 2.5), indicating that a direct link between FSS and CLC 2000 is not possible.

Table 2.3 Correspondence between CLC second level and FSS data classes used in the study.

CLC classes (second level)	FSS classes
Arable land + Heterogeneous agricultural areas (Class 2.1 + 2.4)	Arable land + Set-aside areas under incentive schemes (Class D + I08AD22 - D15_17_G07)
Pastures (Class 2.3)	Permanent grassland and meadow (Class F)
Permanent crops (Class 2.2)	Permanent crops (Class G + D15_17_G07)

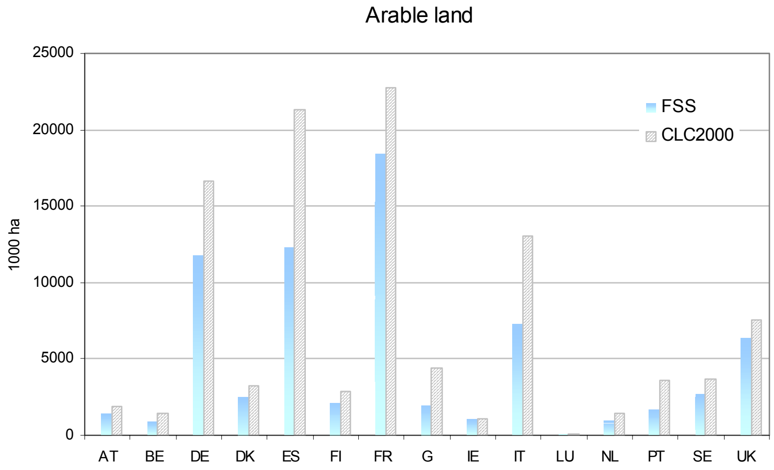


Figure 2.3 Arable land areas reported in FSS and in CLC2000 (Classes are detailed in Table 2.3).

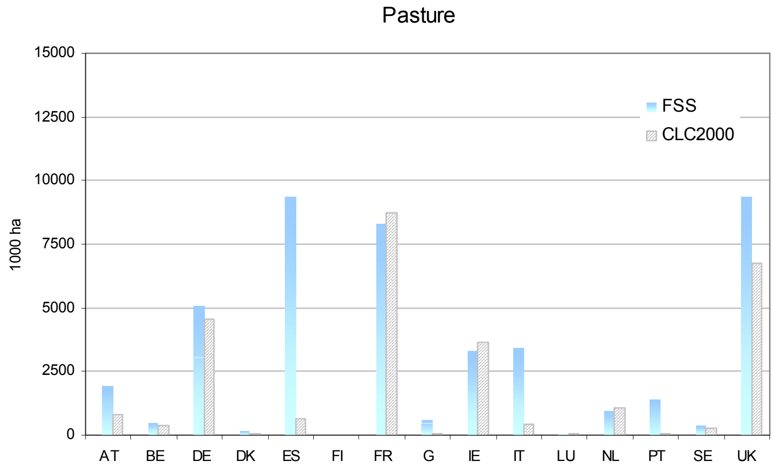


Figure 2.4 Pasture areas reported in FSS and in CLC2000 (Classes are detailed in Table 2.3).

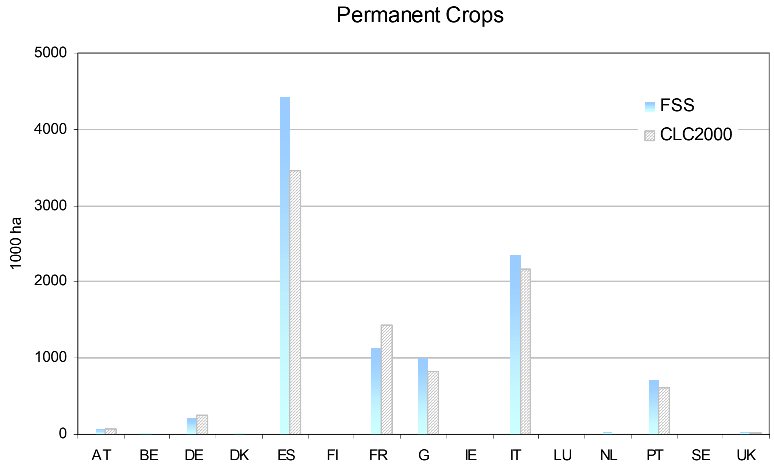


Figure 2.5 Permanent crops areas reported in FSS and in CLC2000 (Classes are detailed in Table 2.3).

The discrepancies arise from the different scopes of the FSS and the CLC database, focused on agricultural inventory for the first and on environmental mapping for the latter, leading to differences in the methodology, definition of classes, survey periods and statistical accuracy (GIM, 2002):

- FSS is based on exact figures of a census, aggregated at territorial units, while CLC database represents the landscape by polygons derived by interpretation of satellite images.

- Classes of nomenclature are defined differently in the two databases. CLC contains also heterogeneous classes while in FSS database crop classes are specified in details.

- The CLC 2000 was performed in a 3 years period from 1999 to 2001 and similarly the FSS was carried out between 01/12/1998 and 01/03/2001, but this does not mean that the census data exactly refer to the date of the satellite images used in the CLC map for the same region.

- CLC uses 25 ha area as mapping unit while FSS distinguishes between parcels of 1 ha.

Discrepancies between FSS and the CLC data of the year 1990 were analysed by Kayadjanian and Vidal (2001) and by GIM (2002). In this study an analysis was conducted to evaluate factors explaining the differences between CLC and FSS data of the year 2000 at NUT3 level. In the analysis the differences between the two databases were considered both in terms of absolute values (surface in ha) and relative values (surface in %).

The absolute value (also called absolute error in this report) was expressed as:

$$CLC_{ij}\text{-}FSS_{ij} \qquad \text{(Equation 1)}$$

while the relative value (also called relative error in this report) was computed as:

$$(CLC_{ij}\text{-}FSS_{ij})*100/CLC_{ij} \qquad \text{(Equation 2)}$$

where CLC_{ij} and FSS_{ij} represent for each NUTS3 j the surface (in ha) reported by the class i in the CORINE and FSS database, respectively. The i classes refer to Table 2.3 and represent the three major types of agricultural landscape: arable land, pasture and permanent crops.

Considering FSS as the reference:

CLC-FSS = 0 indicates an agreement between CLC and FSS data;

CLC-FSS > 0 indicates that CLC overestimates the correspondent class in FSS;

CLC-FSS < 0 indicates that CLC underestimates the correspondent class in FSS.

Figure 2.6 and Table 2.4 show the agreement between FSS and CLC reported areas for each NUTS3, according to the correspondences of classes of Table 2.3. The statistics show a systematic tendency in CLC to underestimate pasture and overestimate agriculture compared to FSS. This may indicate that the CLC class 2.4 (Heterogeneous agricultural areas), considered as arable land in the analysis, contains also pasture areas. Moreover, as indicated by the Nush-Sutcliffe efficiency (Table 2.4) better agreement is found for permanent crops, probably easier to identify by image interpretation, while higher uncertainty occurs in the distinction of pasture and arable land.

The histograms in Figure 2.7, Figure 2.8, Figure 2.9 and Figure 2.10 show the distribution of the CLC-FSS differences (Equation 1) in reported area by NUTS3 per country, for total Utilised Agricultural Area (UAA), arable land, pasture and permanent crops area, respectively. The histograms illustrate the distribution of discrepancies between FSS and CLC classes, sign, frequency and absolute value. Although according to average statistics (Table 2.4) the UAA of FSS is greater than the CLC total agricultural area, Class 4 of Table 2.2, Figure 2.7 shows that for certain countries the CLC agricultural area (Class 4) does not account for all the UAA reported in FSS. Therefore additional classes besides Class 4 may include the agricultural area reported in FSS. This happens in Austria, Spain, France, Portugal, Italy and United Kingdom.

High values of absolute errors do not necessary indicate a relevant under or over estimation of land cover type, as NUTS3 have different size. For this reason the analysis can be integrated considering the relative errors (Equation 2), which is the CLC-FSS difference relative to the NUTS surface. The box plots (*) reported in Figure 2.11, Figure 2.12 and Figure 2.13 show the distribution of the relative error for the three land-use types. In general, the relative error is higher for pasture than for arable land. It is almost positive for arable lands (Figure 2.11), while it is predominantly negative for pasture and permanent crops (Figure 2.12 and Figure 2.13), with extreme negative values occurring for permanent crops. Mediterranean countries, such as Spain, Portugal, Italy and Greece, show higher underestimation of pasture (Figure 2.12).

A spatial representation of CLC-FSS differences allows to identify regions concerned by higher discrepancies, providing suggestions for possible explanations.

(*) **Box plots** graphics allow to compare the distribution for different groups. The box marks the range covered by values between the 25th and 75th percentiles, with a heavy black line inside indicating the 50th percentile, or median, of that distribution. Whiskers appear above and below the boxes. Whiskers are vertical lines ending in horizontal lines at the largest and smallest observed values that are not statistical outliers. Values that are between 1.5 and 3 box lengths from each end of the box are called *outliers* and are identified with an ○, while values that are more than 3 box lengths from each end of the box are called *extreme* values and are marked with an asterisk *.

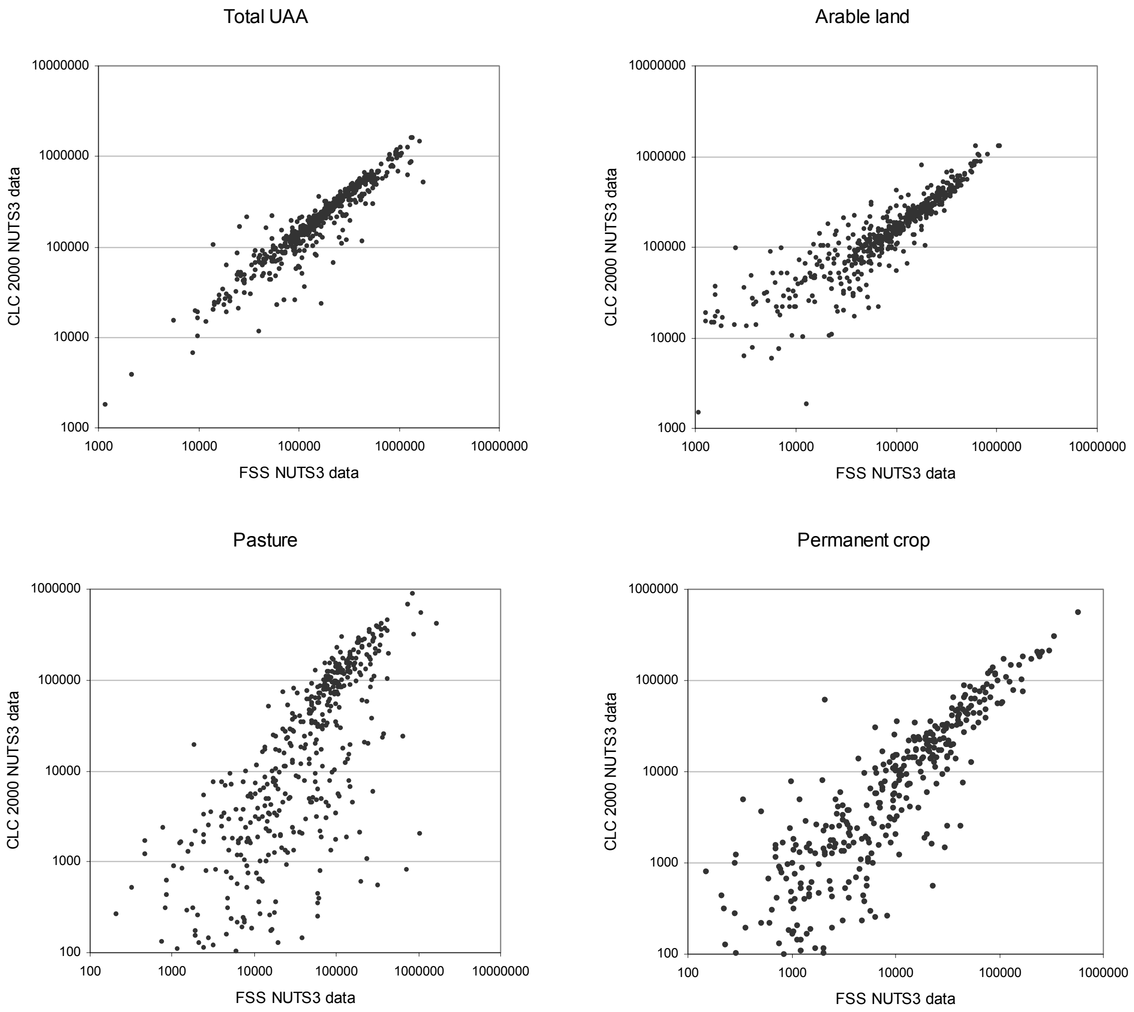


Figure 2.6 FSS towards CLC areas, considering: total agricultural area (Total UAA) and arable land, pasture and permanent crop classes (Classes are detailed in Table 2.3).

Table 2.4 Statistics on the agreement between FSS and CLC data at NUTS3 level.

Statistic	Total UAA	Arable	Grassland	Permanent crops
Mean FSS (ha)	250081	141518	88629	19712
Mean CLC (ha)	278625	207060	54103	17461
Standard deviation FSS (ha)	251918	154609	145850	47025
Standard deviation CLC (ha)	246152	202690	97480	43413
RMSE (ha)	99777	97521	113652	13310
Coefficient of determination R^2	0.86	0.91	0.45	0.92
Nush-Sutcliffe Efficiency	0.84	0.60	0.39	0.92

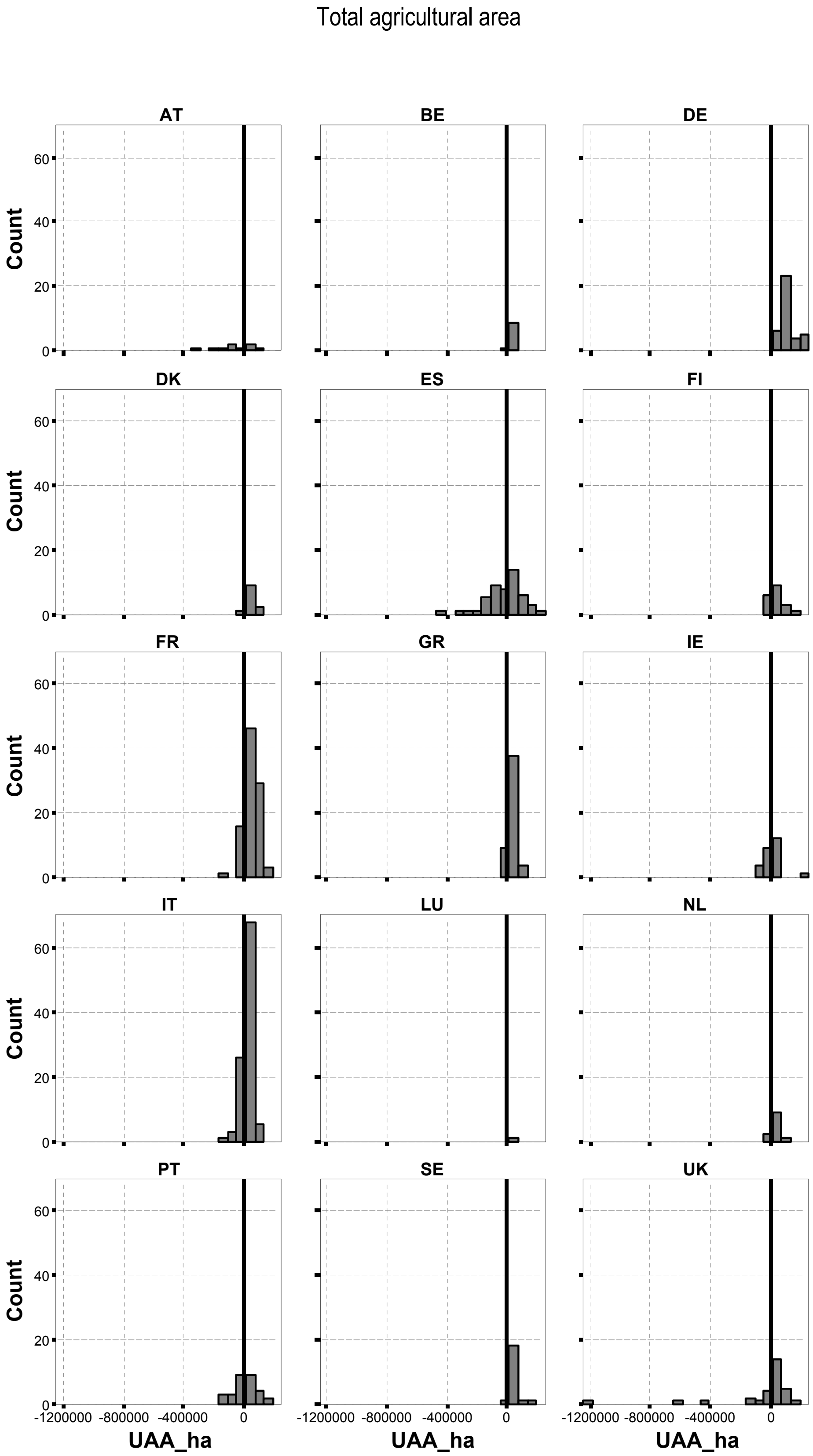


Figure 2.7 Distribution of the residuals CLC-FSS (in ha) in reported total UAA area by NUTS3 per country.

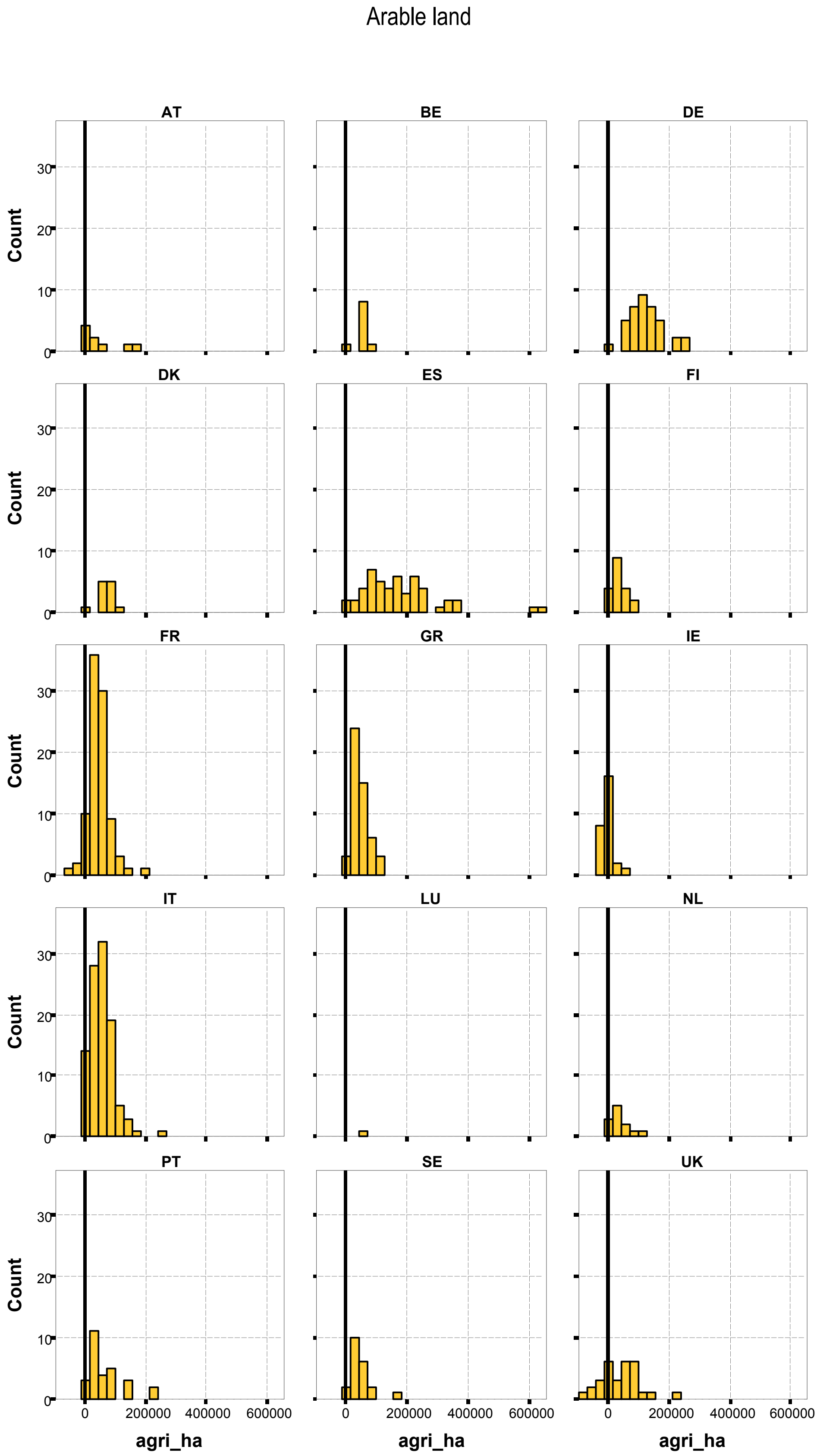


Figure 2.8 Distribution of the residuals CLC-FSS (in ha) in reported arable land area by NUTS3 per country.

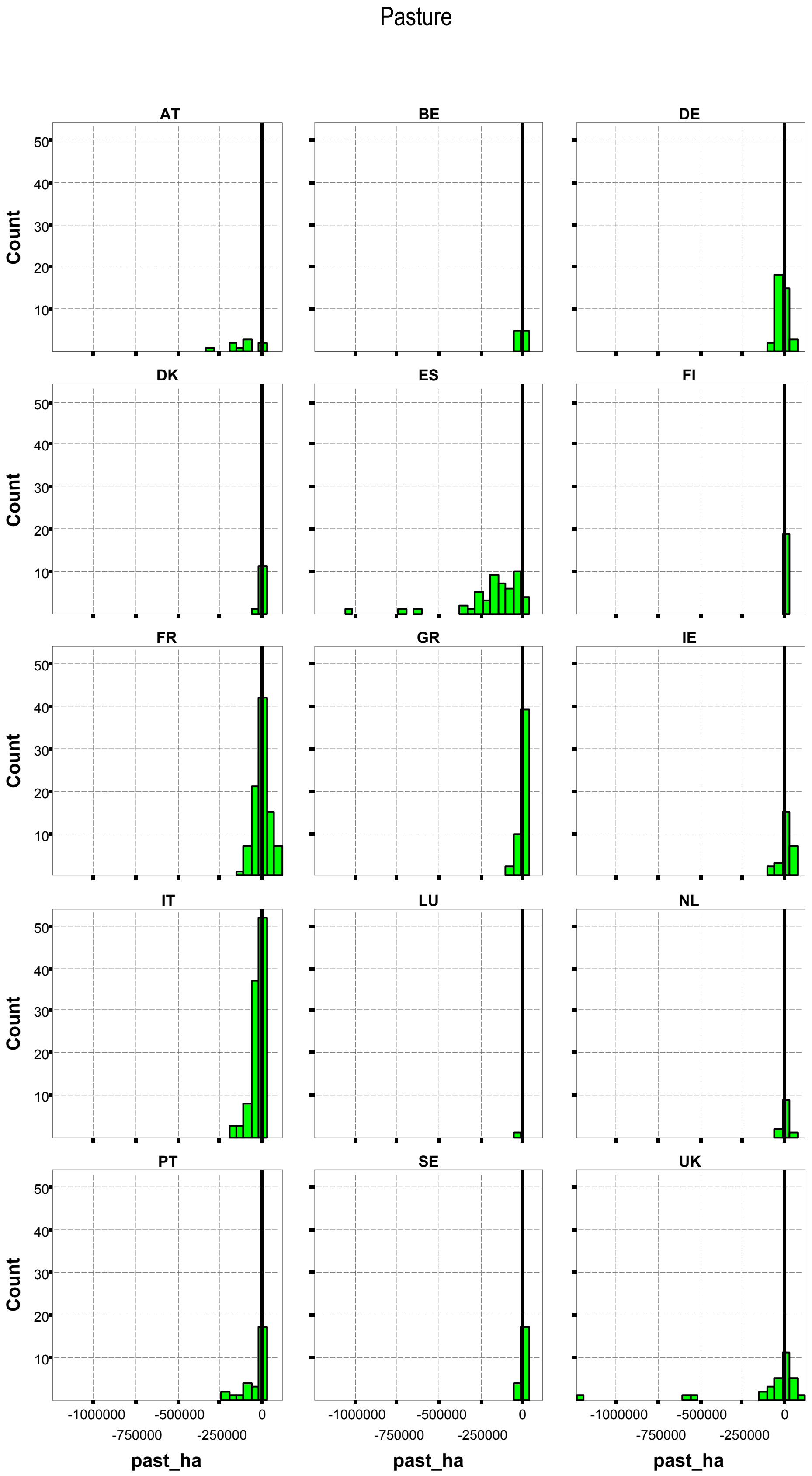


Figure 2.9 Distribution of the residuals CLC-FSS (in ha) in reported pasture area by NUTS3 per country.

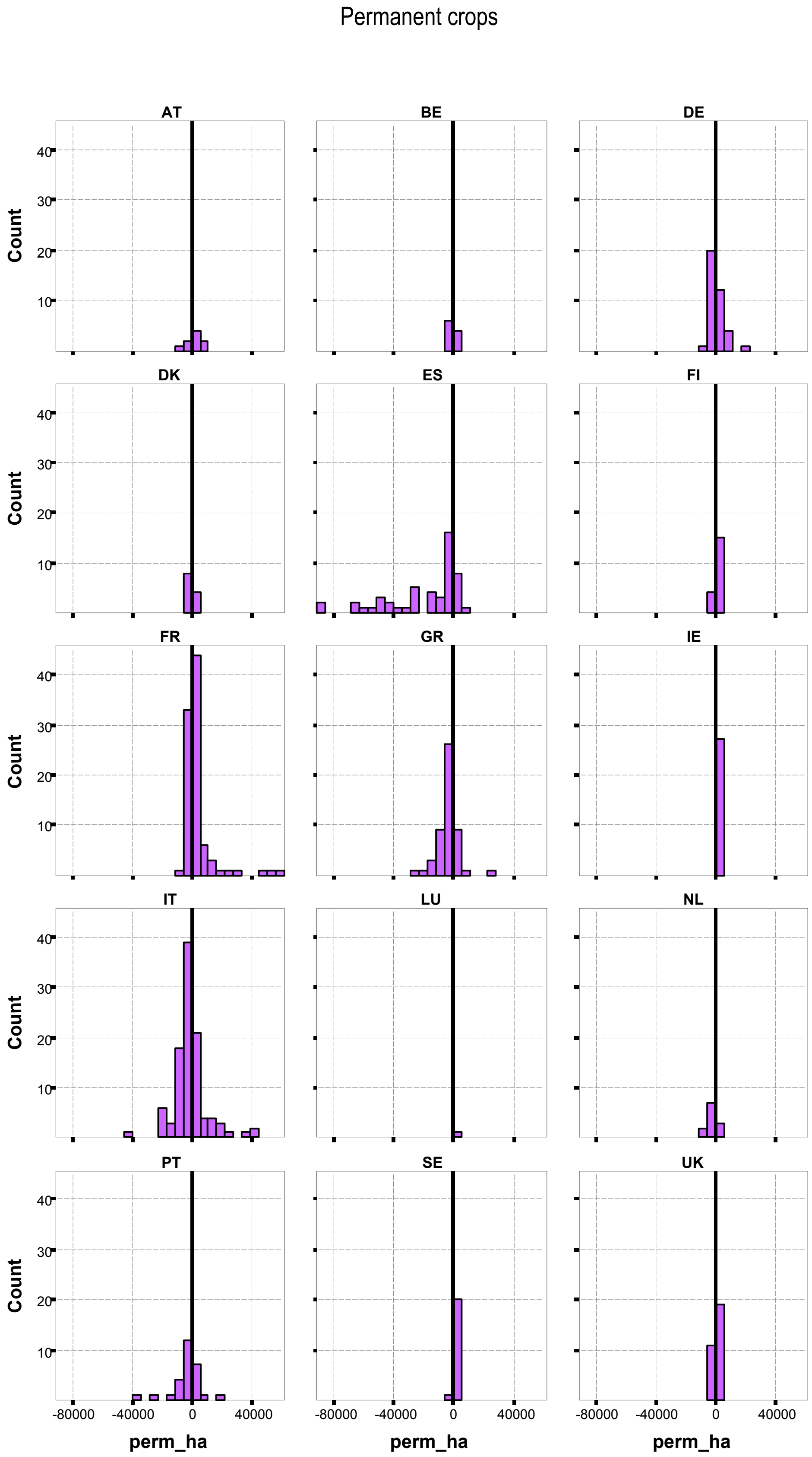


Figure 2.10 Distribution of the residuals CLC-FSS (in ha) in reported permanent crops area by NUTS3 per country.

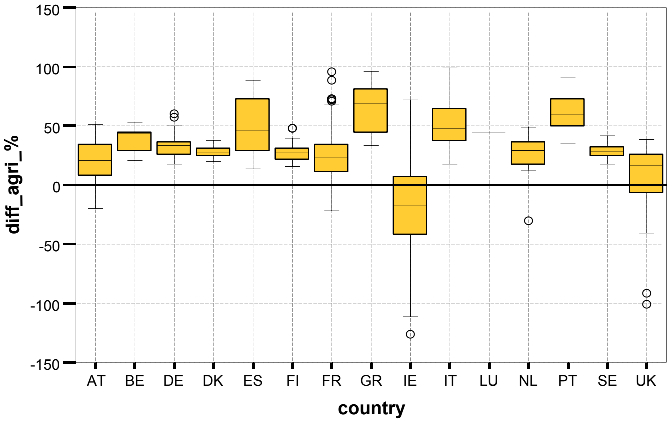


Figure 2.11 Distribution of relative error between CLC and FSS for **arable land** (Equation 2) for different countries. (ES has two extreme negative values out of the graphic scale. IE and UK have one extreme negative value out of the graphic scale).

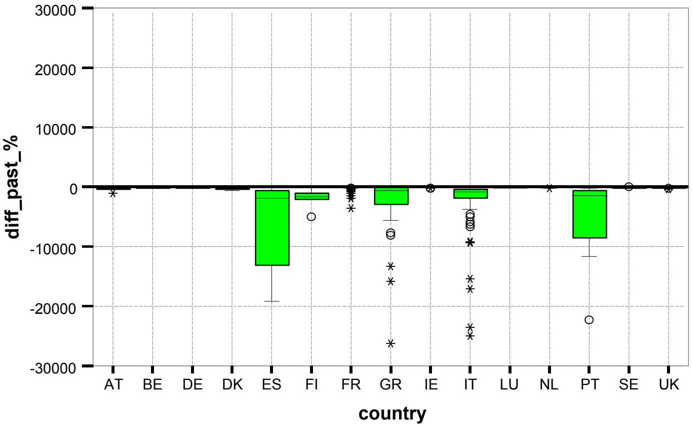


Figure 2.12 Distribution of relative error between CLC and FSS for **pasture** (Equation 2) for different countries. (ES has four extreme negative values out of the graphic scale).

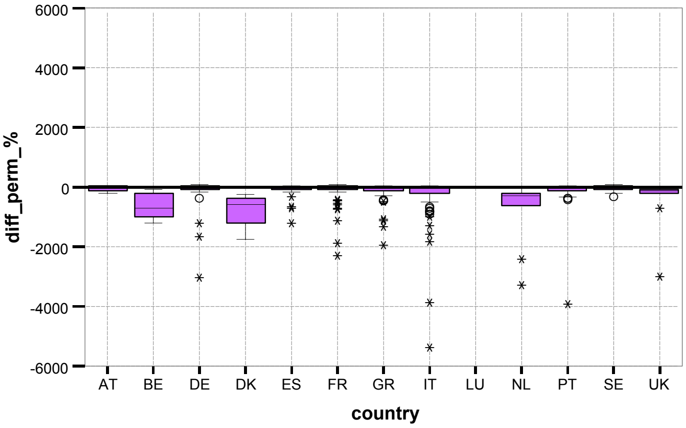


Figure 2.13 Distribution of relative error between CLC and FSS for **permanent crops** (Equation 2) for different countries. (BE has one extreme negative value out of the graphic scale).

2.4 Analysis of discrepancies between FSS and CLC 2000

The relationship between the differences between CLC and FSS data and several variables representing the landscape was investigated to deepen the analysis on the reasons of such discrepancies. In particular, a correlation analysis and a principal component analysis were performed.

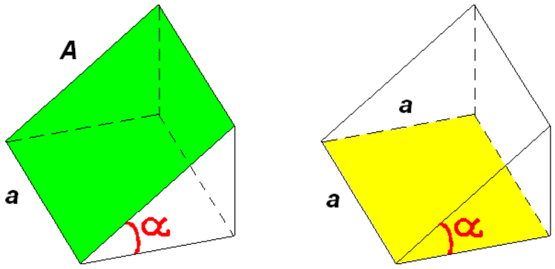
In the analysis, the differences between the two databases were considered both in terms of absolute (Equation 1) and relative values (Equation 2).

The variables considered in the analysis were:

- ***Country***. The country the NUTS3 belongs to may inform about differences related to interpretation or landscape features specific of a country, as national teams performed the interpretation of the satellite images of their country for producing the CLC map.

- ***Slope***. FSS data derive from a census, therefore reported areas corresponds to actual surface of the holdings, although Eurostat slightly modifies figures for confidentiality needs. Differently, CLC data derive from satellite images, then projected in Lambert-Azimuthal Equal-Area (ETRS_1089_LAEA). This projection system preserves the area of individual polygons and maintains the true sense of direction from the centre. However, the CLC is a two-dimensional representation of a three-dimensional landscape, therefore in mountain region the agricultural area computed from CLC may slightly differ from the one obtained by local survey or from cadastral maps.

When the slope α >0 (Figure 2.14) the actual ground surface (CLC_{slope}) is greater than the surface reported by CORINE (CLC):



CLC_{slope} =a*A=a*(a/cos α)=CLC/cos α

CLC=a*a

Figure 2.14 Simplified example of actual ground surface (left) and surface reported by CORINE (right) in mountainous region.

Therefore the potential difference between the actual surface and the surface reported by CLC was calculated as:

$$(CLC_{slope}-CLC)*100/CLC \qquad \text{(Equation 3)}$$

- ***Holding size***. The average size of the holdings within the NUTS3 may inform on the type of agricultural system (intensive/extensive system, small/large holdings), although a better information would have been provided by the inclusion of the standard deviation of holding size, non available for the study.

For each NUTS3 j the average holding size was calculated as the rate between the utilised agricultural area (FSS_j) and the number of holdings (Nho_j) reported in the FSS database:

$$(FSS_j)/(Nho_j) \qquad \text{(Equation 4)}$$

- ***Fraction occupied by arable/pasture/permanent crops within the agricultural land***. Discrepancies may be explained the dominance of an agricultural class, more difficult to be interpreted.

For each NUTS3 j the fraction of different types of agricultural areas i (Table 2.3) was calculated as:

$$(CLC_{ij})/(CLC_{Aj}) \qquad \text{(Equation 5)}$$

where CLC_{Aj} is the area of total agricultural land reported in the CLC Class 4 (Table 2.2).

- ***Fraction occupied by heterogeneous agricultural areas within the agricultural land***. Discrepancies between FSS and CLC may be linked to the prevalence in CLC of agricultural heterogeneous classes with respect to the homogeneous classes (area of CLC Class 2.4 on total area of CLC Class 2, see CLC classes in Table 2.2). The fraction occupied by heterogeneous agricultural areas was computed according to Equation 5, using Class 2.4 as agricultural area type.

- ***Fragmentation of agricultural parcels***. The index of fragmentation of agricultural parcels within a NUTS3 indicates the fragmentation of parcels and therefore potential problems of accuracy due to the CLC limit of 25 ha mapping unit. This can be relevant in highly populated regions where small agricultural parcel are mixed with urban areas.

Different indexes may be used to describe the landscape configuration. In this study, the patch density was chosen to evaluate the spatial heterogeneity of different land cover classes. The patch density expresses the number of patch per unit of area, allowing the comparison in NUTS of different size. The density of patches in a landscape may inform on the spatial heterogeneity and fragmentation of a specific class of land cover, although it does not provide information on the distribution of patches and should be integrated with other metrics to complete the description of the landscape configuration. A landscape with a greater density of patches has a finer grain and a greater heterogeneity given a scale of study. The patch density is constrained by the grain size of the raster image.

In the study, CLC 100m raster resolution was used, allowing the comparison of patch density for all the NUTS. The patch density was calculated using a reclassification of the CORINE land cover, where the classes were reduced from 44 to 10, according to Table 2.5. The reclassification was designed to simplify the computation and the interpretation of the landscape metric. However, it should be noticed that slightly different values would have been obtained using the original CLC 2000 with 44 classes (level 3), as the reclassification reduces the real diversity of the landscape described in the CLC.

The patch density (PD_j) was computed in each NUTS3 j by the FRAGSTAT program (McGarigal et al., 2002) according to the following equation:

$$PD_j = (n_{ij}/A_j)*(10000*100) \qquad \text{(Equation 6)}$$

where n_{ij} is the number of patches in the landscape j (NUTS j) of patch type i (reclassified CLC Class i see Table 2.5) and A_j is the total landscape area (m^2). The ratio is multiply by 10000 and 100 to convert to 100 ha. For this reason the PD is expressed as number per 100 ha.

Table 2.5 Reclassification of CLC 2000 to compute the patch density.

CORINE original		CORINE reclassified for fragmentation analysis
Class Level 1	Class Level 2	
1. Artificial surfaces	1.1 Urban fabric	1
	1.2 Industrial, commercial and transport units	
	1.3 Mine, dump and construction sites	
	1.4 Artificial, non-agricultural vegetated areas	
2. Agricultural areas	2.1 Arable land	21
	2.2 Permanent crops	22
	2.3 Pastures	23
	2.4 Heterogeneous agricultural areas	24
3. Forest and semi natural areas	3.1 Forests	31
	3.2 Scrub and/or herbaceous vegetation associations	32
	3.3 Open spaces with little or no vegetation	33
4. Wetlands	4.1 Inland wetlands	4
	4.2 Maritime wetlands	
5. Water bodies	5.1 Inland waters	5
	5.2 Marine waters	

Figure 2.15, Figure 2.16, Figure 2.17 and Figure 2.18 illustrate the distribution of NUTS3 patch density for the different types of agricultural land cover per country. Patch density is greater for pasture and agricultural land than for permanent crops. Higher values are found in Belgium, Germany and France, for arable land and pasture classes, and also in Finland, Italy and Portugal, for the heterogeneous agricultural land class.

The spatial distribution of patch density for NUTS3 in EU15 is reported in Figure 2.19 and Figure 2.20. The fragmentation of the urban areas (Figure 2.19a) is greater in the flat and densely populated areas of the Po plain, in the northeast France, in Belgium and Germany. Arable areas seem more fragmented in Belgium, France and Germany (Figure 2.19b and d), while permanent crops appear more heterogeneously distributed on the coasts of the Mediterranean countries (Figure 2.19c). Similar results were observed for CORINE 1990 by Eiden et al. (2000), who underlined that for the CLC map in France, Belgium and part of Spain minimum mapping units less than 25 ha were used, due to national specific requirements. Concerning pasture, higher values of patch density are present in France, Germany and United Kingdom for CLC class 2.3, pasture within agricultural areas, (Figure 2.20a), and in Scandinavian countries and southern Europe for the CLC Class 3.2, scrub and/or herbaceous vegetation associations, which plays an important role in extensive agricultural areas, particularly breeding (Figure 2.20b).

This pattern reflects the different composition of landscape, according to the region and climate, represented in the CLC map by different land cover classes. However, when comparing the patch density among regions it has to be considered that the landscape diversity depends also on the way the CLC methodology has been applied in the different regions. In fact the landscape fragmentation may be influenced by the resolution of the satellite images available and depends on how meticulous was the work of photo-interpretation (Gallego et al., 2000). Moreover, in some regions the minimum polygon size of 25 ha is rather large compared with the average agricultural field size.

Finally, Table 2.6 summarises the variables used in the correlation and factor analysis.

Table 2.6 Variables considered in the analysis (legend, unit of measure and definition).

Legend	Explanation
agri_ha	Difference between CLC and FSS agricultural areas, calculated according Equation 1 (CLC class 12+13+14+19+20+21+22). (ha).
past_ ha	Difference between CLC and FSS pasture areas, calculated according Equation 1 (CLC class 18). (ha).
perm_ ha	Difference between CLC and FSS pasture areas, calculated according Equation 1 (CLC class 15+16+17). (ha).
diff_agri_%	Difference between CLC and FSS agricultural areas, calculated according Equation 2 (CLC class 12+13+14+19+20+21+22). (%).
diff_past_%	Difference between CLC and FSS pasture areas, calculated according Equation 2 (CLC class 18). (%).
diff_perm_%	Difference between CLC and FSS pasture areas, calculated according Equation 2 (CLC class 15+16+17). (%).
Country	EU15 country
slope_%	Difference in CLC agricultural area due to slope, calculated according to Equation 3 (class from 12 to 22). (%).
hold_size_ha	Average holding size, calculated according Equation 4. (ha).
agri_frac	Fraction of agricultural area (homogenious + heterogenius) on total agricultural area, calculated according Equation 5 (area class 12+13+14+19+20+21+22)/(area class from 12 to 22).
past_frac	Fraction of pasture area on total agricultural area, calculated according Equation 5 (area class 18)/(area class from 12 to 22).
perm_frac	Fraction of permanent crop area on total agricultural area, calculated according Equation 5 (area class 15+16+17)/(area class from 12 to 22).
hetero_agri_frac	Fraction of heterogeneous agricultural area on total agricultural area, calculated according Equation 5 (area class 19+20+21+22)/(area class from 12 to 22).
PD_*i*	Patch Density of reclassified CLC class *i* (Table 2.5), calculated by the software FRAGSTATS, Equation 6. (Number per 100 ha).

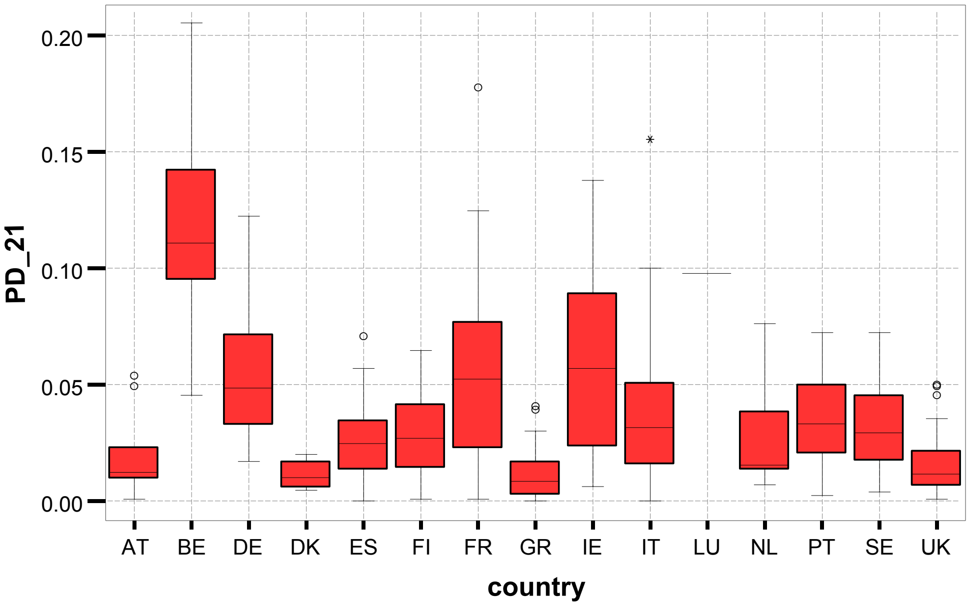


Figure 2.15 Distribution of NUTS3 patch density for **arable land** (CLC class 2.1 level 2, see Table 2.5) per country.

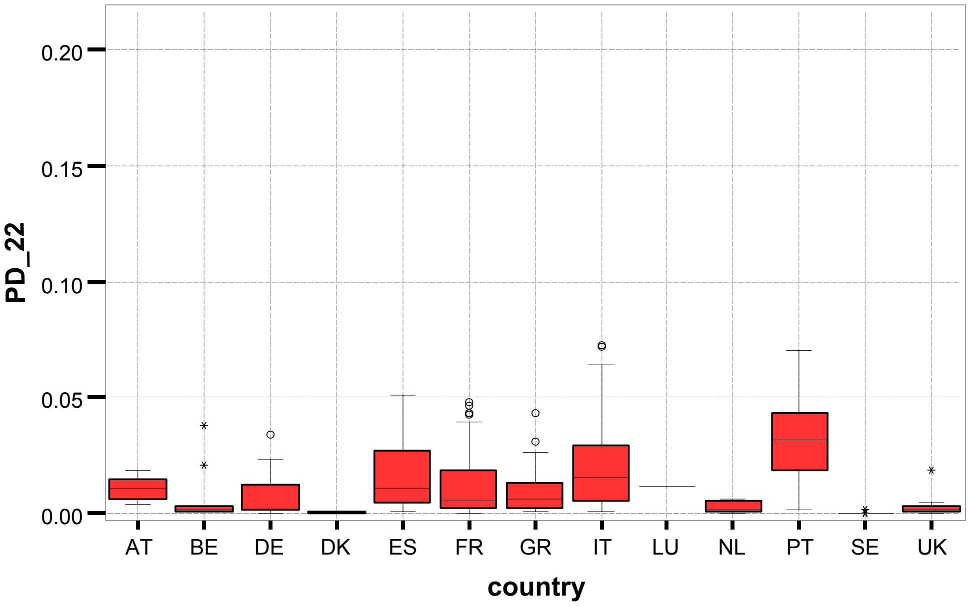


Figure 2.16 Distribution of NUTS3 patch density for **permanent crop**s (CLC class 2.2 level 2, see Table 2.5) per country.

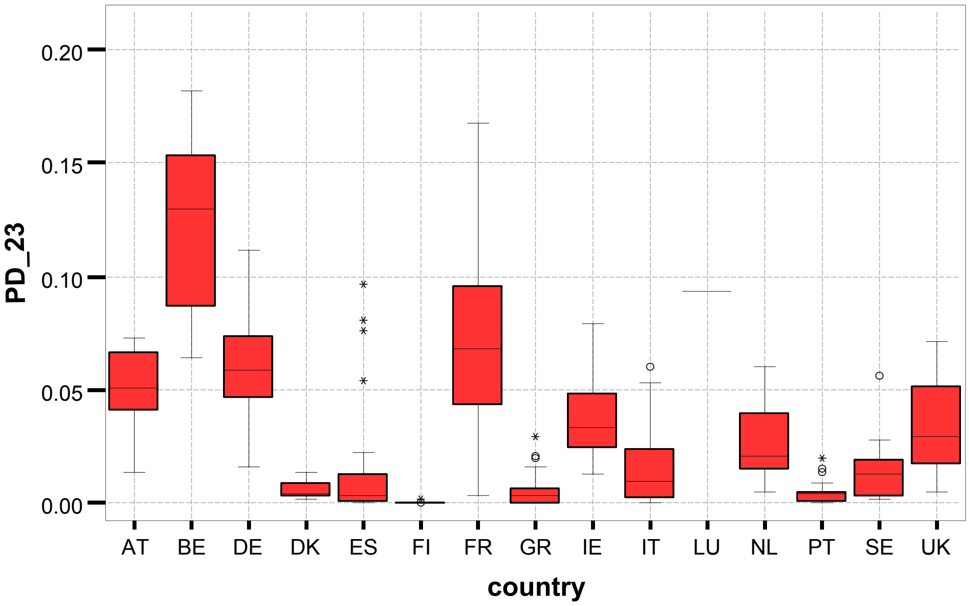


Figure 2.17 Distribution of NUTS3 patch density for **pasture** (CLC class 2.3 level 2, see Table 2.5) per country.

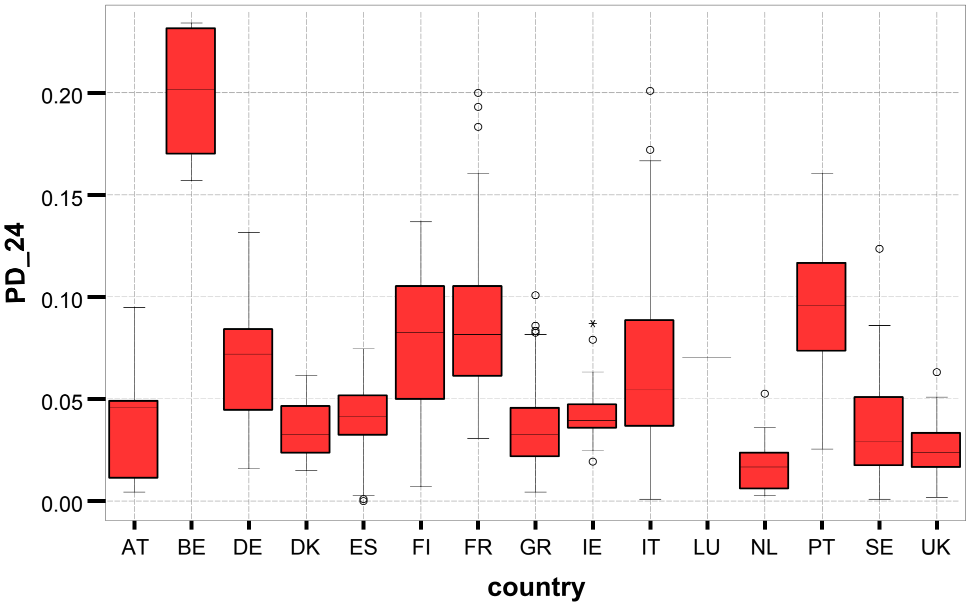
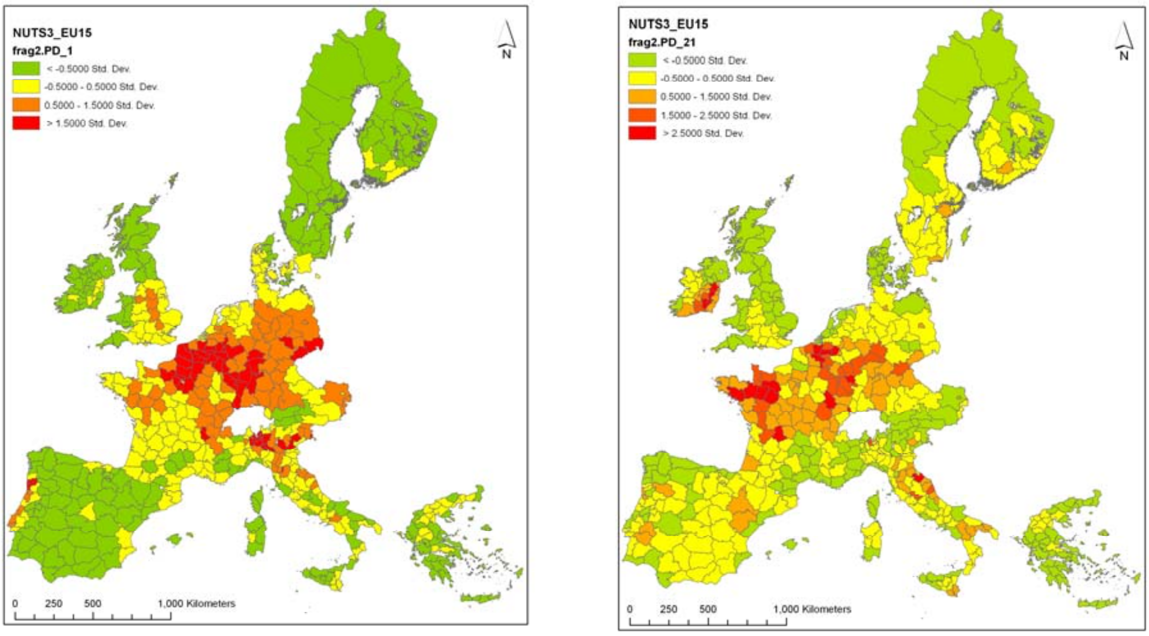
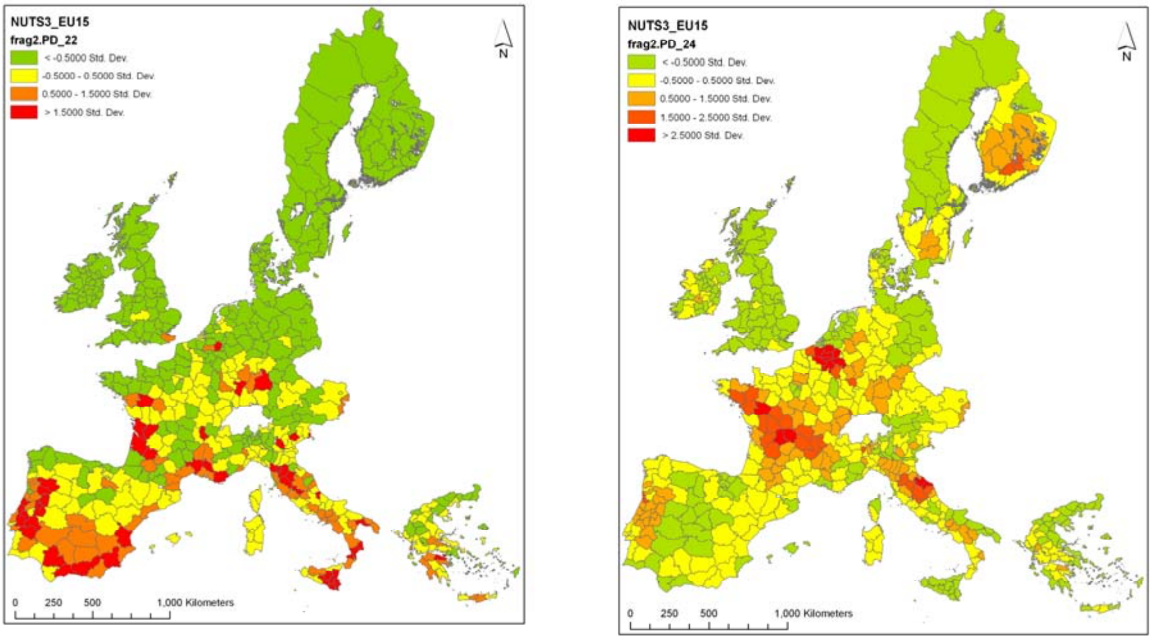


Figure 2.18 Distribution of NUTS3 patch density for **heterogeneous agricultural areas** (CLC class 2.4 level 2, see Table 2.5) per country.



a) Artificial surface

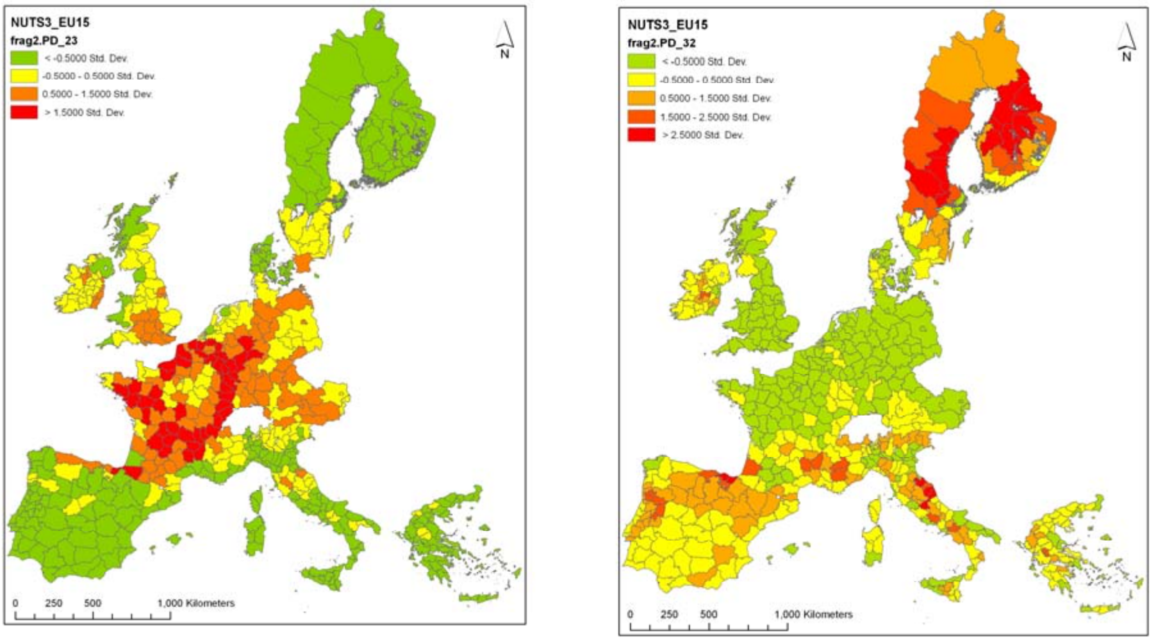
b) Arable land



c) Permanent crops

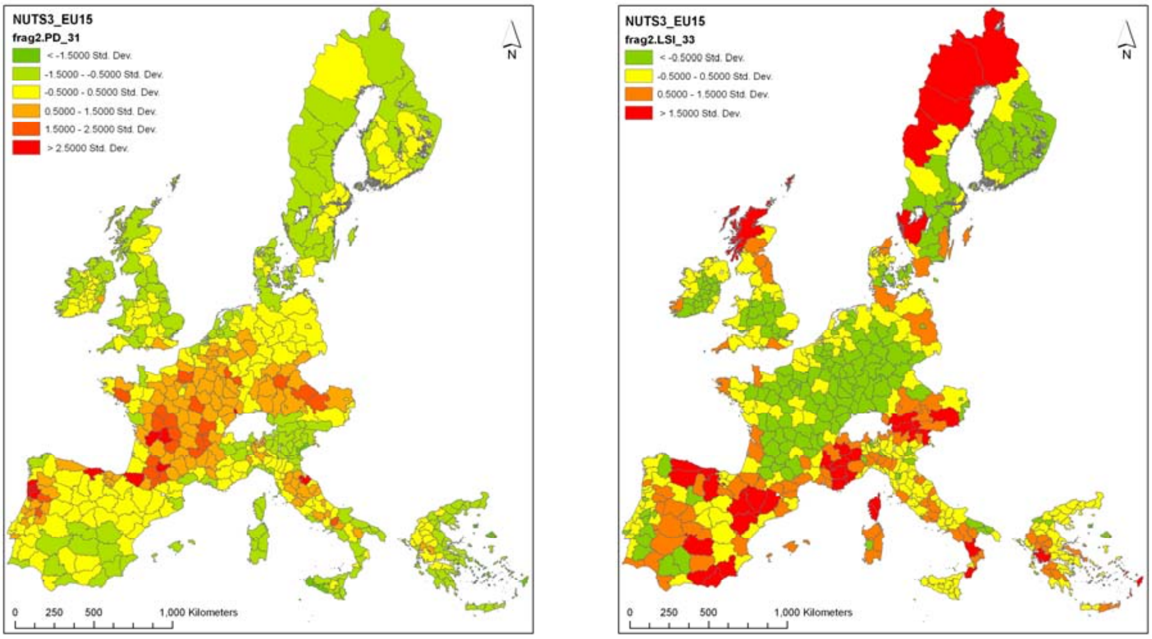
d) Heterogeneous agricultural areas

Figure 2.19 Distribution of patch density per NUTS3 for different CLC land covers (CLC reclassified according to Table 2.5).



a) Pasture

b) Scrub and/or herbaceous vegetation associations



c) Forests

d) Open spaces with little or no vegetation

Figure 2.20 Distribution of patch density per NUTS3 for different CLC land covers (CLC reclassified according to Table 2.5).

2.4.1 Results of the Correlation Analysis

The variables described in the previous paragraph and summarised in Table 2.6 were considered for the correlation analysis. The results are shown in Table 2.7. In the analysis, correlation coefficients significant with $p<0.01$ were considered.

The correlation between absolute and relative errors, as defined in Equation 1 and 2, occurs only for pasture, although it is slightly week. However, considering the correlation by country more positive relationship appears, even for agricultural land and permanent crops (Table 2.7).

Concerning the role of slope in explaining the discrepancies between CLC and FSS no correlation is present between *slope_%* and relative errors. However, when separating negative (CLC<FSS) and positive (CLC>FSS) errors, it appears a significant negative (-0.57**, N=32) and positive (0.64**, N=472) correlation, respectively. The first correlation may indicate that effectively when CLC<FSS the slope could be a factor to explain the underestimation of FSS areas. The second correlation shows an opposite tendency. It seems that for positive errors, the effect of slope on CLC underestimation is less evident than other factors explaining errors, such as that in steeper landscapes: permanent crops and heterogeneous agricultural land cover a larger surface (positive correlation with *perm_frac* and *hetero_agri_frac*), while arable land are reduced (negative correlation with *agri_frac*), the average holding size decreases (negative correlation with *hold_size_ha*) and semi-natural areas are more fragmented (positive correlation with *PD_32* and *PD_33*) (Table 2.7).

The relative and absolute overestimation of arable land increases in NUTS3 where the fraction occupied by arable land is higher (positive correlation of absolute and relative errors with *agri_frac*). Moreover, overestimation of arable land and underestimation of pasture occur in NUTS3 with larger areas covered by the CORINE heterogeneous agricultural land class (see correlations of absolute and relative errors with *hetero_agri_frac*) (Table 2.7).

The patch density was used in this study as a proxy for the landscape fragmentation, but this choice constitutes a simplification, and a more comprehensive set of metrics should have been considered for an appropriate study of the landscape fragmentation. This limitation has to be taken into account when evaluating the different correlations.
Considering the error in absolute terms, the patch density of several classes is positively correlated to the discrepancies recorded in pasture and permanent crops classes, indicating how the landscape fragmentation of a specific class may be one of the factors explaining the error. However, the pattern appears more complex once considering the correlations by countries, with significant correlations of both positive and negative sign. These values have to be interpreted considering the local landscape characteristics and error type (over or under estimation). Moreover, it has to be considered that the fragmentation can represent two opposite situations: a meticulous work of photo-interpretation and delineation (thus decreasing the errors) or a difficult landscape to be interpreted and classified according to the CORINE land cover specifications (thus increasing the errors).

In general when the surface of the heterogeneous agricultural land class increases, its fragmentation increases as well, while the fragmentation of other homogeneous classes, such as urban, arable or pasture land, decrease (correlation of *hetero_agri_frac* positive with *PD_24*; and negative with *PD_1*, *PD_21* and *PD_23*) (Table 2.7).

The picture resulting from the previous considerations already reveals how complex the relationship between the different variables is, as the effects of several processes, specific regional landscape features, economic systems, and definitely possible error sources are mixed together.

In the following principal component analysis an attempt is made to find out and display in a effective way the principal factors of variation that can explain the discrepancies between CLC and FSS.

Table 2.7 Results of correlation analysis. (Significant positive and negative correlations discussed in the text are highlighted in blue and in red colour, respectively).

All countries

	agri _ha	past _ha	perm _ha	diff_ agri_ %	diff_ past _%	diff_ perm _%	slope _%	hold_ size_ ha	agri _frac	past _frac	perm _frac	hetero _agri_ frac	PD _1	PD _21	PD _22	PD _23	PD _24	PD _31	PD _32	PD _33	area_ nuts_ ha
agri_ha	1.00	-.51**	-.47**	.07	-.34**	.05	-.13**	.06	.32**	-.35**	.06	.12**	-.09*	-.05	.08	-.06	-.03	-.02	-.05	-.07	.25**
past_ha	-.51**	1.00	.24**	-.02	.15**	-.08	-.10*	-.17**	-.01	.03	-.05	-.10*	.23**	.21**	-.08	.17**	.17**	.12**	-.09	-.11*	-.25**
perm_ha	-.47**	.24**	1.00	-.01	.25**	.06	.00	.05	-.22**	.11*	.19**	-.16**	.12**	.00	-.04	.13**	.03	.05	-.09*	-.04	-.11*
diff_agri_%	.07	-.02	-.01	1.00	-.02	.09	-.07	-.01	.19**	-.23**	.07	.14**	.02	-.16**	.22**	-.10*	.08	-.07	-.16**	.01	.01
diff_past_%	-.34**	.15**	.25**	-.02	1.00	-.02	.00	.06	-.10*	.10*	-.01	-.16**	.11*	.04	.01	.12**	.00	.02	-.04	.00	-.06
diff_perm_%	.05	-.08	.06	.09	-.02	1.00	.07	.04	-.11*	-.06	.20**	.00	-.15**	-.20**	.21**	-.16**	-.19**	-.04	.03	.00	.08
slope_%	-.13**	-.10*	.00	-.07	.00	.07	1.00	-.32**	-.15**	-.01	.29**	.39**	-.20**	-.29**	.06	-.13**	-.07	-.06	.25**	.49**	-.17**
hold_size_ha	.06	-.17**	.05	-.01	.06	.04	-.32**	1.00	-.05	.23**	-.33**	-.45**	.13**	.09*	-.28**	.23**	-.11*	.10*	-.24**	-.21**	.20**
agri_frac	.32**	-.01	-.22**	.19**	-.10*	-.11*	-.15**	-.05	1.00	-.85**	-.23**	.29**	.13**	-.04	-.15**	-.26**	.12**	.04	.10*	.02	.08
past_frac	-.35**	.03	.11*	-.23**	.10*	-.06	-.01	.23**	-.85**	1.00	-.32**	-.38**	-.01	.16**	-.31**	.39**	-.08	.08	-.10*	-.06	-.01
perm_frac	.06	-.05	.19**	.07	-.01	.20**	.29**	-.33**	-.23**	-.32**	1.00	.19**	-.21**	-.22**	.52**	-.29**	-.07	-.22**	.00	.07	-.13**
hetero_agri_frac	.12**	-.10*	-.16**	.14**	-.16**	.00	.39**	-.45**	.29**	-.38**	.19**	1.00	-.19**	-.19**	.16**	-.22**	.23**	.10*	.33**	.30**	-.03
PD_1	-.09*	.23**	.12**	.02	.11*	-.15**	-.20**	.13**	.13**	-.01	-.21**	-.19**	1.00	.43**	-.04	.46**	.39**	.42**	-.32**	-.08	-.21**
PD_21	-.05	.21**	.00	-.16**	.04	-.20**	-.29**	.09*	-.04	.16**	-.22**	-.19**	.43**	1.00	.04	.53**	.57**	.42**	-.08	-.15**	-.12**
PD_22	.08	-.08	-.04	.22**	.01	.21**	.06	-.28**	-.15**	-.31**	.52**	.16**	-.04	.04	1.00	-.17**	.26**	.11*	.24**	.05	-.14**
PD_23	-.06	.17**	.13**	-.10*	.12**	-.16**	-.13**	.23**	-.26**	.39**	-.29**	-.22**	.46**	.53**	-.17**	1.00	.51**	.50**	-.23**	-.15**	-.05
PD_24	-.03	.17**	.03	.08	.00	-.19**	-.07	-.11*	.12**	-.08	-.07	.23**	.39**	.57**	.26**	.51**	1.00	.61**	.12**	.07	-.15**
PD_31	-.02	.12**	.05	-.07	.02	-.04	-.06	.10*	.04	.08	-.22**	.10*	.42**	.42**	.11*	.50**	.61**	1.00	.13**	.09	-.08
PD_32	-.05	-.09	-.09*	-.16**	-.04	.03	.25**	-.24**	.10*	-.10*	.00	.33**	-.32**	-.08	.24**	-.23**	.12**	.13**	1.00	.37**	.18**
PD_33	-.07	-.11*	-.04	.01	.00	.00	.49**	-.21**	.02	-.06	.07	.30**	-.08	-.15**	.05	-.15**	.07	.09	.37**	1.00	-.10*
area_nuts_ha	.25**	-.25**	-.11*	.01	-.06	.08	-.17**	.20**	.08	-.01	-.13**	-.03	-.21**	-.12**	-.14**	-.05	-.15**	-.08	.18**	-.10*	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

2.4.2 Results of the Principal Component Analysis

A Principal Component Analysis was performed (SPSS, 2003) including several variables (Table 2.6) that were considered to represent possible sources of discrepancy between CLC and FSS databases. Three components were extracted explaining 70% of the total variance (Table 2.8). The table of communalities shows for each variable the amount of variance explained by the extracted components (Table 2.8). Communalities take values between 0 and 1, with 1 indicating that all the variance is captured.

Table 2.8 Variance explained by the extracted components and communalities table.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.162	31.620	31.620	3.162	31.620	31.620	2.655	26.551	26.551
2	2.124	21.237	52.857	2.124	21.237	52.857	2.286	22.861	49.413
3	1.672	16.722	69.580	1.672	16.722	69.580	2.017	20.167	69.580
4	1.184	11.845	81.425						
5	.609	6.089	87.514						
6	.412	4.115	91.629						
7	.384	3.843	95.471						
8	.278	2.780	98.251						
9	.175	1.749	100.000						
10	-4.72E-16	-4.721E-15	100.000						

Extraction Method: Principal Component Analysis.

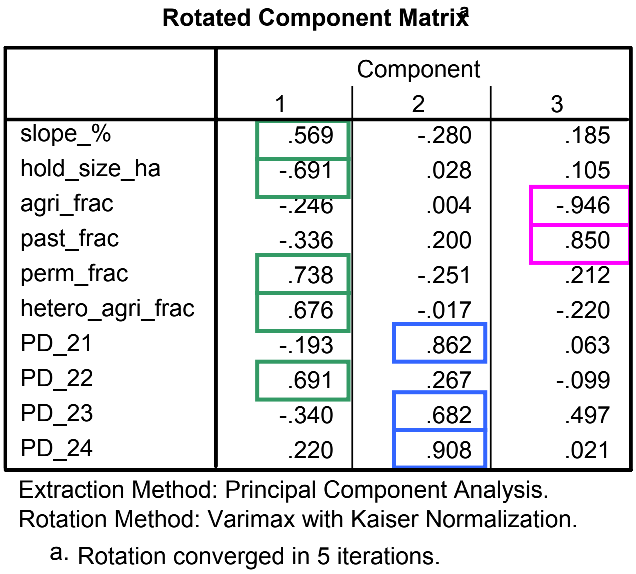
Communalities

	Initial	Extraction
slope_%	1.000	.437
hold_size_ha	1.000	.490
agri_frac	1.000	.955
past_frac	1.000	.875
perm_frac	1.000	.653
hetero_agri_frac	1.000	.505
PD_21	1.000	.784
PD_22	1.000	.559
PD_23	1.000	.828
PD_24	1.000	.872

Extraction Method: Principal Component Analysis.

The three components were rotated to facilitate the interpretation by the *Varimax* method (SPSS, 2003), which conserves the orthogonality of the principal components. The results are shown in Table 2.9. Coloured boxes highlight the components where each variable contribute the most.

Table 2.9 Rotated Principal Components



Rotated Component Matrix[a]

	Component		
	1	2	3
slope_%	.569	-.280	.185
hold_size_ha	-.691	.028	.105
agri_frac	-.246	.004	-.946
past_frac	-.336	.200	.850
perm_frac	.738	-.251	.212
hetero_agri_frac	.676	-.017	-.220
PD_21	-.193	.862	.063
PD_22	.691	.267	-.099
PD_23	-.340	.682	.497
PD_24	.220	.908	.021

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

According to the variables contributions (Table 2.9) the three principal components may be interpreted to represent axis of variation for the landscape analysis:

1. Five variables contribute to the first component, notably: *slope_%*, *hold_size_ha*, *perm_frac*, *hetero_agri_frac* and *PD_22*. Component 1 could be interpreted as the gradient in the landscape type from a homogeneous and intensive agricultural landscape, with large holdings in flat areas, to an extensive agricultural landscape with smaller holdings in hill or steep regions, characterised by larger areas of heterogeneous agricultural land and fragmented permanent crops. (Axes called **Landscape type**)

2. Variables *PD_21*, *PD_23* and *PD_24* contribute to the second factor. Component 2 could simply represent the degree of landscape fragmentation. (Axes called **Fragmentation**)

3. Arable land and pasture fractions contribute with opposite sign to the third component, which could be interpreted as an axis of arable versus pasture landscape. (Axes called **Arable vs. pasture**)

Figure 2.21, Figure 2.22, Figure 2.23, Figure 2.24, show for each country the NUTS3 values according to the new components (score plots). In the graphs, a colour scale was applied to the points to show the potential correlation between NUTS3 landscape type and the correspondent relative error for arable land (*diff_agri_%*) or pasture land (*diff_past_%*). The graphs allow to analyse the discrepancies between CLC and FSS according to the characteristics of landscape in the different NUTS3. To facilitate the reading in both axes of the graphs a darker line highlights the zero value. The plots are therefore divided into four squares, which correspond to specific landscape types. The pattern of points in the graph allows to compare the landscape in the different NUTS3 of the various countries. Figure 2.25 provide a simplify key to read the score plots.

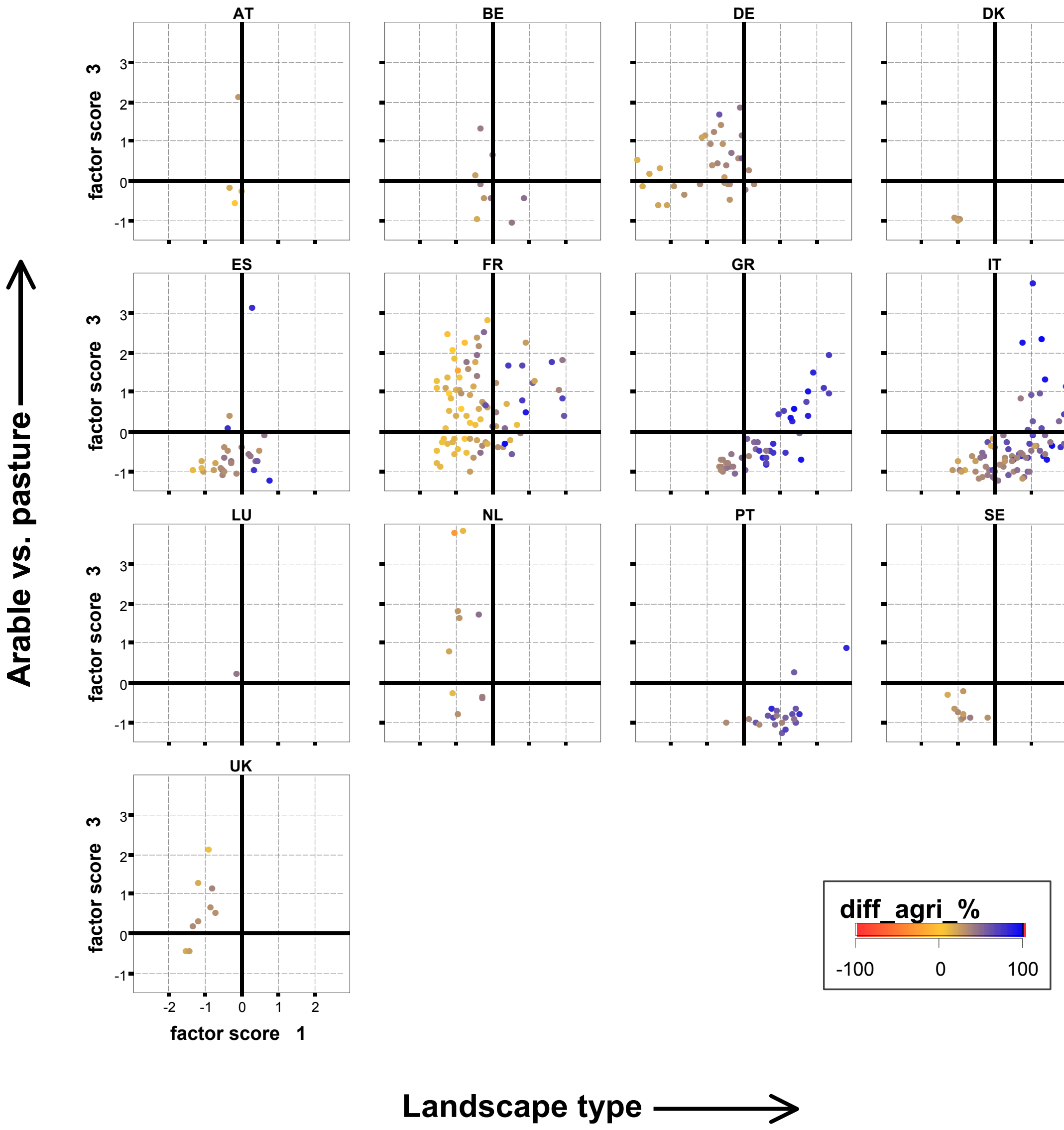
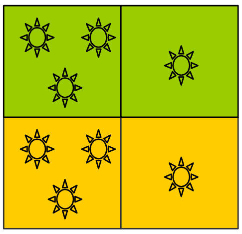


Figure 2.21 Score plots of NUTS3 values according to the principal component 1 (Landscape type) and 3 (Arable versus pasture landscape). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

According to Figure 2.21, in CLC maps the larger overestimations of arable land (positive error, CLC>FSS) are associated with extensive heterogeneous landscape in hilly regions (See Spain, France, Greece, Italy and Portugal).



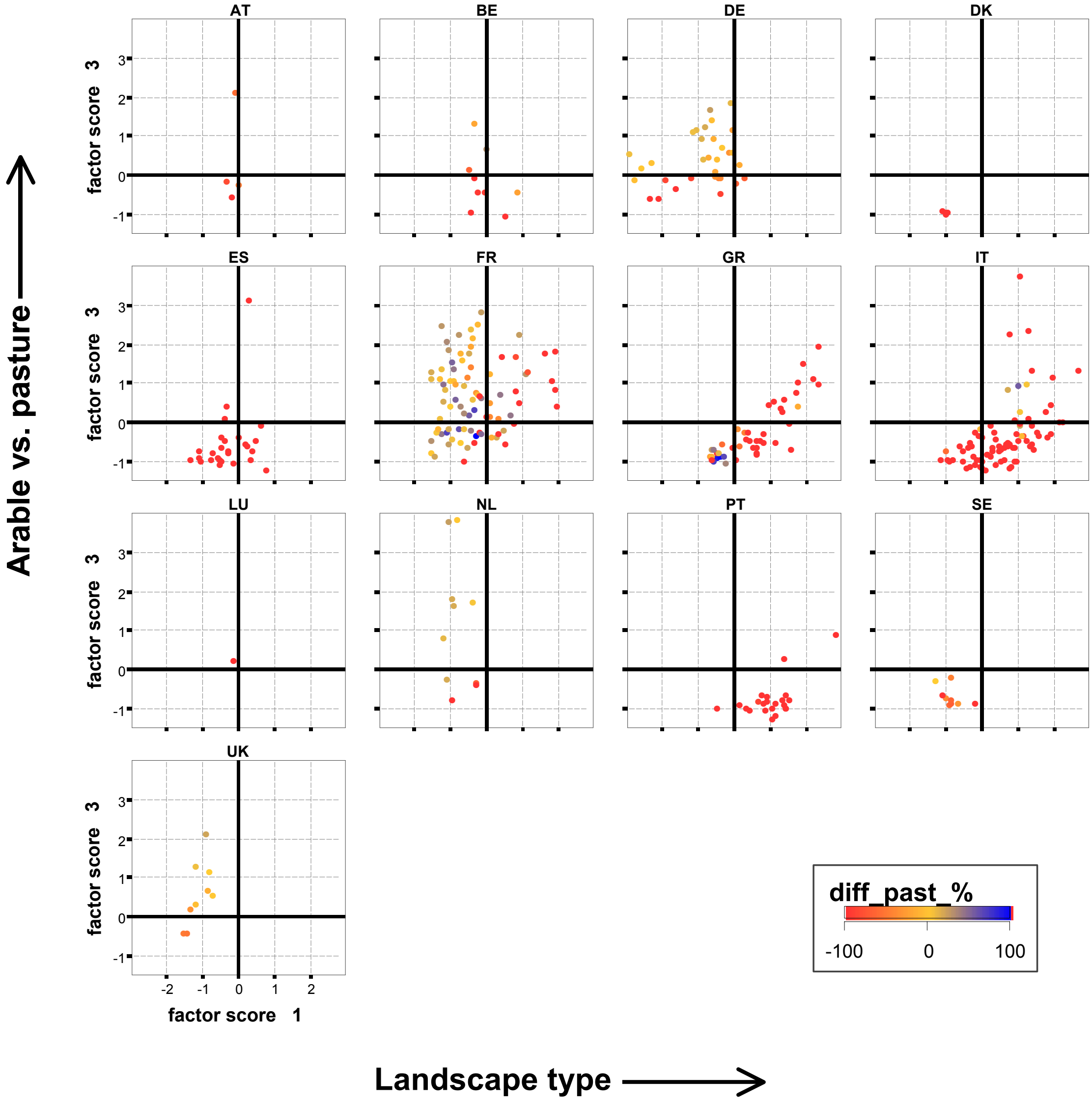
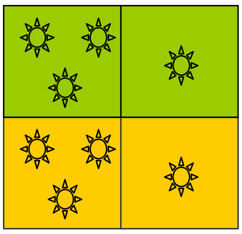


Figure 2.22 Score plots of NUTS3 values according to the principal component 1 (Landscape type) and 3 (Arable versus pasture landscape). Colour scale indicates the value of the relative error for arable land (*diff_past_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

According to Figure 2.22, in CLC map the larger underestimations of pasture land are associated with extensive heterogeneous landscape in hilly regions, where arable land dominates compared to the pasture fraction. However, underestimations are present also in intensive arable area in Spain and Italy.



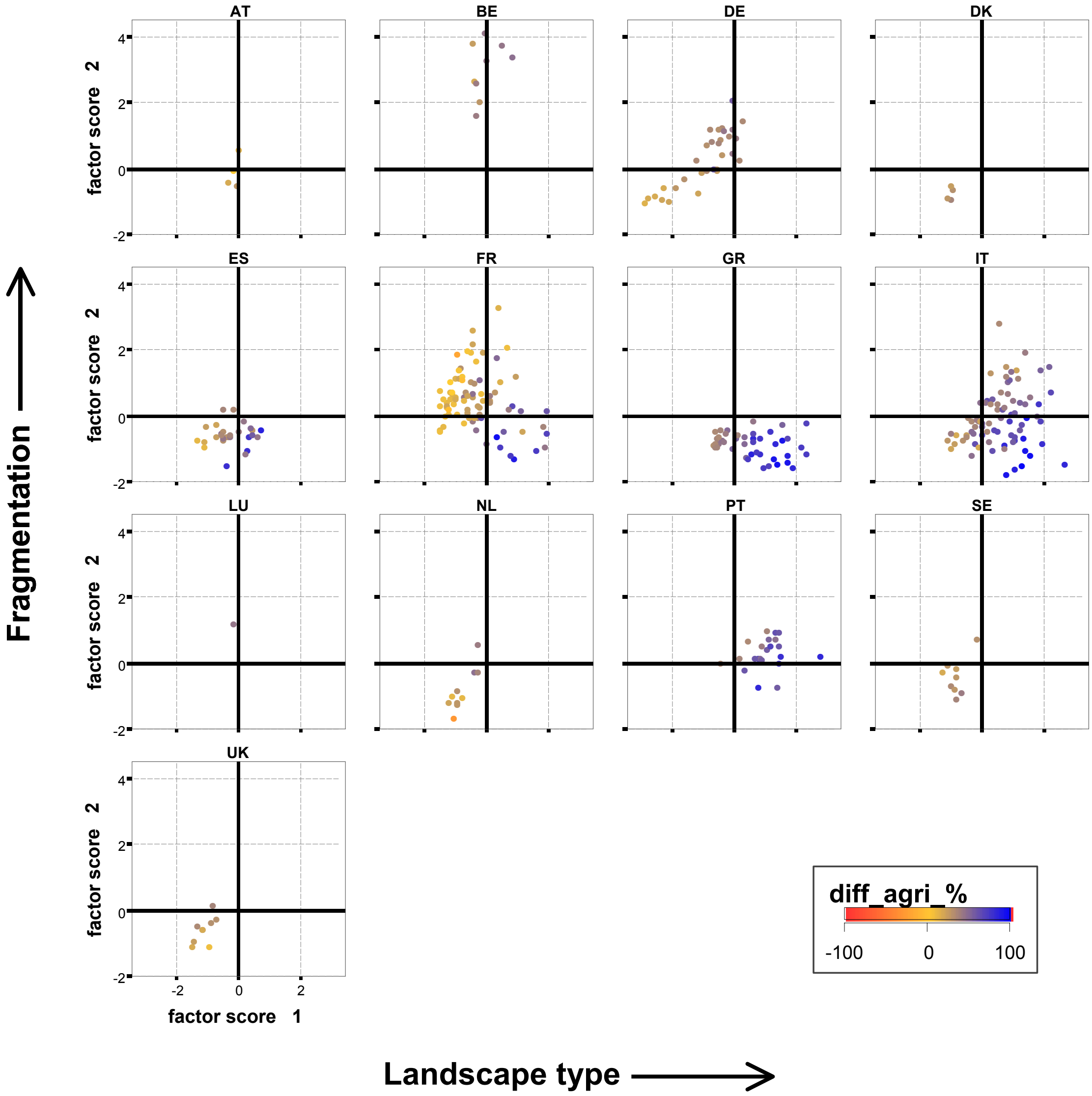
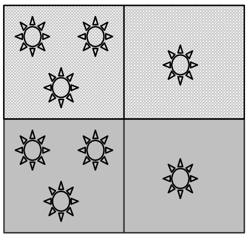


Figure 2.23 Score plots of NUTS3 values according to the principal component 1 (Landscape type) and 2 (Fragmentation). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.



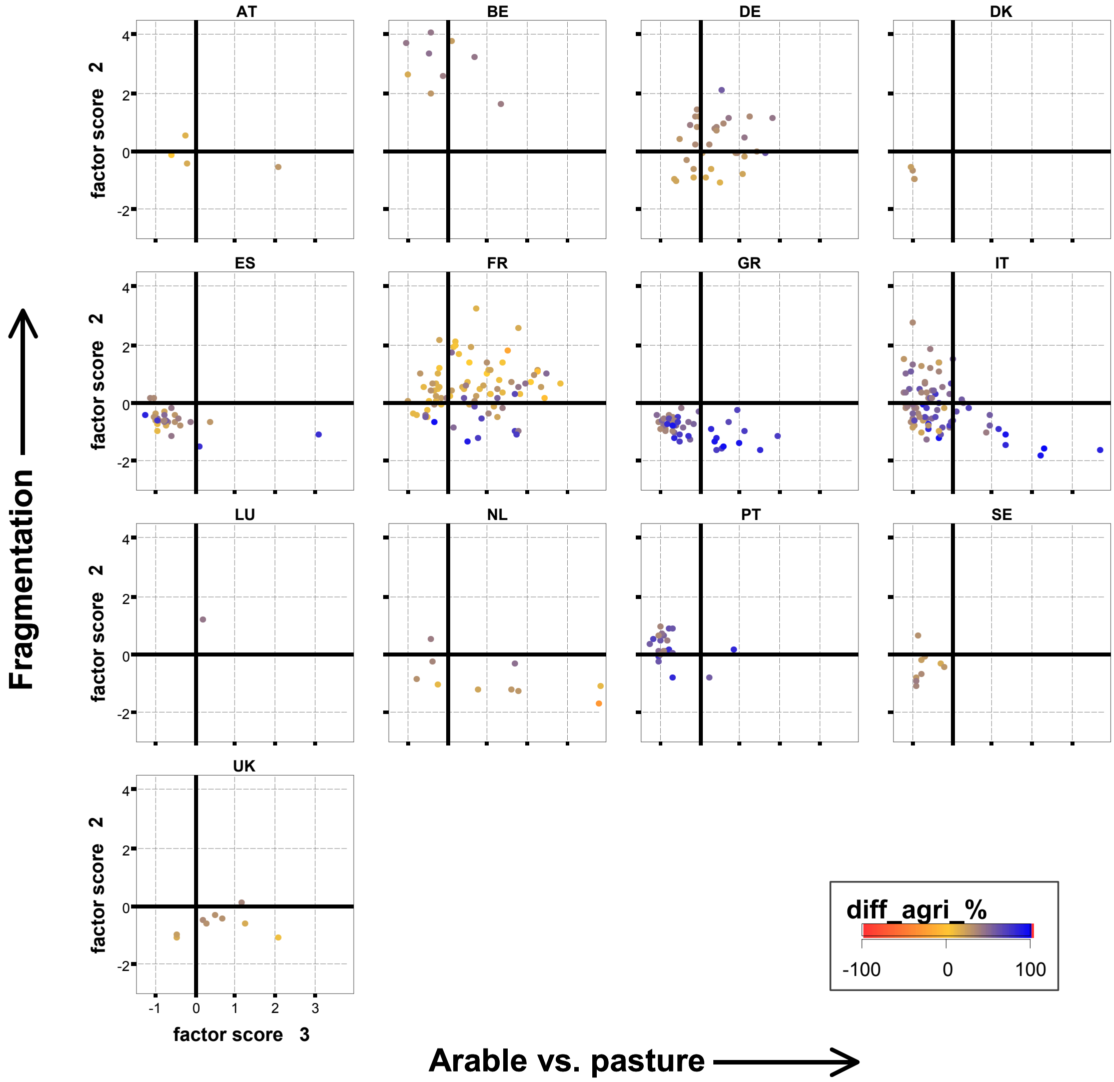
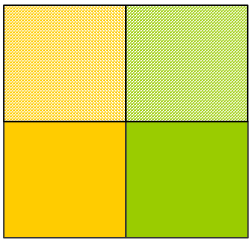


Figure 2.24 Score plots of NUTS3 values according to the principal component 3 (Arable versus pasture landscape) and 2 (Fragemtation). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

In France lower relative errors are associated with higher fragmentation, indicating that in this country the fragmentation is more an index of a meticulous work of satellite images interpretation than a source of error. An opposite tendency seems to be present in Nederland, Belgium and Germany (Figure 2.24).



Intensive homogeneous flat Pasture landscape	Extensive heterogeneous steep Pasture landscape
Intensive homogeneous flat Arable landscape	Extensive heterogeneous steep Arable landscape

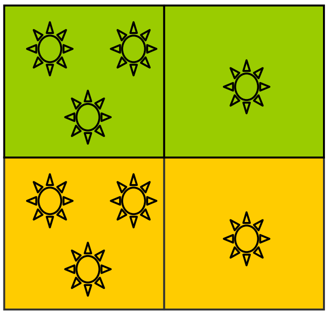


Figure 2.21, Figure 2.22 and Figure 2.26

Intensive homogeneous flat More fragmented landscape	Extensive heterogeneous steep More fragmented landscape
Intensive homogeneous flat Less fragmented landscape	Extensive heterogeneous steep Less fragmented landscape

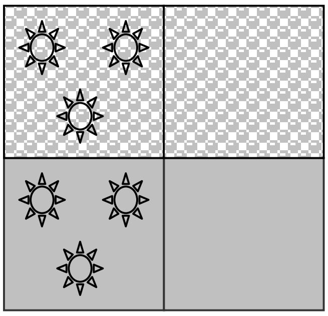


Figure 2.23 and Figure 2.27

Arable More fragmented landscape	Pasture More fragmented landscape
Arable Less fragmented landscape	Pasture Less fragmented landscape

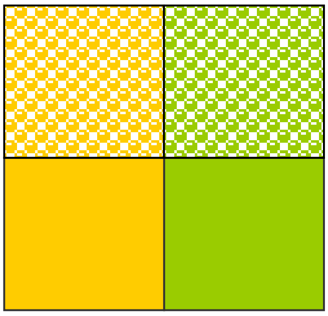


Figure 2.24 and Figure 2.28

Legend of landscape type:

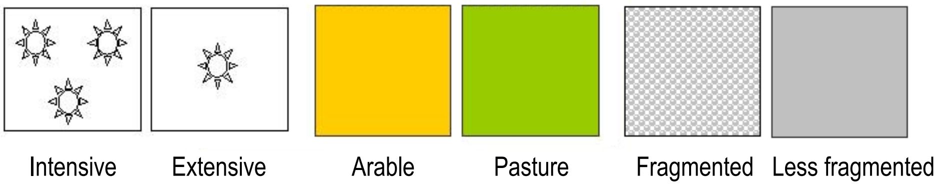


Figure 2.25 Simplified key to interpreted the score plot graphic in Figure 2.21, Figure 2.22, Figure 2.23, Figure 2.24, Figure 2.26, Figure 2.27 and Figure 2.28.

The same principal component analysis was run without the variables related to permanent crops, *perm_frac* and the *P_22* variables, in order to include Finland and Ireland in the analysis, as these countries have no surface cover by CLC permanent crops class. In this case the total variance explained by three extracted factors was 78% (Table 2.10). The principal components could be interpreted as in the previous analysis, although the order they appear is different (Table 2.11):

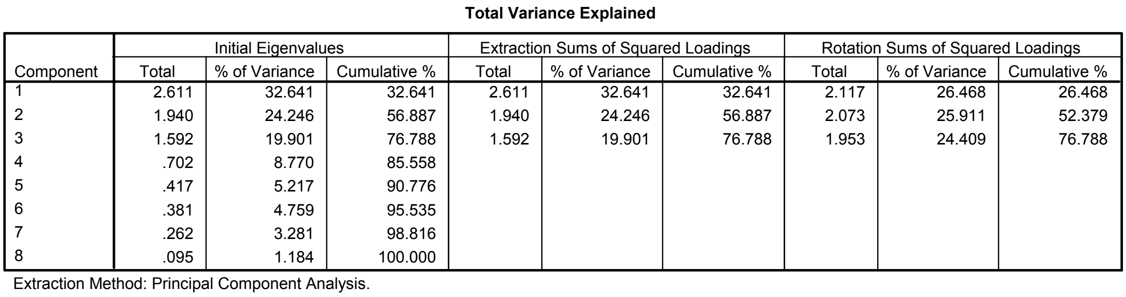
1. Component 1 of analysis 2 represents the **fragmentation** axis and corresponds to component 2 of analysis 1.

2. Component 2 of analysis 2 is the gradient of **arable versus pasture** land and corresponds to component 3 of analysis 1.

3. Component 3 of analysis 2 represents the **landscape type** axes and corresponds to component 1 of analysis 1.

Figure 2.26, Figure 2.27 and Figure 2.28 illustrate the same relation as in the previous graphics using the components found out in the second analysis.

Table 2.10 Variance explained by the extracted components excluding permanent crops variables.

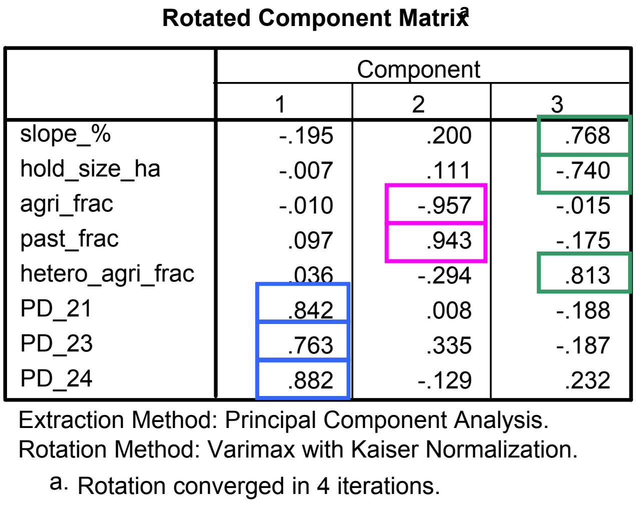


Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.611	32.641	32.641	2.611	32.641	32.641	2.117	26.468	26.468
2	1.940	24.246	56.887	1.940	24.246	56.887	2.073	25.911	52.379
3	1.592	19.901	76.788	1.592	19.901	76.788	1.953	24.409	76.788
4	.702	8.770	85.558						
5	.417	5.217	90.776						
6	.381	4.759	95.535						
7	.262	3.281	98.816						
8	.095	1.184	100.000						

Extraction Method: Principal Component Analysis.

Table 2.11 Rotated Principal Components excluding permanent crops variables.



Rotated Component Matrix[a]

	Component		
	1	2	3
slope_%	-.195	.200	.768
hold_size_ha	-.007	.111	-.740
agri_frac	-.010	-.957	-.015
past_frac	.097	.943	-.175
hetero_agri_frac	.036	-.294	.813
PD_21	.842	.008	-.188
PD_23	.763	.335	-.187
PD_24	.882	-.129	.232

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

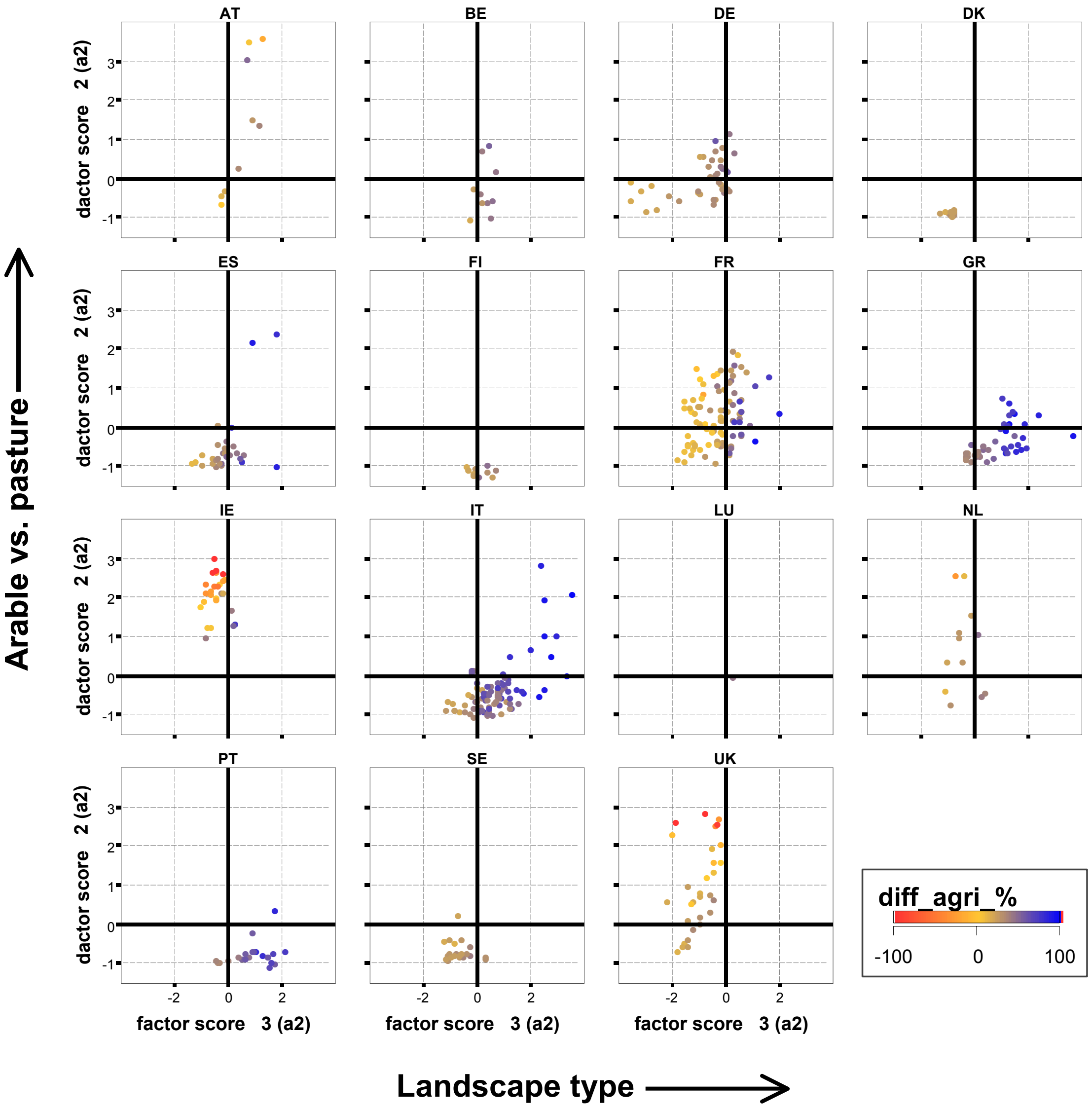
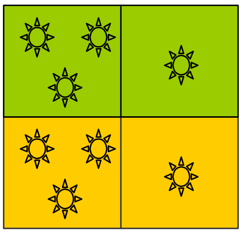


Figure 2.26 Score plots of NUTS3 values according to the principal component 3 (analysis2) (Landscape type) and 2 (analysis 2) (Arable versus pasture landscape). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

Figure 2.26 indicates that stronger negative errors (underestimation of arable land) occur in the presence of larger fraction of pasture land in flat and agricultural dominated landscapes (see UK and IE), while larger positive errors (overestimation of arable land) appear more frequently in extensive heterogeneous agricultural land where the pasture fraction prevails.



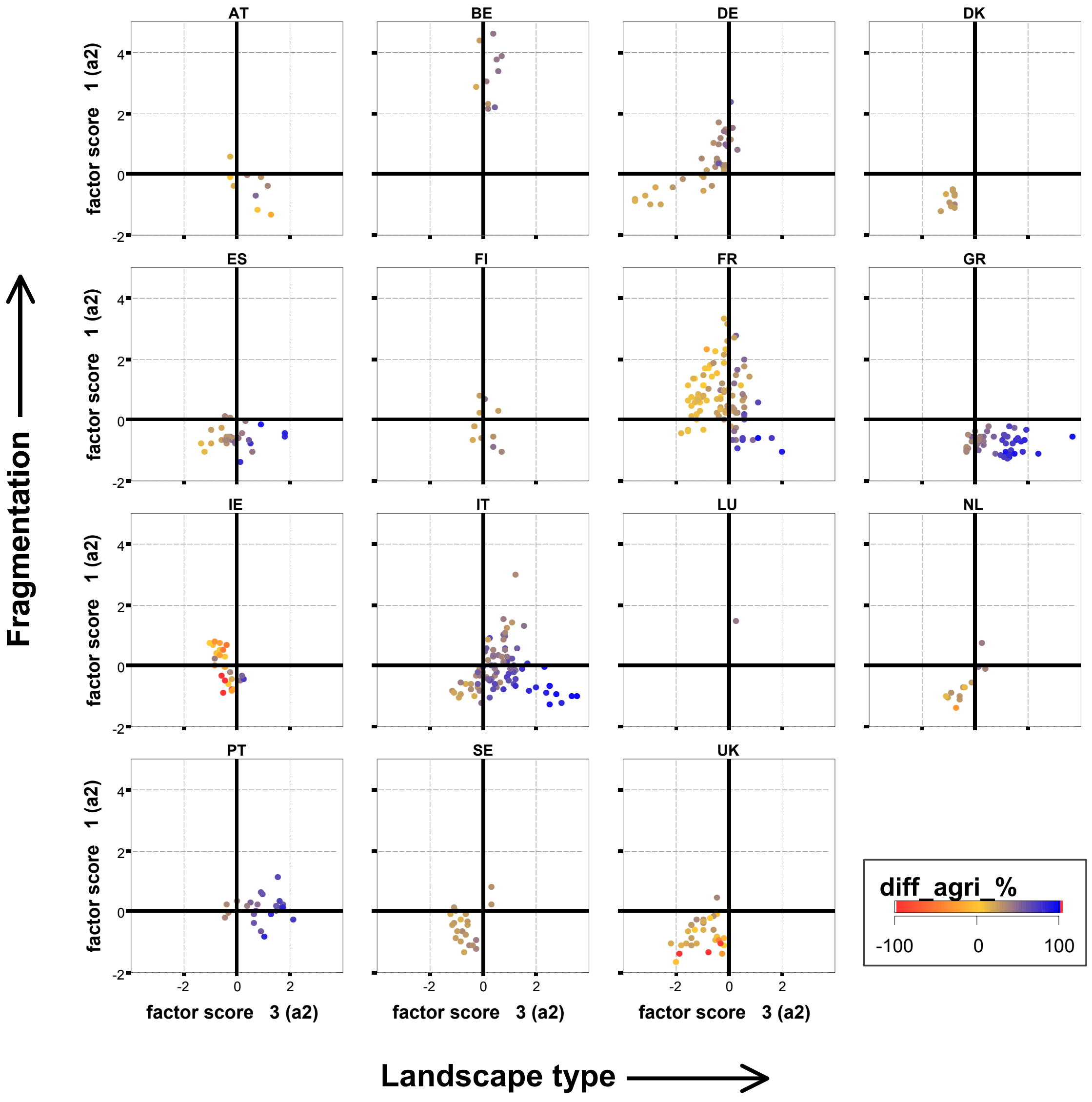
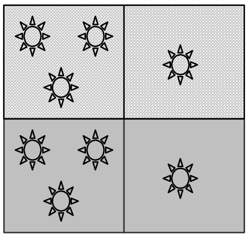


Figure 2.27 Score plots of NUTS3 values according to the principal component 3 (analysis2) (Landscape type) and 1 (analysis 2) (Fragmentation). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

In France, Italy and Greece where the landscape is heterogeneous in the CLC the errors are not correlated to the fragmentation, but more to the extension of the heterogeneous class (Figure 2.27).



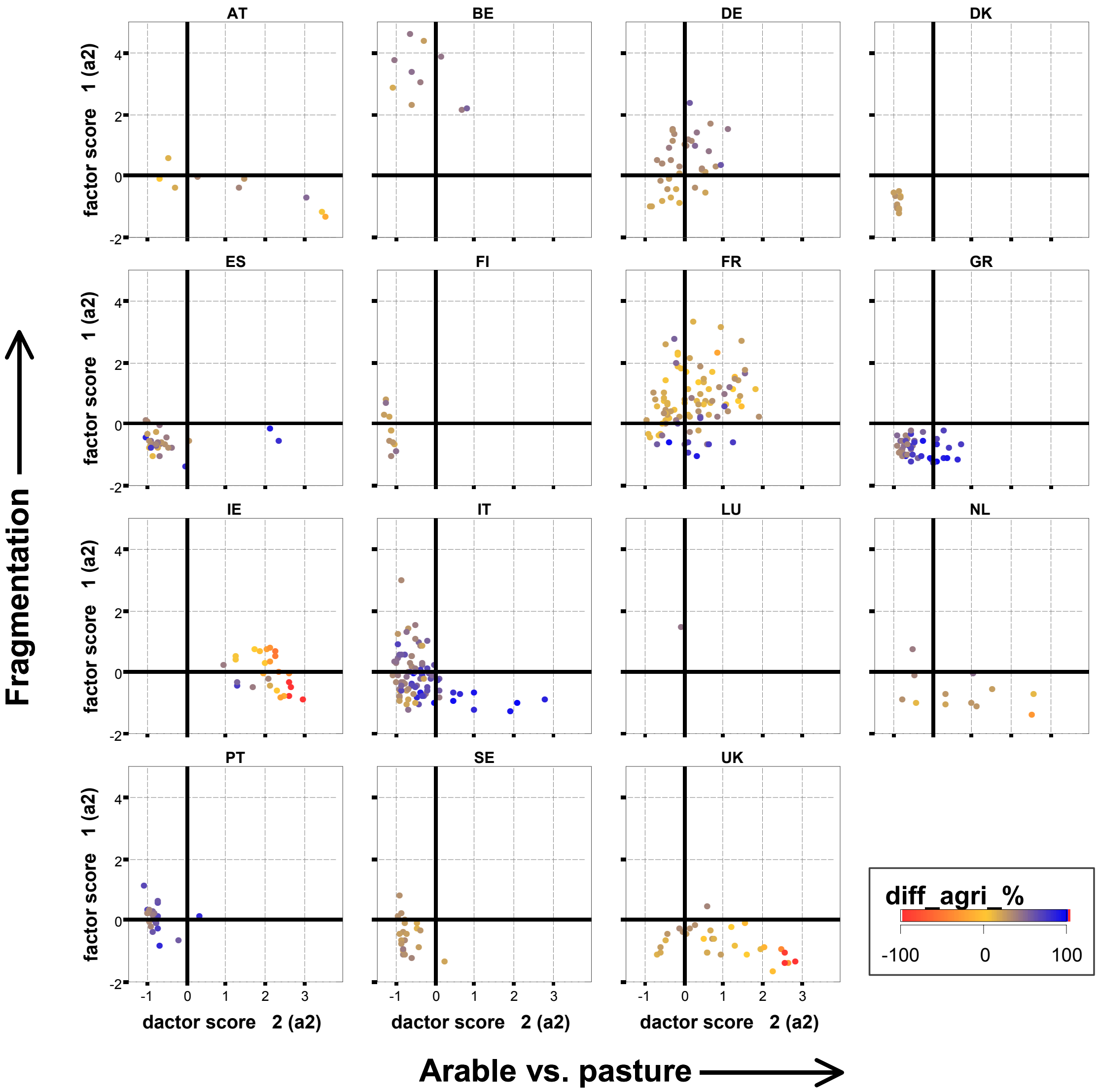


Figure 2.28 Score plots of NUTS3 values according to the principal component 2 (analysis2) (Arable versus pasture) and 1 (analysis 2) (Fragmentation). Colour scale indicates the value of the relative error for arable land (*diff_agri_%* variable). The colour scale ranges from red, indicating negative errors (CLC<FSS), to blue, indicating positive errors (CLC>FSS), passing through yellow-orange for values close to zero.

2.5 Data consistency in European databases

The inconsistencies between CLC and FSS areas may not be surprising when looking at other EU official data sources, such as the IRENA indicator 18 (gross nutrient balance per country) and IRENA indicator 13, (cropping/livestock patterns) (Figure 2.29).

The differences, evident already at national scale, highlight the difficulties in estimating the agricultural areas due to different methods purposes and accuracy. In particular it is interesting to note that two European indicators are based on different UAA. This may be explained by the data sources, whether they are based on Eurostat data or data provided directly by Member States. This indicates that Member States have a key role in assuring coherence and quality check of data provided to Eurostat. Quality check and feedback from all users will ensure the collection of coherent datasets at EU level.

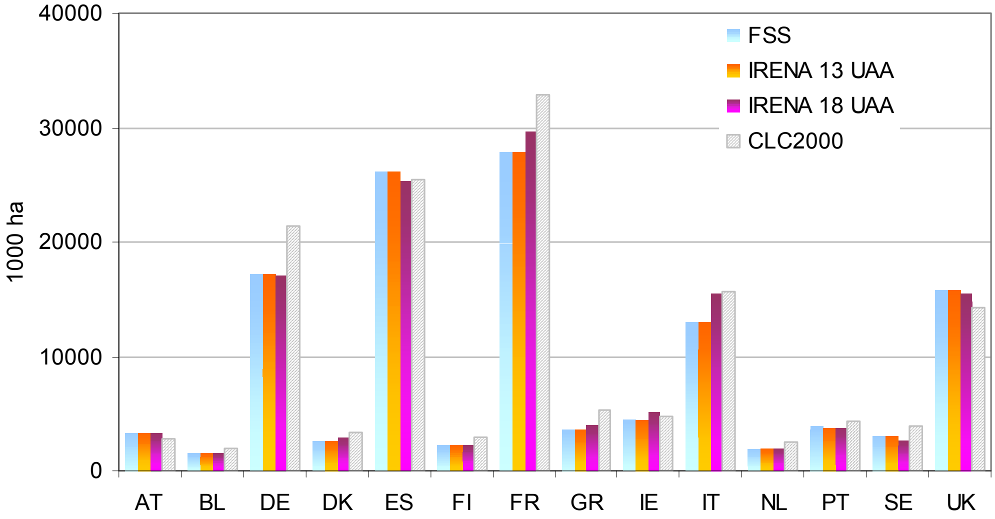


Figure 2.29 Agricultural area reported by FSS, CLC and the IRENA indicators 13 and 18 (data refer to the year 2000).

3 Land-use map

The Farm Structure Survey and the CORINE Land Cover 2000 databases constitute the best available information on agricultural status land cover spatial distribution for Europe, although some discrepancies occur in the reported agricultural areas. A reliable nutrient balance should be based on FSS areas, which could more reasonably match the real extension of crops, as they originated from an agricultural census accounting for specific crop parcels of 1 ha or larger. However, FSS data do not provide the location of the holdings within the territorial unit. The additional information on the crop spatial distribution can be obtained including CLC 2000 data, as shown in previous studies (Crouzet 2000, Kayadjanian M. and Vidal C. 2001, GIM 2002, Campling et al., 2005). This chapter describes the methodology developed in this study to produce a European land-use map where crop data provided by FSS are combined with the geographical information of CLC 2000, respecting FSS crop areas.

3.1 Spatialisation of FSS crop data using CLC 2000

The discrepancies between the reported areas of FSS and CLC 2000 (Chapter 2) prevented from a direct link between the two databases. To spatialise the FSS crop data a procedure was developed based on a spatial modification of the CLC classes, using the CLC 100 m raster as initial map. The aim was to ensure that FSS crop areas fit into CLC classes. Figure 3.1 shows a flow chart of the methodology.

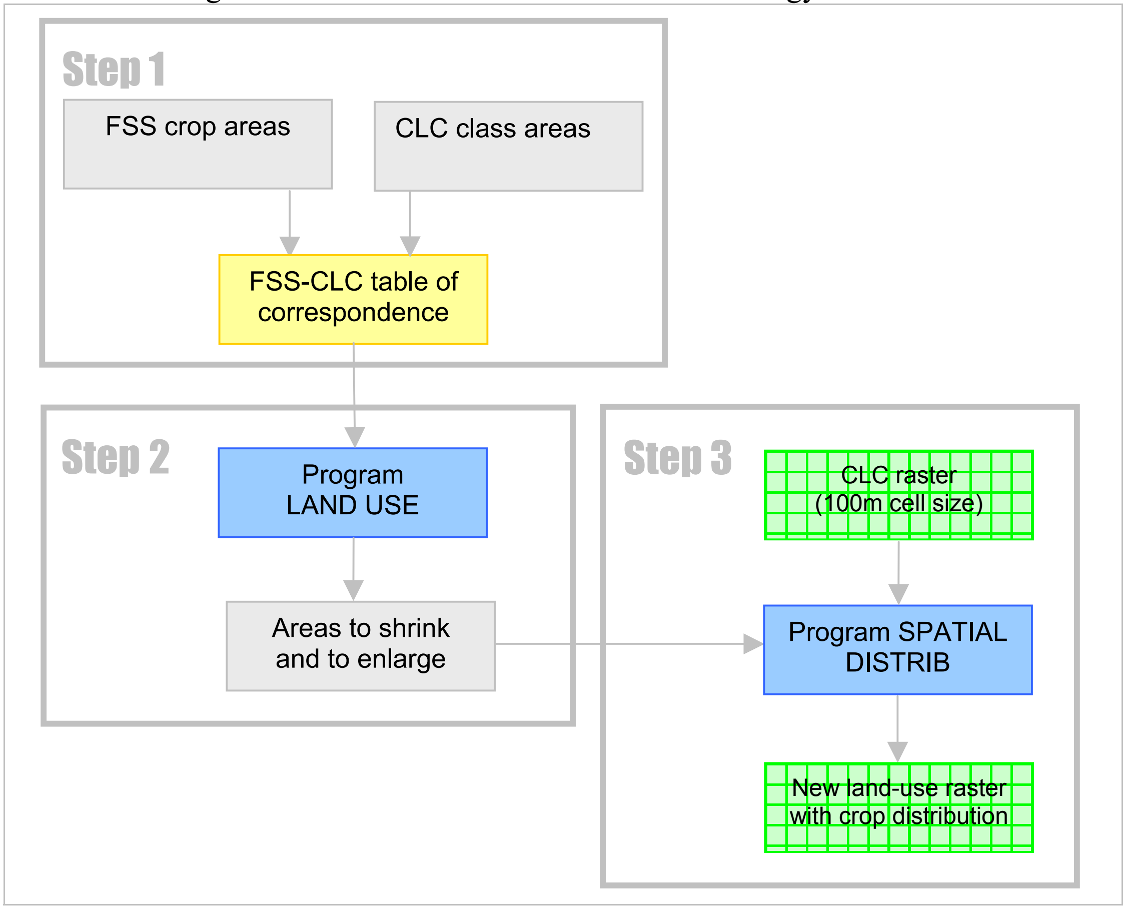


Figure 3.1 Flow chart of the methodology developed to create the new land-use map.

3.1.1 Step 1 – Comparison

Evaluate correspondence between CLC and FSS using seven principal classes

A table of correspondence between CLC and FSS was established (Table 3.1). Seven classes were first used to combine the CLC and FSS databases (Table 3.1). FSS permanent grassland and meadow was associated with CLC pasture (CLC raster class ID 18), FSS olive plantations with CLC olive grow (CLC raster class ID 17), FSS vineyards with CLC vineyards (CLC raster class ID 15), the other FSS permanent crops with CLC fruit and berry plantations (CLC raster class ID 16), FSS rice with CLC rice field (CLC raster class ID 14), FSS maize was chosen as the preferential irrigated crop (CLC raster class ID 13), as it covers the larger share in irrigated crops (see IRENA fact sheet 10), and finally the other crops reported in FSS were associated with CLC non-irrigated arable land (CLC raster class ID 12).
Except for CLC class 14 and 13, which were associated to rice and grain maize respectively, all the other classes correspond to a group of crops reported in FSS (Table 3.2).

Table 3.1 Table of correspondence established in the study to compare CLC and FSS areas.

CLC Class legend	CLC Class Level 3	CLC raster Class ID	FSS Class legend
Rice field	2.1.3	14	D07 (Rice)
Permanently irrigated land	2.1.2	13	D06 (Grain maize)
Non-irrigated arable land	2.1.1	12	D (Arable land) + I08AD22 (fallow land set-aside) - D06 - D07
Vineyards	2.2.1	15	G04 (Vineyards total)
Fruit trees and berry plantations	2.2.2	16	G (Permanent crops) - G03 - G04
Olive growes	2.2.3	17	G03 (Olive plantations total)
Pastures	2.3.1	18	F (Total:Permanent grassland and meadow)

For each NUTS3 *j* the difference FC_{ij} (ha) between CLC area, CLC_{ij} (ha), and FSS crop area, FSS_{ij} (ha), was computed referring to the seven classes *i* established in Table 3.1, according to the equation:

$$FC_{ij} = CLC_{ij} - FSS_{ij} \qquad \text{(Equation 7)}$$

The following inference rules where established:

$FC_{ij} > 0$	CLC_{ij} overestimates the correspondent class FSS_{ij} and therefore CLC_{ij} has to be shrunk.
$FC_{ij} < 0$	CLC_{ij} underestimates the correspondent class FSS_{ij} and therefore CLC_{ij} has to be enlarged.
$FC_{ij} = 0$	there is an agreement between CLC_{ij} and FSS_{ij} data and no changes have to be made to the CLC map.

Table 3.2 Detailed list of FSS crops within each class established in Table 3.1.

FSS Class legend	Crops which are included
D07 (Rice)	D07 - Rice
D06 (Grain maize)	D06 - Grain maize
D (Arable land) + I08AD22 (fallow land set-aside) - D06 - D07	D01 - Common wheat and spelt
	D02 - Durum wheat
	D03 - Rye
	D04 - Barley
	D05 - Oats
	D08 - Other cereals
	D09 - Pulses - total
	D10 - Potatoes
	D11 - Sugar beet
	D12 - Fodder roots and brassicas
	D13A - Tobacco
	D13B - Hops
	D13C - Cotton
	D13D1A - Rape and turnip:Other oil-seed or fibre plants
	D13D1B - Sunflower:Other oil-seed or fibre plants
	D13D1C - Soya:Other oil-seed or fibre plants
	D13D1D - Others:Other oil-seed or fibre plants
	D13D2 - Aromatic-; medicinal and culinary plants
	D13D3 - Industrial plants - Others
	D14 - Outdoor:Fresh vegetables; melons; strawberries
	D15 - Under glass:Fresh vegetables; melons; strawberries
	D16 - Outdoor:Flowers and ornemental plants
	D17 - Under glass:Flowers and ornemental plants
	D18A - Forage plants - temporary grass
	D18B1 - Green maize:Other green fodder:Forage plants
	D18B2 - Leguminous plants:Other green fodder:Forage plants
	D18B3_2000 - age plants - other green fodder - others
	D20 - Other crops
	D21 - Fallow land without subsidies
	I08AD22 - Fallow land with no economic use:Set-aside areas under incentive schemes
G04 (Vineyards total)	G04A - Vineyards - quality wine
	G04B - Vineyards - other wines
	G04C - Vineyards - table grapes
	G04D - Vineyards - raisins
G (Permanent crops) - G03 - G04	G01 - Fruit and berry plantations - total
	G02 - Citrus plantations
	G05 - Nurseries
	G06 - Other permanent crops
	G07 - Permanent crops under glass
G03 (Olive plantations total)	G03A - Olive plantations - table olives
	G03B - Olive plantations - oil production
F (Total:Permanent grassland and meadow)	F01 - Pasture and meadow:Permanent grassland and meadow
	F02 - Rough grazings:Permanent grassland and meadow

3.1.2 Step 2 – Computation

Reduce CLC classes where CLC>FSS, creating a buffer class, and enlarge CLC classes where CLC<FSS, according to enlarging rules (program LANDUSE)

A program, called LANDUSE, was developed to automatically calculate in all NUTS3 the area of each of the seven classes established for the comparison (Table 3.1) that have to be shrunk or enlarged in the CLC map.
The program computes first the CLC areas to be shrunk (the case $FC_{ij} > 0$). The areas in excess are converted in a new buffer class, called F51, when the original class belongs to permanent crops (buffer class for permanent crops), and F50 in all the other cases (buffer class for agricultural land). Class F50 and F51 constitute artificial intermediate classes, where other classes underestimated by CLC can be expanded.

When the surface reported by FSS is larger than the one described in the CLC (the case $FC_{ij} < 0$) referring to the seven classes of correspondence (Table 3.1), the LANDUSE program assigns the missing areas in other CLC classes, starting to fill firstly the buffer artificial class F50 and F51. This step, which constitutes an enlargement of the classes used for the correspondence, is executed following precise rules, called *enlarging rules*. The description of the enlarging rules is given in Paragraph 3.1.4.

Once the seven classes used for the analysis (Table 3.1) were modified to fit the FSS data, the area covered by the different crops within each class (Table 3.2) was assigned according to FSS data, and a correspondent ID code was established for the new land use map (Table 3.3). Therefore, the classes of the new land cover map are the result of mixing the original CLC map with the FSS crops classification. The areas of crops respect the values of FSS and the class location include the information of the CLC map.

3.1.3 Step 3 – Spatialisation

Spatially distribute FSS crops in pertinent areas

The program LANDUSE, calculate the total area per class and per NUTS3 that have to be changed and the class type this area have to be converted to. Then, a GIS application, called SPATIAL DISTRIB, was developed to spatially locate the pixels to be modified. In each NUTS3, for class of Table 3.1, the program SPATIAL DISTRIB randomly selects within each class CLC_{ij} the number of pixel correspondent to the area to be shrunk or enlarged, and convert them into the appropriate class. Therefore, according to this methodology, the crop distribution is random only within a coherent CLC class.

After the spatialisation, in the NUTS where CLC>FSS, the original CLC agricultural areas resulted only partially covered by crops, leaving part of their surface not assigned to any FSS crop. This is the case of classes 50, 51, 19, 20, 21 and 22 in the new land use map (Table 3.3).

Table 3.3 New land use map classes.

New land use map class legend	New land use map class ID
1.1.1 Continuous urban fabric	1
1.1.2 Discontinuous urban fabric	2
1.2.1 Industrial or commercial units	3
1.2.2 Road and rail networks and associated land	4
1.2.3 Port areas	5
1.2.4 Airports	6
1.3.1 Mineral extraction sites	7
1.3.2 Dump sites	8
1.3.3 Construction sites	9
1.4.1Green urban areas	10
1.4.2 Sport and leisure facilities	11
D07 - Rice	67
D06 - Grain maize	66
D01 - Common wheat and spelt	65
D02 - Durum wheat	70
D03 - Rye	71
D04 - Barley	72
D05 - Oats	73
D08 - Other cereals	74
D09 - Pulses - total	75
D10 - Potatoes	76
D11 - Sugar beet	77
D12 - Fodder roots and brassicas	78
D13A - Tobacco	79
D13B - Hops	80
D13C - Cotton	81
D13D1A - Rape and turnip:Other oil-seed or fibre plants	82
D13D1B - Sunflower:Other oil-seed or fibre plants	83
D13D1C - Soya:Other oil-seed or fibre plants	84
D13D1D - Others:Other oil-seed or fibre plants	85
D13D2 - Aromatic-; medicinal and culinary plants	86
D13D3 - Industrial plants - Others	87
D14 - Outdoor:Fresh vegetables; melons; strawberries	88
D15 - Under glass:Fresh vegetables; melons; strawberries	89
D16 - Outdoor:Flowers and ornemental plants	90
D17 - Under glass:Flowers and ornemental plants	91
D18A - Forage plants - temporary grass	92
D18B1 - Green maize:Other green fodder:Forage plants	93
D18B2 - Leguminous plants:Other green fodder:Forage plants	94
D18B3_2000 - age plants - other green fodder - others	95
D20 - Other crops	96
D21 - Fallow land without subsidies	97
I08AD22 - Fallow land with no economic use:Set-aside areas under incentive schemes	98

Table 3.3 (Continue) New land use map classes.

New land use map class legend	**New land use map class ID**
G04A - Vineyards - quality wine	55
G04B - Vineyards - other wines	52
G04C - Vineyards - table grapes	53
G04D - Vineyards - raisins	54
G01 - Fruit and berry plantations - total	64
G02 - Citrus plantations	60
G05 - Nurseries	61
G06 - Other permanent crops	62
G07 - Permanent crops under glass	63
G03A - Olive plantations - table olives	56
G03B - Olive plantations - oil production	57
F01 - Pasture and meadow:Permanent grassland and meadow	100
F02 - Rough grazings:Permanent grassland and meadow	101
3.1.1 Broad-leaved forest	23
3.1.2 Coniferous forest	24
3.1.3 Mixed forest	25
3.2.1 Natural grasslands	26
3.2.2 Moors and heathland	27
3.2.3 Sclerophyllous vegetation	28
3.2.4Transitional woodland-shrub	29
3.3.1 Beaches, dunes, sands	30
3.3.2 Bare rocks	31
3.3.3 Sparsely vegetated areas	32
3.3.4 Burnt areas	33
3.3.5 Glaciers and perpetual snow	34
4.1.1 Inland marshes	35
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3.1.4 Expand CLC classes to fit FSS data: the enlarging rules

The enlarging rules (Table 3.4) set the class priority (type and order) for locating the missing area to create the new land use map. The enlarging rules indicate in which CLC class the missing FSS areas have to be found.

Table 3.4 Enlarging rules in the LANDUSE program.

Correspondence CLC-FSS (7 classes, Table 3.1)			Enlarging rules	
CLC Class legend	CLC raster Class ID	FSS Class legend	CLC raster Class ID	CLC Class legend
Rice field	14	D07 (Rice)	50	Buffer class for agricultural land
			21	Land principally occupied by agriculture
Permanently irrigated land	13	D06 (Grain maize)	50	Buffer class for agricultural land
			21	Land principally occupied by agriculture
			19	Annual crops associated with permanent crops
			20	Complex cultivation patterns
Non-irrigated arable land	12	D (Arable land) + I08AD22 (fallow land set-aside) - D06 - D07	50	Buffer class for agricultural land
			21	Land principally occupied by agriculture
			19	Annual crops associated with permanent crops
			20	Complex cultivation patterns
			36	Peat bogs
Vineyards	15	G04 (Vineyards total)	51	Buffer class for permanent crops
			20	Complex cultivation patterns
			19	Annual crops associated with permanent crops
			21	Land principally occupied by agriculture
Fruit trees and berry plantations	16	G (Permanent crops) - G03 - G04	51	Buffer class for permanent crops
			20	Complex cultivation patterns
			19	Annual crops associated with permanent crops
			21	Land principally occupied by agriculture
Olive growes	17	G03 (Olive plantations total)	51	Buffer class for permanent crops
			20	Complex cultivation patterns
			19	Annual crops associated with permanent crops
			21	Land principally occupied by agriculture
Pastures	18	F (Total:Permanent grassland and meadow)	50	Buffer class for agricultural land
			22	Agro-forestry areas
			21	Land principally occupied by agriculture
			20	Complex cultivation patterns
			19	Annual crops associated with permanent crops
			26	Natural grasslands
			51	Buffer class for permanent crops
			27	Moors and heathland
			28	Sclerophyllous vegetation
			36	Peat bogs
			23	Broad-leaved forest

For each class used in the comparison, the enlarging rule consists in a list of classes, including the buffer classes F50 and F51 and the CLC classes not used in the comparison of Table 3.1, that have to be followed to locate the missing areas (Table 3.4). In the list, the classes are ranked according to a decreasing probability of the missing area to be situated in the class. When converting in the convenient FSS class type, the CLC classes listed in the enlarging rule are filled in sequentially and they are not modified until the previous class is not completely filled in.
For example, in a NUTS3 where the maize surface reported by FSS is larger than the one present in the CLC map, the LANDUSE program may reassign partially or completely the classes F50, CLC 21, CLC 19 and CLC 20 to maize, according to their order in the list, until all the FSS area of maize missed in the original CLC map has found a location (Table 3.4).

The enlarging rules were established considering the description of CLC class types and additional information:

- The description of CLC classes (Brossard et al. 2000) provides detailed information on possible minor cover types within each CLC class.

- Previous studies (although referring to CLC 1990) showed the systematic error found in some countries due to their specific vegetation covers or agro-forestry systems. For example, Kayadjanian and Vidal (2001) suggested that CLC 1990 did not correctly estimate pasture areas in the South of Europe (especially Spain and part of Italy) because of the difficulties in that region to distinguish pasture areas from other semi-natural areas in the photo-interpretation. Similarly, Gallego (2001) observed discrepancies on pasture and natural vegetation comparing CLC 1990 with a more detailed database in central Italy.

- The analysis of maps showing the discrepancies per NUTS3 between CLC and FSS data for different CLC classes give an indication of the possible classes where the missing areas can be found, as the under-estimation in one class may correspond spatially to the over-estimation in an other class (as shown by Kayadjanian and Vidal (2001) for CLC 1990).

- The PELCOM 1-km land cover map (Pan-European Land Cover Monitoring project), which was derived by multi-spectral and multi-temporal NOAA-AVHRR satellite imagery, was considered to have an indication on the location in CLC map of the missing agricultural areas according to the comparison CLC-FSS (Table 2.3).

  The PELCOM and CLC maps have different scale of resolution, source of information and classification system. Comparing two geospatial land cover data layers without taking into account their different scales could be misleading (Gallego, 2001). For this reason, the results of the comparison between PELCOM and CLC have to be considered only as indicative.
  The distribution of CLC agricultural areas on PELCOM arable land (Figure 3.2 upper), shows that there is a general agreement between the two maps, while for Finland and Sweden most of the PELCOM grassland corresponds to forest and semi-natural areas in CLC (Figure 3.2 middle). This can indicate that in these two

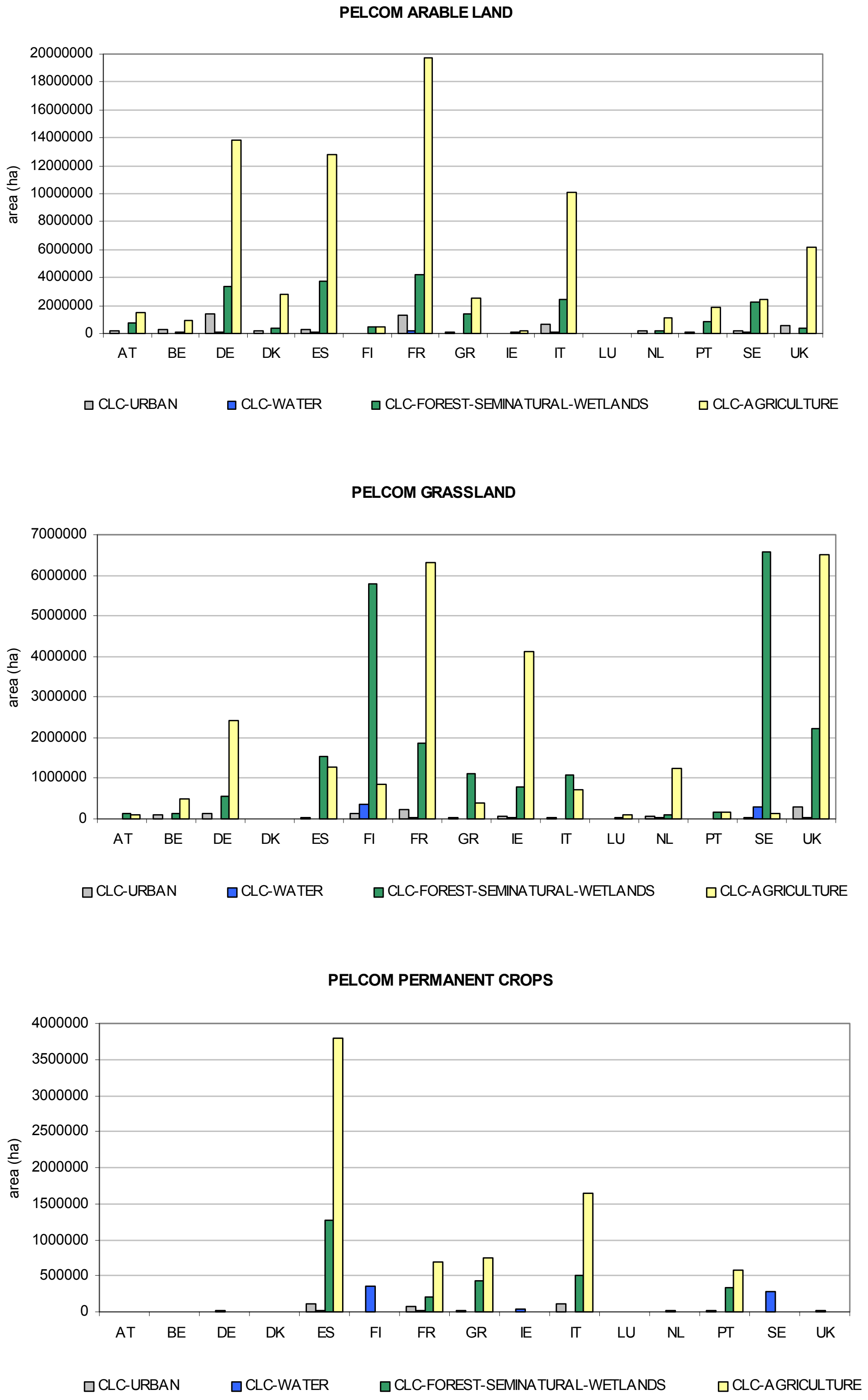
countries eventual missing pasture areas could be found in CLC semi-natural areas.

The analysis can be deepened considering the CLC agricultural classes at level 3. The distribution of CLC agricultural areas on PELCOM arable land, grassland and permanent crops (Figure 3.3), provides information on the priority in choosing among the heterogeneous agricultural areas classes (CLC classes 19, 20, 21 and 22), when establishing the enlarging rules. The overlay suggests for example that missing pasture could be located for Spain in CLC agro-forestry areas and for France in CLC complex cultivation patterns class. Similar information could be found in the graphs showing the distribution of CLC classes other than agricultural area classes on PELCOM arable land, grassland and permanent crops (Figure 3.4). These graphs suggest that missing pasture could be assigned to natural grassland in Spain, Greece, Italy and United Kingdom, and to “Moors and heathland” and “Sclerophyllous vegetation” classes for Sweden, United Kingdom and Finland (Figure 3.4).

The enlarging rules were developed iteratively, adding new classes in the list until all the missing areas were assigned to appropriate CLC classes. However, after the whole process, for few NUTS3 the total balance between CLC and FSS areas (according to Table 3.1) was still negative, requiring to include agricultural areas in additional CLC class type. As the residual areas to be distributed were significantly smaller than the NUTS surface, the decision was taken not to locate these agricultural areas, to avoid the assignment of arable land in non pertinent classes (such as urban or water classes). Moreover, this indicate that even FSS data may contain imprecision. The total areas not distributed are reported in the table below per country (Table 3.5).

Table 3.5 Areas reported in FSS still missed in the new land use map.

Area (km^2)	AT	ES	IT	UK
Arable areas	20	39	-	1035
Permanent crops	4	26	14	26
Pasture	991	-	490	1931



Legend: CLC-URBAN includes CLC class from 1 to 11
CLC-WATER includes CLC class from 40 to 43
CLC-FOREST-SEMINATURAL-WETLANDS includes CLC class from 23 to 39
CLC-AGRICULTURE includes CLC class from 12 to 22

Figure 3.2 Distribution of CLC classes (Level 1) on PELCOM agricultural areas (upper), grassland (middle) and permanent crops (below) according to the PELCOM-CLC overlay.

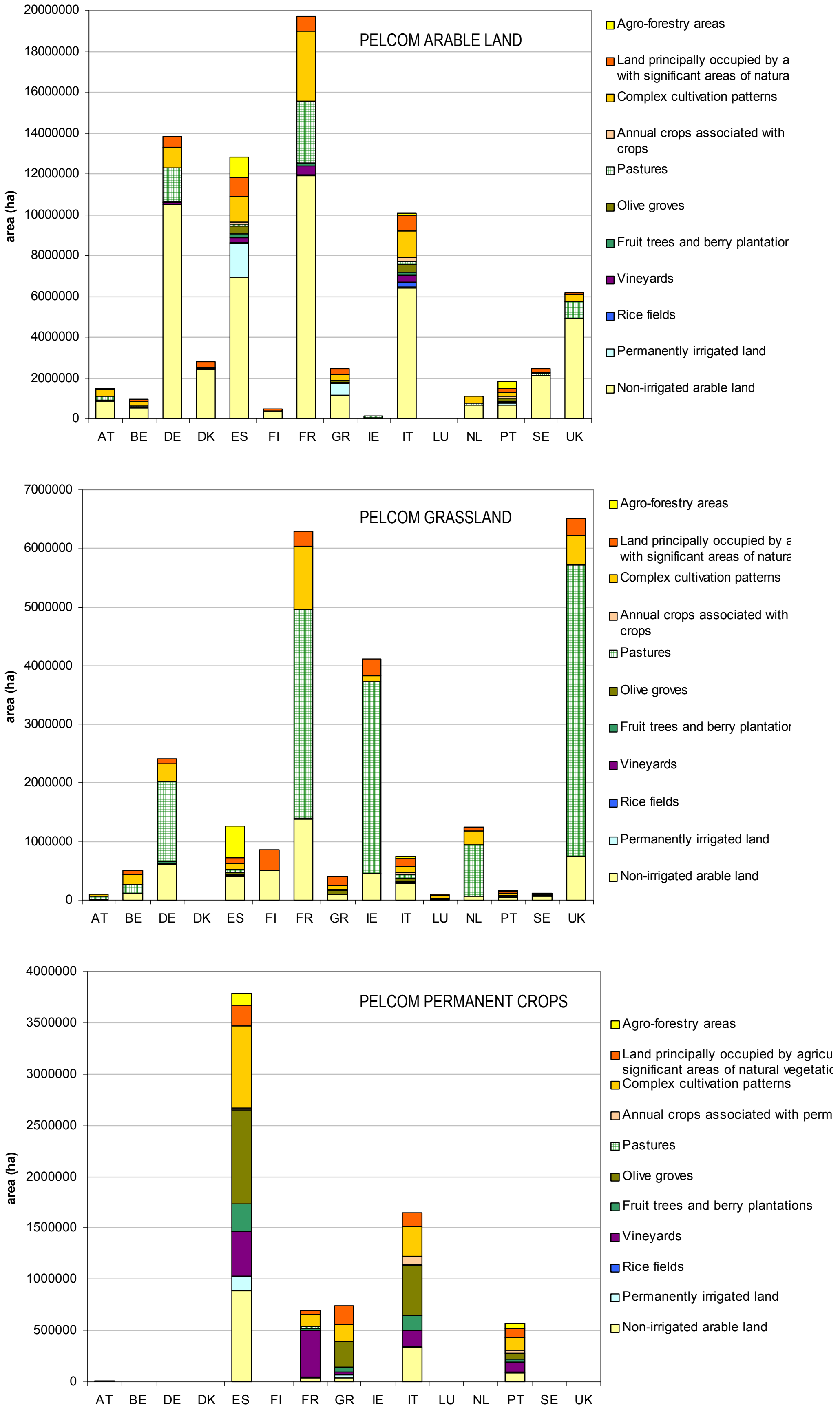


Figure 3.3 Distribution of agricultural areas CLC classes (Level 3) on PELCOM agricultural areas (upper), grassland (middle) and permanent crops (below).

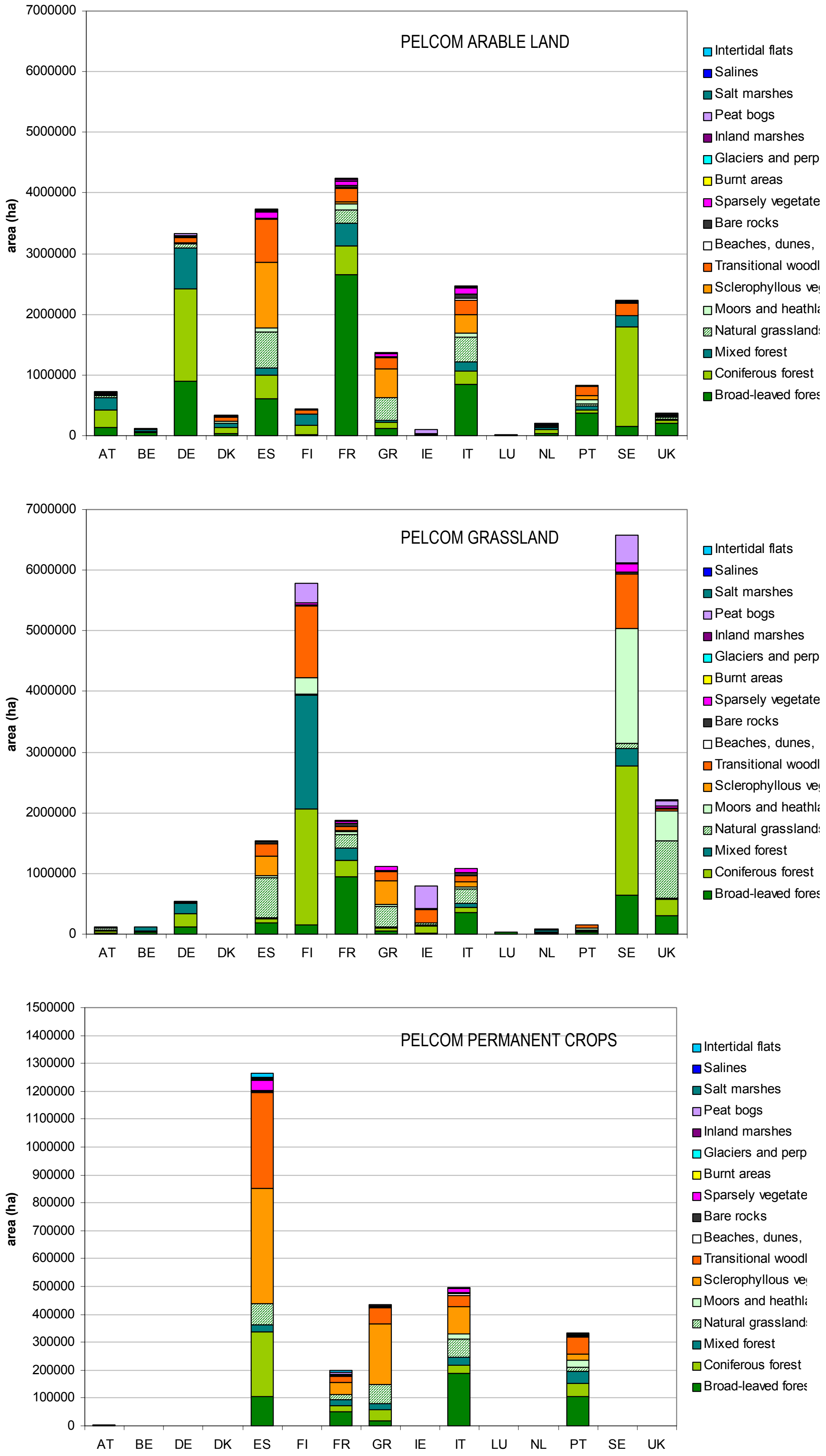


Figure 3.4 Distribution of forest and semi natural areas CLC classes (Level 3) on PELCOM agricultural areas (upper), grassland (middle) and permanent crops (below).

3.2 European map of land-use including crop distribution

After the spatialisation of FSS crop data according to the methodology described in the previous paragraph, the new land use map appears still very similar to the CLC map, but it includes the FSS crop types and it is consistent with the FSS crop areas (Figure 3.5).

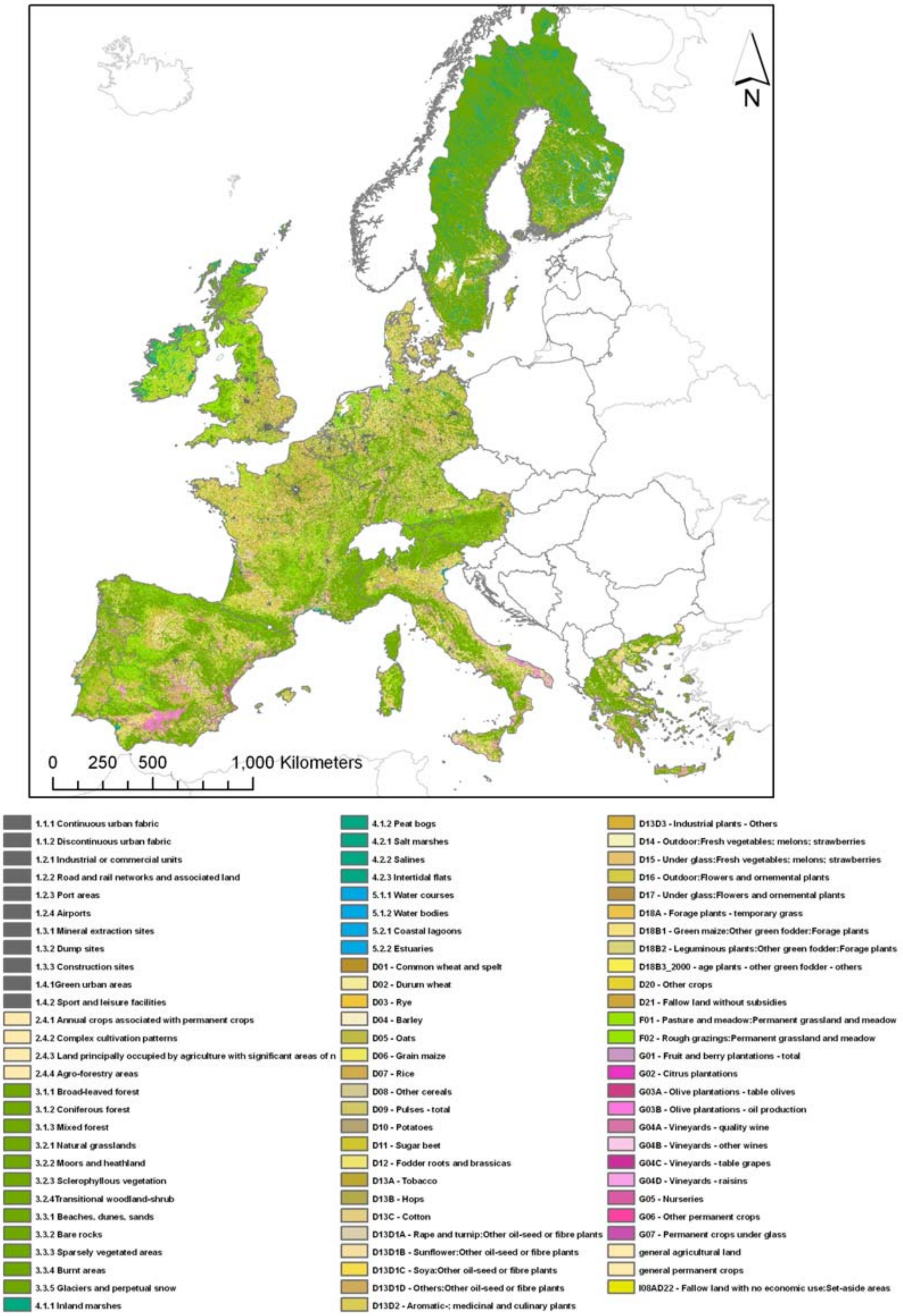


Figure 3.5 New land use map after spatialisation of crops reported in FSS. (100m raster).

The new-land use map relies on the following assumptions, which were explained and justified in the methodology (Paragraph 3.1):

- the link between FSS and CLC data refers to the table of correspondence established in Table 3.1 (Table 3.2 provides details);
- where CLC<FSS, the modification of CLC classes is performed according to the enlargement rules listed in Table 3.4;
- the FSS crops are distributed semi-randomly, respecting their correct areas, within the coherent CLC class.

The latter implies that the random distribution is assumed to better represent the spatial distribution of crops at the scale where the CLC map can not provide any more information. Several reasons may justify this choice:

Data on soils characteristics (texture, organic carbon content, depth, slope), which may inform on soil suitability for specific crop types, where not directly considered in the analysis, as the land cover constitutes already a synthesis of land suitability, partially including already information on soil characteristics.

Moreover, other factors besides soils influence the crop distribution and the landscape pattern, such as historical settlement development, farm type (whether it includes only crop production or also animal breeding), economic schemes, access to machinery facilities, farmer behaviour and proximity to holding buildings, water resources and irrigation systems. Several studies have focused on farm spatial land use (Thenail and Baudry, 2004; Rounsevell et al., 2003) and on the impacts of arable intensification on landscape pattern and ecological system in Europe (Stoate et al., 2001), showing how an integration of factors may influence the land use pattern. Schmit et al. (2006) found that the agricultural land use location is determined by the relative position of the various fields to the farm. They showed that in central Belgium grassland is the dominant land use close to farms, while the winter wheat and sugar beat areas increase with the distance from farms. In fact, where grassland is used for dairy cows, it is preferentially located near the farm, as animals need to be close to the farm buildings.

The random distribution within the coherent CLC classes was considered as a suitable representation of the various dynamics determining the landscape feature, integrating the physical, historical, economical and anthropological factors. Additional information would have not necessarily improved the reliability of the crop distribution considering the target scale of modelling (catchment unit) and nutrient input uncertainty (see next Chapter) in European wide database.

4 Spatialised nutrient pressures

To estimate the spatialised the nutrient balance for EU15, two main types of information are needed: the nitrogen and phosphorus input and losses per land cover and in particular per crop type, in the different EU regions, and the crop spatial location. The development of a revised land-use map, including the spatial location of FSS crops, was presented in Chapter 3. This chapter focuses on the estimation of nutrient inputs and losses, per crop type, in order to perform the spatialised nutrient balance. The assessment was based on the collection of best European wide available information and, where data were lacking, on modelling assumptions.

4.1 Gross nutrient balance components

According to the OECD/Eurostat definition (OECD, 2007) the gross nutrient balance includes all residual emissions of nutrient compounds from agriculture into soil, water and air. This means that the nutrient losses from the soil by leaching, runoff and for nitrogen by denitrification and volatilisation are included in the balance as well as the ammonia (NH_3) volatilisation during manure accumulation, storage and spreading.
In this study, the nutrient balance for agricultural lands was calculated as the difference between nutrient input and output, as follow:

Gross nutrient balance = nutrient input–nutrient output

(Equation 8)

In particular:

Gross nitrogen balance = (mineral fertilisers + livestock manure + biological fixation + atmospheric deposition) – crop uptake

(Equation 9)

Gross phosphorus balance= (mineral fertilisers + livestock manure) – crop uptake

(Equation 10)

A positive gross nutrient balance indicates that nutrient losses may occur in soil, water and air, with therefore a risk of pollution for these compartments, while a negative gross nutrient balance designates soils, which with time may lose their fertility.

The gross nutrient balance was computed spatially, overlaying the data layers (1 ha raster) representing the different terms of the Equation 9 and 10.

The following paragraphs illustrate how nitrogen and phosphorus inputs and outputs (Equations 9 and 10) were evaluated in this study, describing both their estimation and their spatial distribution.

4.1.1 Crop uptake

Crop yield was collected from EUROSTAT, from the Theme on “Agriculture and Fisheries”. The yield data consisted in total dry yield per crop in tons per ha on a NUTS2 level. When yield data for a specific region was missing it was assigned the national average. The data were collected for year 2000. The crop yield was then converted into nitrogen and phosphorus uptake by multiplying the yield by crop coefficients derived from the OECD (OECD, 2007). A 1 ha raster map of crop yield was then produced, based on the yield per crop type estimated for each NUTS2 and the newly produced land-use map, which provides the location of crop types within the NUTS2s.

4.1.2 Atmospheric nitrogen deposition

The EMEP data on nitrogen atmospheric deposition (Co-operative Programme for the Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe, EMEP, 2001) were used for this study. The EMEP data are already spatialised according to a 50 km grid. On the basis of this, a raster of 1 ha size was created of the yearly-accumulated values of total deposition of nitrogen (oxidised + reduced nitrogen) (kg N/ha).

4.1.3 Biological nitrogen fixation

Nitrogen fixation was calculated using the OECD coefficients (OECD, 2007), which are crop and country specific. Fixation was calculated for the following crops: pulses, soya, fodder, green fodder, and leguminous crops. Moreover, for all the arable land a soil organisms fixation of 4 kg/ha was considered. A 1 ha raster map of nitrogen fixation was then produced using the land-use map developed in this study.

4.1.4 Mineral fertilisers

Mineral fertiliser data were gathered from the International Fertiliser Association (IFA, 2006). The data consisted in application rate per country and per crop type of nitrogen (N) and phosphorus (P_2O_5). Table 4.1 illustrates the correspondence established in this study between IFA and FSS crop types.

For each crop, the total amount of nutrient (N and P) applied for one country was calculated as the total area covered by a specific crop multiplied by the application rate (IFA, 2006). Then the resulting amount of total nitrogen and phosphorus applied per crop was distributed at NUTS2 level using the regional crop yield (from EUROSTAT) as weighing factors. This operation allowed to apply more mineral fertiliser in areas with higher yield while maintaining the total amount of applied fertilisers. Finally a fertiliser application rate per crop type was computed at NUTS2 level.

Table 4.1 Correspondence established between IFA and FSS crops.

IFA crops	FSS crops
Wheat	D01 - Common wheat and spelt
	D02 - Durum wheat
Barley	D04 - Barley
Rye, oat, rice	D03 - Rye
	D05 - Oats
	D08 - Other cereals
	D07 - Rice
Grain maize, incl. CCM	D06 - Grain maize
Potato	D10 - Potatoes
Sugar beet	D11 - Sugar beet
Oilseed rape	D13D1A - Rape and turnip:Other oil-seed or fibre plants
Sunflower, soya, linseed	D13D1B - Sunflower:Other oil-seed or fibre plants
	D13D1C - Soya:Other oil-seed or fibre plants
	D13D1D - Others:Other oil-seed or fibre plants
Pulses (peas, beans)	D09 - Pulses - total
Vegetables	D14 - Outdoor:Fresh vegetables; melons; strawberries
	D15 - Under glass:Fresh vegetables; melons; strawberries
	D16 - Outdoor:Flowers and ornemental plants
	D17 - Under glass:Flowers and ornemental plants
Fodder (legumes)	D18B2 - Leguminous plants:Other green fodder:Forage plants
Fodder (others)	D18A - Forage plants - temporary grass
	D21 - Fallow land without subsidies
	D18B3_2000 - age plants - other green fodder - others
	D12 - Fodder roots and brassicas
	D20 - Other crops
Silage maize	D18B1 - Green maize:Other green fodder:Forage plants
Others (incl. tobacco)	D13A - Tobacco
	D13D2 - Aromatic-; medicinal and culinary plants
	D13D3 - Industrial plants - Others
	D13B - Hops
	D13C - Cotton
Perm. crops (fruit, vineyard)	G04A - Vineyards - quality wine
	G04B - Vineyards - other wines
	G04C - Vineyards - table grapes
	G04D - Vineyards - raisins
	G01 - Fruit and berry plantations - total
	G02 - Citrus plantations
	G05 - Nurseries
	G06 - Other permanent crops
	G07 - Permanent crops under glass
	G03A - Olive plantations - table olives
	G03B - Olive plantations - oil production
Grassland fertilized	F01 - Pasture and meadow:Permanent grassland and meadow
	F02 - Rough grazings:Permanent grassland and meadow
Set-aside, industrial crops	I08AD22 - Fallow land with no economic use:Set-aside areas under incentive schemes

Based on the fertiliser application rate per crop type computed at NUTS2 level, the value at NUTS3 level was established according to the distribution of NUTS3 within NUTS2 administrative units. NUTS3 mineral fertiliser rates per crop type were used together with the new land-use map to create the maps of nitrogen and phosphorus mineral fertiliser input, as rasters of 1ha cell size. The Figure 4.1 and Figure 4.2 show the distribution of mineral fertiliser application rate on agricultural lands across EU15 according to the estimated maps. The maps are presented in Paragraph 4.2.1.

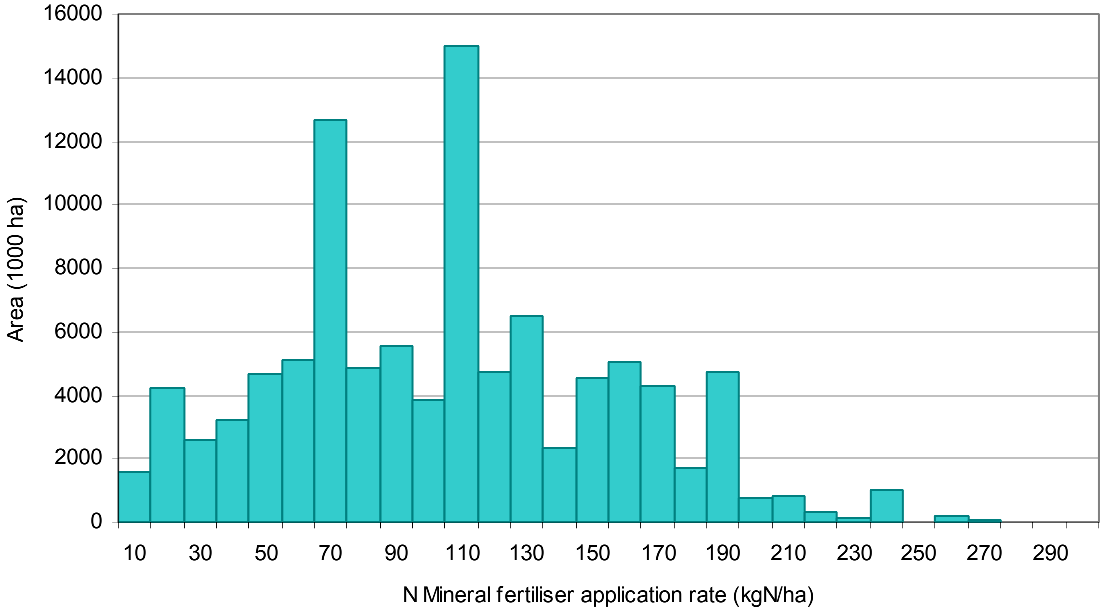


Figure 4.1 Distribution of nitrogen mineral fertiliser application rate on agricultural land across EU15.

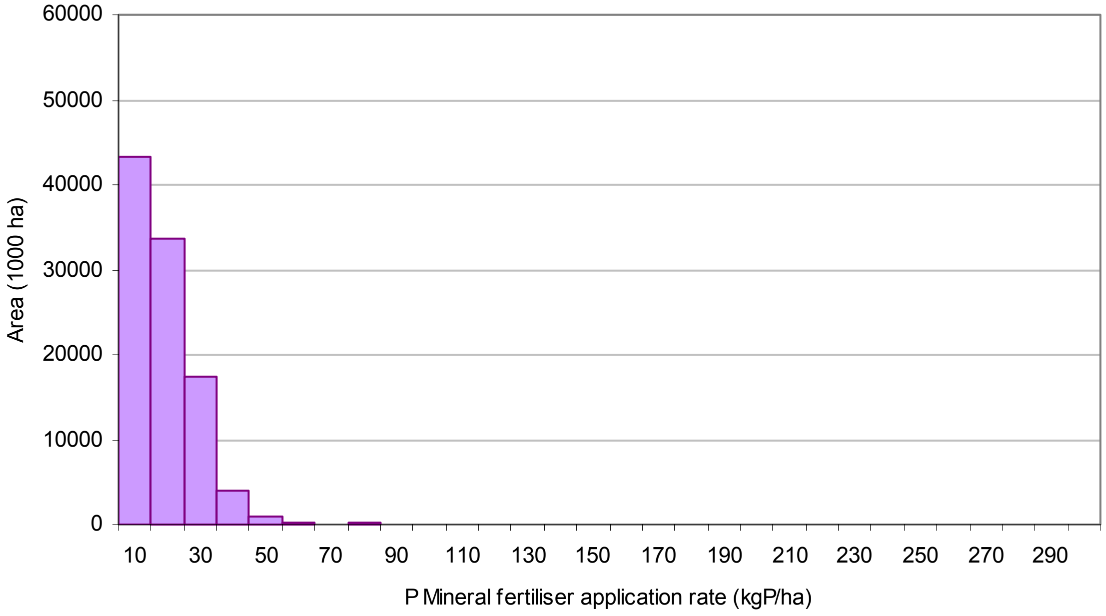


Figure 4.2 Distribution of phosphorus mineral fertiliser application rate on agricultural land across EU15.

4.1.5 Manure

The amount of nitrogen and phosphorus originating from manure was computed for each NUTS3 j multiplying the livestock number of the animal category k (in heads) by the excretion coefficient per animal category of the country c (kg N or P/ head·year), according to the following equation:

$$Manure\ in\ NUTS3_j = livestock\ number_{k,j} * excretion\ coefficient_{k,c} \qquad \text{(Equation 11)}$$

Livestock numbers per different animal category at NUTS3 level were extracted from FSS data (Table 2.1), while country specific nitrogen and phosphorus excretion coefficients per animal category were available from OECD data (OECD, 2007). These coefficients are provided by Member States based on national averages.
FSS reports the number of animals recorded on a specific census day of year 2000, therefore miscalculation due to animals with the several production cycles per year (as pigs and poultry) are avoided and excretion coefficients in terms of kg/head·year can be used.

The animal category considered in FSS data are listed in Table 4.2 and Table 4.3 together with range of variation of the excretion coefficients used in this study for nitrogen and phosphorus, respectively. Excretion coefficients per country and per animal type were taken from OECD (2007). Figure 4.3 and Figure 4.4 illustrate the manure production per livestock type and per country. Figure 4.5 offers an overview of the animal production, expressing the contributions of different livestock types in livestock units (LSU), where a LSU corresponds to the environmental impact of a 500 kg dairy cow. The conversion to LSU was performed multiplying the livestock number for the animal specific coefficient reported by EUROSTAT (EUROSTAT, 2006b).

Table 4.2 Range of variation of nitrogen excretion coefficients (kgN/head·yr) per animal type used in this study. Nitrogen excretion coefficients were taken from OECD, 2007.

Code FSS	Minimum	Maximum
Equidae	28	80
Bovine <1 year old - total	15	40
Bovine 1-<2 years - males	43	70
Bovine 1-<2 years - females	42	83
Bovine 2 years and older - males	47	68
Heifers; 2 years and older	47	101
Dairy cows	55	126
Other cows; bovine 2 years old &over	47	98
Sheep - total	7	23
Goats	6	19
Pigs - piglets under 20 kg	0	4
Pigs - breeding sows over 50 kg	13	35
Pigs - others	7	15
Poultry - broilers	0.2	0.8
Laying hens	0.4	0.9
Poultry - others	0.2	2.1

Table 4.3 Range of variation of phosphorus excretion coefficients (kgP/head·yr) per animal type used in this study. Phosphorus excretion coefficients were taken from OECD, 2007.

Code FSS	Minimum	Maximum
Equidae	7	22
Bovine <1 year old - total	3	5
Bovine 1-<2 years - males	8	12
Bovine 1-<2 years - females	7	11
Bovine 2 years and older - males	8	17
Heifers; 2 years and older	7	17
Dairy cows	13	20
Other cows; bovine 2 years old &over	9	17
Sheep - total	1	4
Goats	1	8
Pigs - piglets under 20 kg	0	8
Pigs - breeding sows over 50 kg	5	8
Pigs - others	2	8
Poultry - broilers	0.1	0.2
Laying hens	0.1	0.2
Poultry - others	0.1	0.7

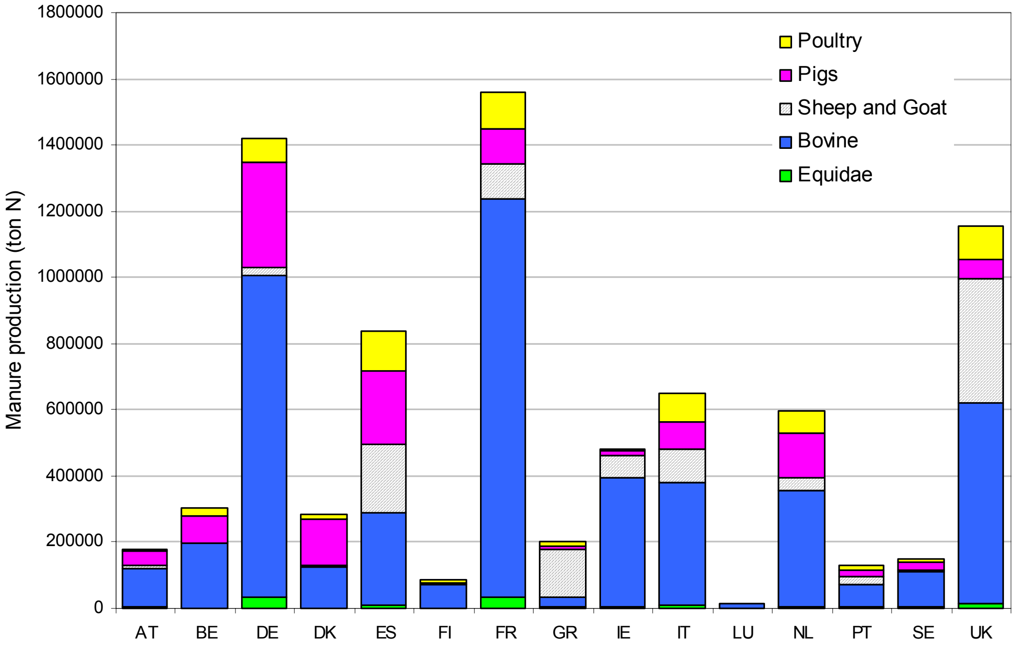


Figure 4.3 Estimated nitrogen manure production (ton N) distributed for different animal types for EU15 countries.

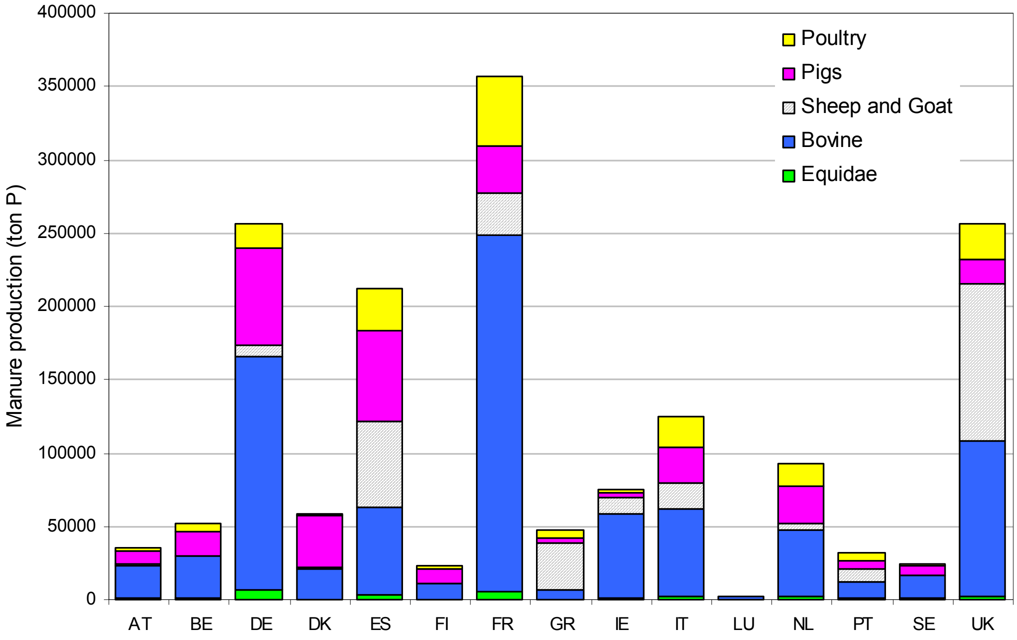


Figure 4.4 Estimated phosphorus manure production (ton P) distributed for different animal types for EU15 countries.

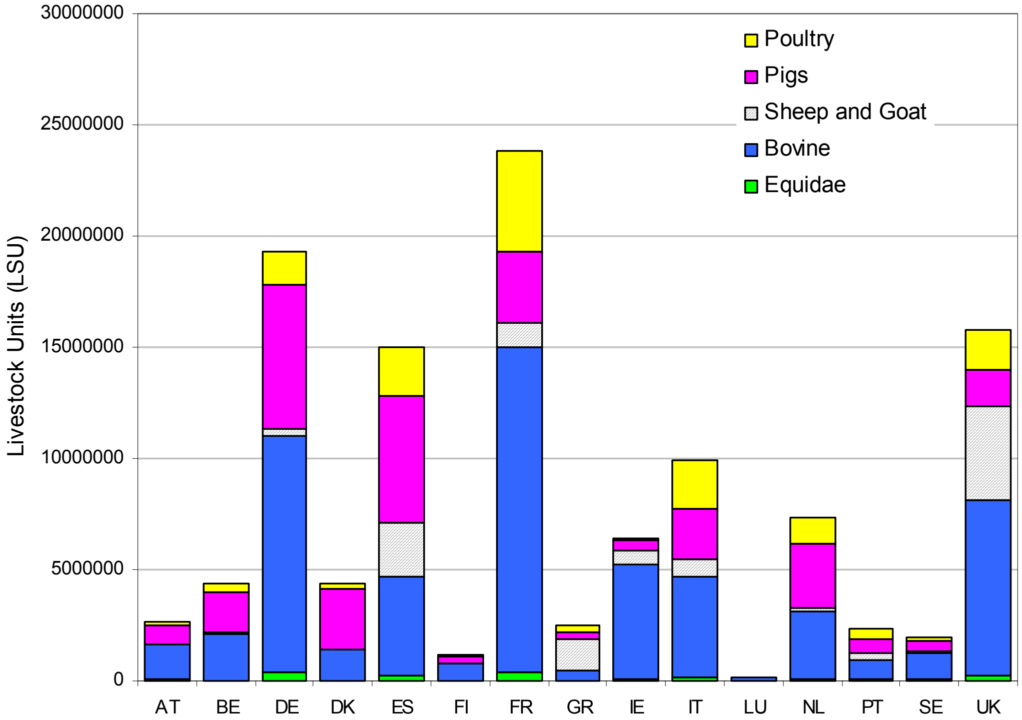


Figure 4.5 Livestock Units (LSU) according to FSS data and EUROSTAT coefficients for computing LSU (EUROSTST, 2006b).

The estimation of the nitrogen and phosphorus contained in the manure exibits a great uncertainty due to the difficulties in estimating representative excretion coefficients per animal type (reference to the document of EUROSTAT meeting). In fact, the excretion coefficients depend on several factors which may vary from region to region, such as the livestock breed, the animal diet, the housing system and the farm type (which influences the breeding and manure management), and therefore national excretion coefficients represents only average values. In addition, the characteristic and timing of manure collection, storage, transport and spreading affect the type of manure produced (solid or slurry), its nutrient content, the nitrogen emissions into the atmosphere, the crops consumption and consequently the nutrient losses into soils and waters. Data on all these factors related to manure production and management were not available at the scale of study.

For this reason, the estimation of manure input at the European scale required several simplifications: principal classes of livestock were considered, national values of excretion coefficients per animal category were used, no distinction was made for the type of manure (solid or slurry), the nutrient fraction lost during storage, transport and spreading is included in the manure input and contribute to the potential nutrient surplus.

The uncertainty on excretion coefficient values, as well as possible differences in the livestock numbers of reference, may explain the discrepancies in the estimations of nitrogen input from manure at the European scale (Figure 4.6).

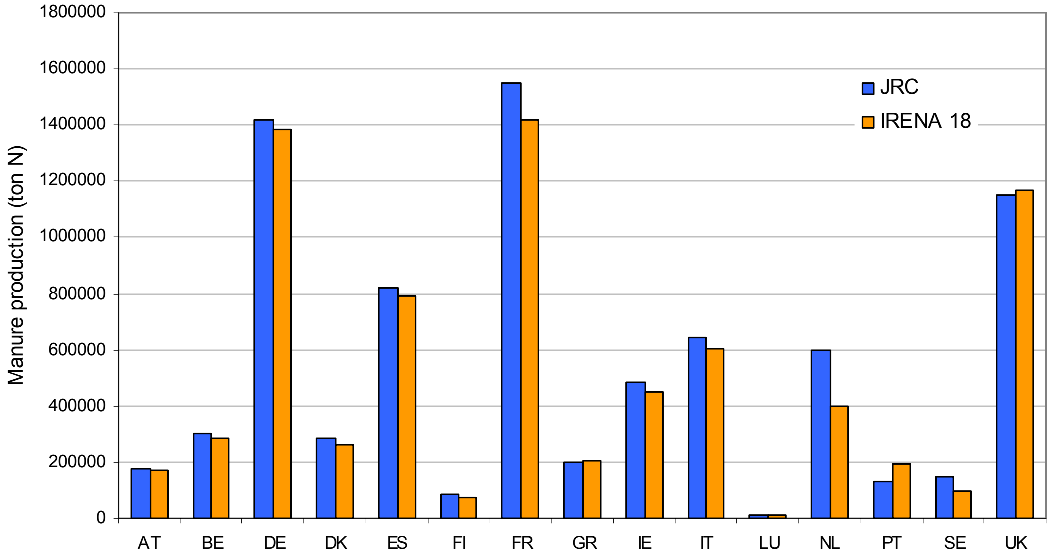


Figure 4.6 Estimated nitrogen manure production (ton N) for EU15 countries, according to JRC and IRENA 18 indicator.

In order to evaluate the impact of the uncertainty of excretion coefficients on manure estimation, a sensitivity analysis was conducted for manure nitrogen production. 1000 estimations of nitrogen from manure produced per country were performed making the excretion coefficients randomly vary within an interval of ±50% of their initial value (Table 4.2). The results show that such variation in the excretion coefficients produced a deviation of the estimated manure nitrogen of about ±30% compared to the original estimation, with national differences mainly linked to the composition of the livestock (Figure 4.7). In fact, countries dominated by one type of animal result more sensitive to a variation of the excretion coefficient.

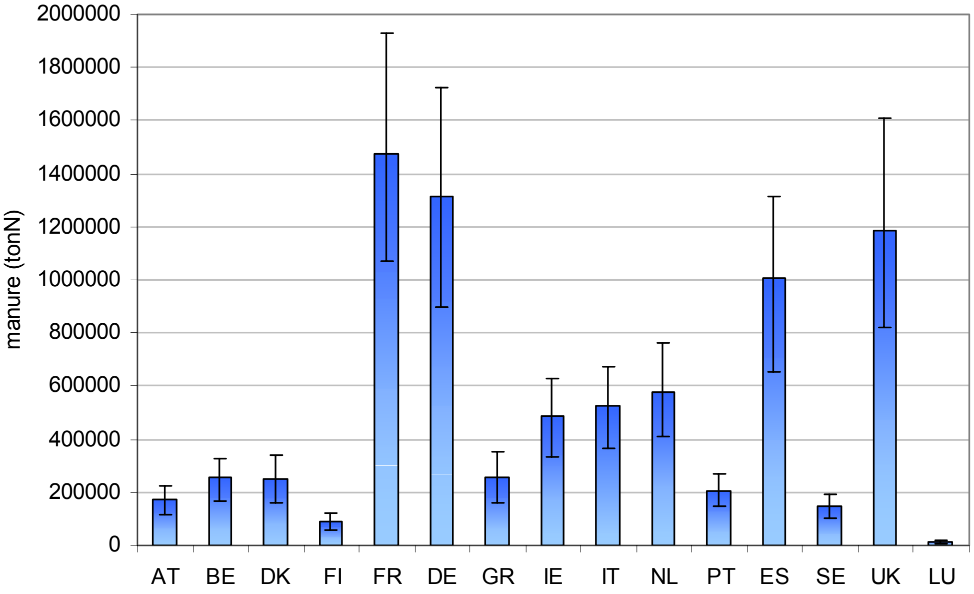


Figure 4.7 Estimated nitrogen manure for countries and relative uncertainty interval.

The FSS data on livestock numbers combined with the OECD excretion coefficients allowed the estimation of the total amount of nitrogen and phosphorus originating from manure in each NUTS3. The land-use map developed in this study provides the spatial location of FSS crops within the NUTS3. However, the information on specific rates of manure application per crop per region was not available at the scale of study. For this reason, a methodology was developed to estimate the manure applications based on crop needs.

The assumption was made that manure is applied preferentially on fodder crops or is naturally spread on grassland by animal grazing. Seven FSS classes, listed in Table 4.4, were selected as the preferential crops receiving manure input.

Table 4.4 FSS crops preferentially receiving manure input.

D12 - Fodder roots and brassicas
D18A - Forage plants - temporary grass
D18B1 - Green maize:Other green fodder:Forage plants
D18B2 - Leguminous plants:Other green fodder:Forage plants
D18B3 - Other green fodder
F01 - Pasture and meadow:Permanent grassland and meadow
F02 - Rough grazings:Permanent grassland and meadow

For each of these seven crop types (Table 4.4), the nitrogen need, called “fodder need” of the crop *f* (*Fneed*), was calculated per each NUTS3 *j*, as:

$$Fneed_{j,f} = N\ uptake_{j,f} - N\ mineral\ fertilisers_{j,f} - N\ fixation_{j,f}$$

(Equation 12)

The fodder need (*Fneed*) can be higher or lower than the total nitrogen manure (*TotN_man*), computed according to Equation 12. It was assumed that when applying manure, the available manure would have been spread first on the fodder crops and on pasture land (FSS classes listed in Table 4.4), and then on the other crops. In particular, when:

1) $TotN\_man \leq Fneed$

the estimated total nitrogen manure was distributed only on crops listed in Table 4.4 proportionally to their needs, computing the nitrogen manure application rate (*N_Man* in kgN/ha) according to the following equation:

$$N\_Man_{j,f} = \frac{\dfrac{\left(Fneed_{j,f} \times area_{j,f}\right)}{\sum_f^F \left(Fneed_{j,f} \times area_{j,f}\right)} \times TotN\_man_j}{area_{j,f}}$$

(Equation 13)

where *j* is the NUTS3, *f* is the fodder crop (Table 4.4), *F* is the total number of fodder crops (*F*=7), *area* is the fodder crop surface (ha), *Fneed* is the fodder need of nitrogen manure computed according Equation 12 (kg of N), and *TotN_man* is the total nitrogen manure computed according to Equation 11 (kg of N).

2) $TotN\_man > Fneed$

the estimated total nitrogen manure was distributed first on crops listed in Table 4.4 filling their requirements, and the remaining quantity of nitrogen manure was distributed on all the crops within the NUTS *j* proportionally to their yield, computing the nitrogen manure application rate (*N_Man*), according to the following equation:

$$N\_Man_{j,i} = \frac{\dfrac{\left(Nyield_{j,i} \times area_{j,i}\right)}{\sum_{i}^{I}\left(Nyield_{j,i} \times area_{j,i}\right)} \times \left(TotN\_Man_{j} - Fneed_{j}\right)}{area_{j,i}}$$

(Equation 14)

where *j* is the NUTS3, *i* is the FSS crop type including fodder crops, *I* the total number of FSS crops including fodder crops, *area* is the crop surface (ha), and *Nyield* is the nitrogen crop yield computed according paragraph 4.1.1 (kg of N), *Fneed* is the fodder need in nitrogen manure computed according Equation 12 (kg of N), and *TotN_man* is the total nitrogen manure computed according to Equation 11 (kg of N).

Concerning phosphorus, in order to ensure that the quantity of phosphorus coming from manure was proportional to that of nitrogen, the phosphorus manure application rate (*P_Man* in kgN/ha) for each NUTS3 *j* was computed considering nitrogen manure application rate (which already includes the distribution assumptions previously illustrated) and the ratio between the estimated total nitrogen and phosphorus manure, according to the following equation:

$$P\_Man_{j,i} = N\_Man_{j,i} \times \frac{TotP\_Man_{j}}{TotN\_Man_{j}}$$

(Equation 15)

where *j* is the NUTS3, *i* is the crop including fodder crops, *TotN_man* is the total nitrogen manure (kg of N), and *TotP_man* is the total phosphorus manure (kg of P).

Once established the nitrogen and phosphorus manure rate per NUTS3 and per crop type, the maps of nitrogen and phosphorus manure input were created as raster of 1ha cell size based on the new land-use map. The Figure 4.8 and Figure 4.9 show the distribution of manure application rate on agricultural land across EU15 according to the estimated maps. The maps are presented in Paragraph 4.2.2.

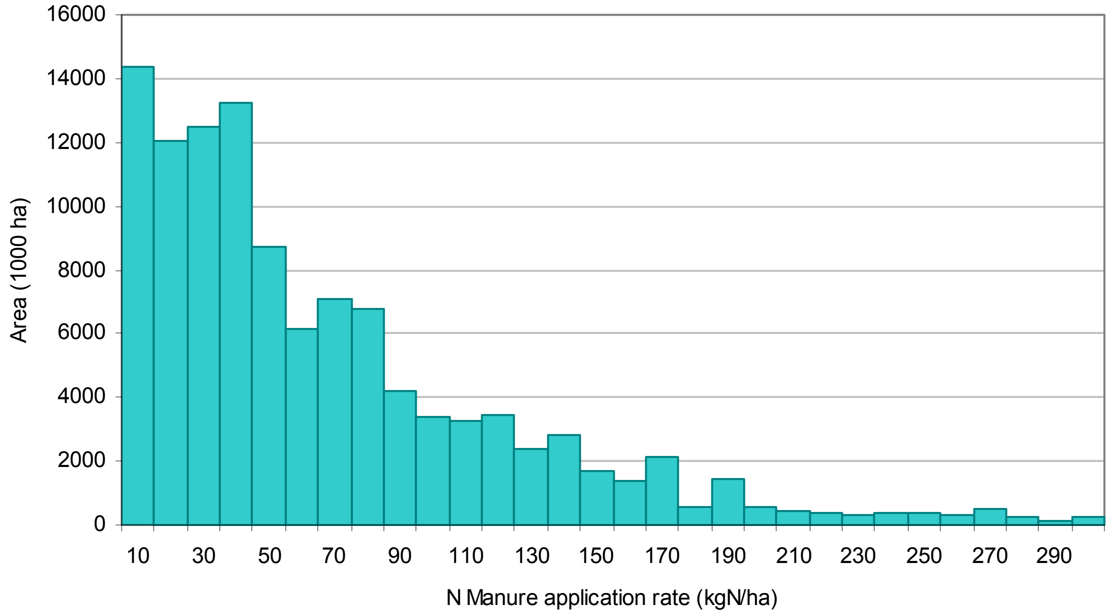


Figure 4.8 Distribution of nitrogen manure application rate on agricultural land across EU15.

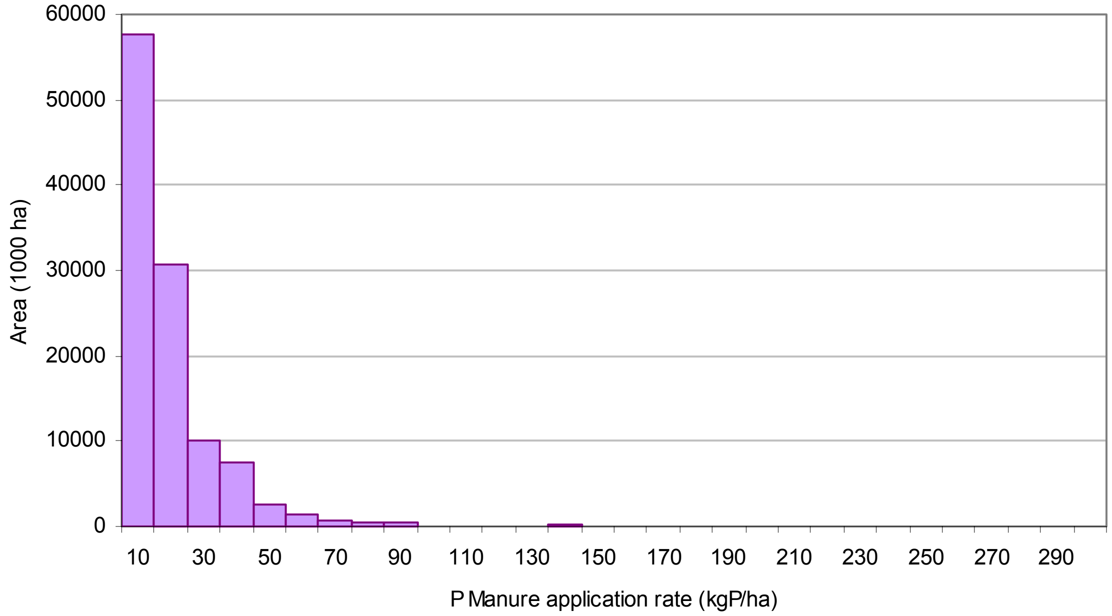


Figure 4.9 Distribution of phosphorus manure application rate on agricultural land across EU15.

4.1.6 National gross nutrient balance

Figure 4.10 and Figure 4.11 show for EU15 countries the total and average gross nitrogen balance, respectively, obtained in this study. Higher values of nitrogen surplus per agricultural area (Figure 4.11) are present in the Netherlands, Belgium, Denmark and Germany. These countries are, however, among those adopting more advanced agriculture techniques and management plans to reduce nitrogen losses in air and water.

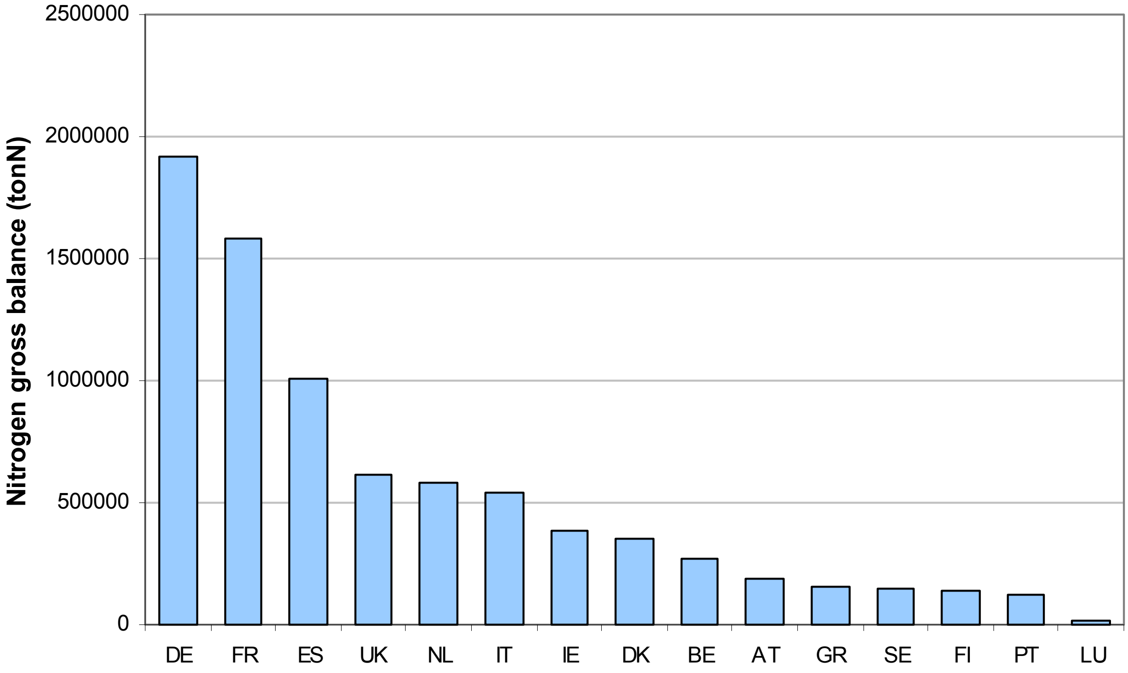


Figure 4.10 Total gross nitrogen balance for EU15 countries.

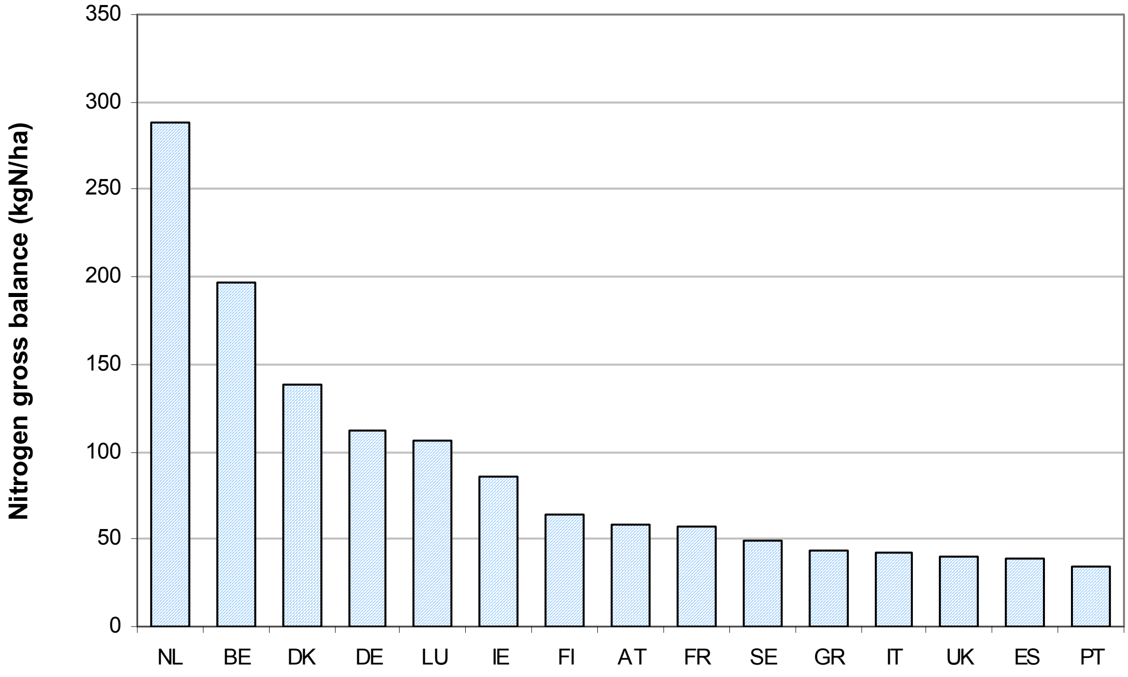


Figure 4.11 Average gross nitrogen balance per agricultural area for EU15 countries.

Similarly, Figure 4.12 and Figure 4.13 show for EU15 countries the total and average gross balance, respectively, estimated for phosphorus. The Netherlands and Belgium present greater values of phosphorus surplus per agricultural area, while all the other countries take values between 3 and 13 kg P/ha (Figure 4.13).

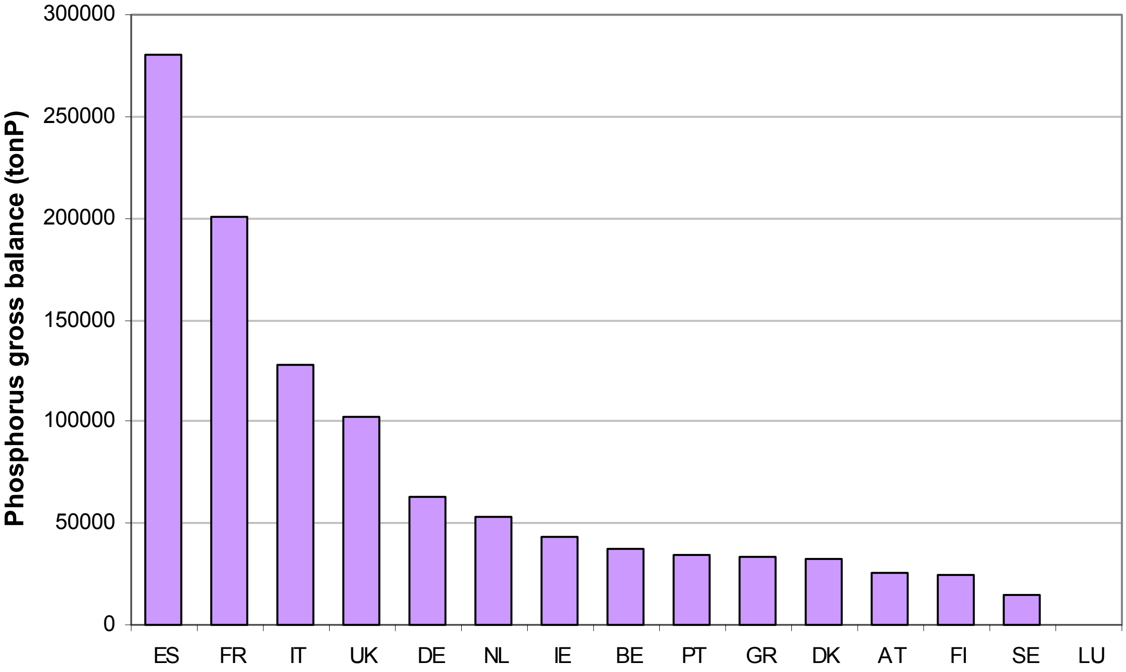


Figure 4.12 Total gross phosphorus balance for EU15 countries.

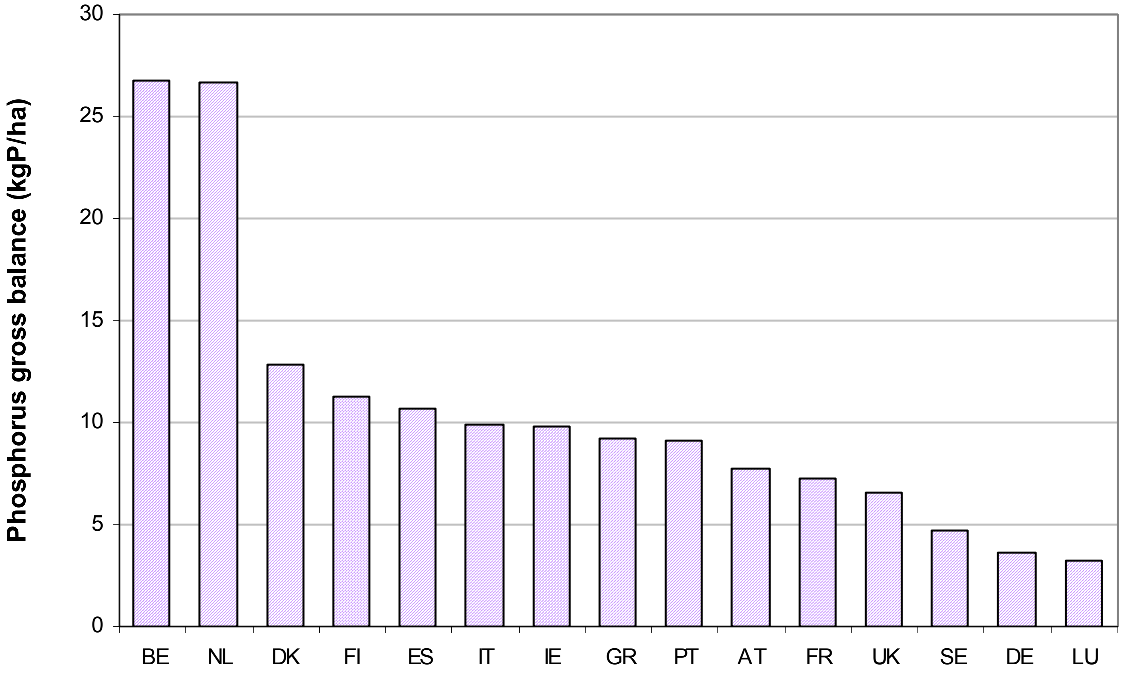


Figure 4.13 Average gross phosphorus balance per agricultural area for EU15 countries.

The results of this study were compared with the values reported by IRENA 18 indicator (EEA, 2005). Major discrepancies were found for Denmark, France, Greece, Ireland and the Netherlands (Figure 4.14 and Figure 4.15). The mismatches for France, Greece and Ireland are possibly due to differences in the agricultural area considered, while for the other countries the differences are probably the result of different agronomic coefficients used.

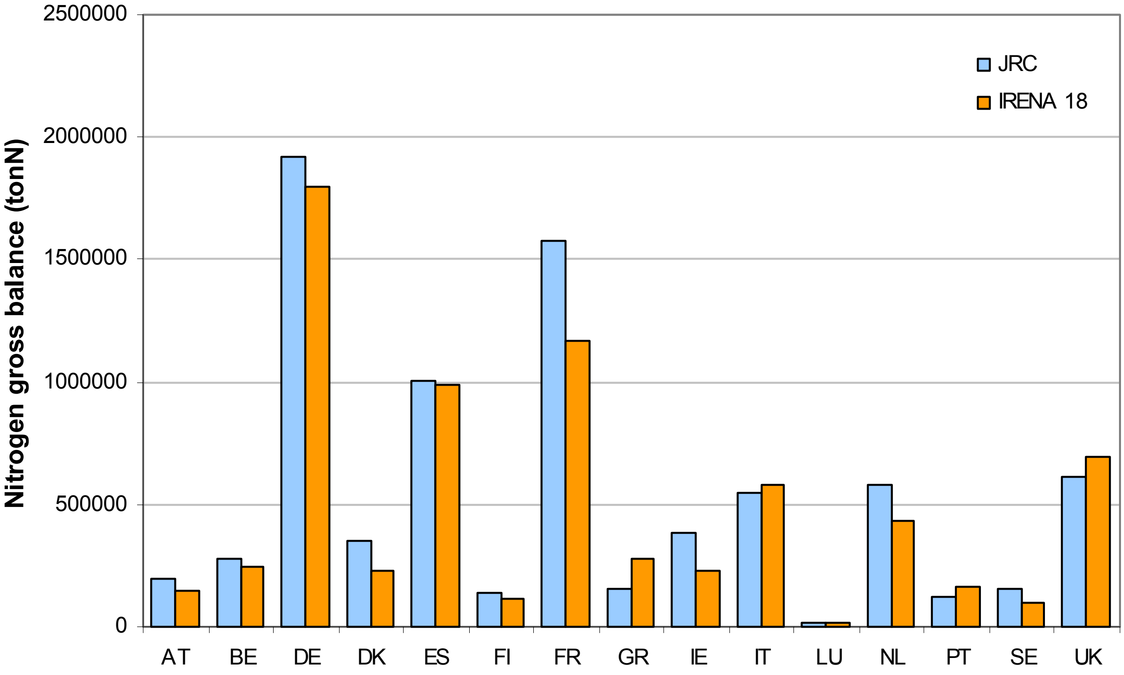


Figure 4.14 Total gross nitrogen balance for EU15 countries, according to this study (blue) and to IRENA 18 estimation (orange).

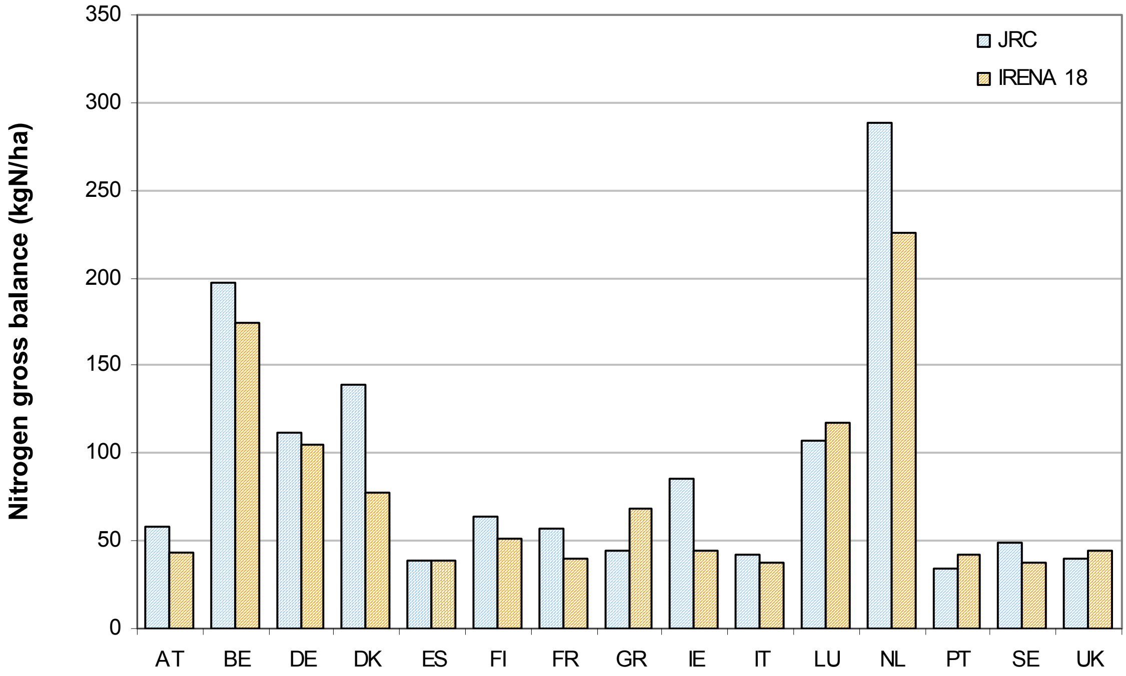


Figure 4.15 Average gross nitrogen balance per agricultural area for EU15 countries, according to this study (blue) and to IRENA 18 estimation (orange).

4.2 European maps of nutrient pressures

Spatial maps of nitrogen and phosphorus input and losses (the terms of Equations 9 and 10) were created as raster of 100 m grid size (1 ha grid). Then the values were recalculated on the basis of 10 km grid size (10 km^2 grid) to improve and facilitate the identification of spots and regional patterns at EU scale.

Average values of nutrient input on the 10 km^2 grid were provided both per total surface and per agricultural surface. The first type of map informs on the average nutrient pressure on the area (actual pressure), while the second one indicates the actual amount of nutrient per unit of agricultural area occurring within the 10 km^2 cell (pressure on arable land). The results are presented in the following paragraphs.

4.2.1 European maps of N and P mineral fertiliser input

Figure 4.16 and Figure 4.17 illustrate the European map of nitrogen mineral fertiliser input estimated per total surface and per agricultural area, respectively. Similarly, Figure 4.18 and Figure 4.19 present the European map of phosphorus mineral fertiliser input estimated per total surface and per agricultural area, respectively. Following, the distribution of the fertiliser application rate per country correspondent to the maps is shown in Figure 4.20 and Figure 4.21 for nitrogen, and in Figure 4.22 and Figure 4.23 for phosphorus.

Higher values of mineral fertiliser application are observed for nitrogen in Eastern UK, the Netherlands, Belgium, Germany, Seine basin (FR), Po valley (IT) and part of Greece (Figure 4.17), and for phosphorus in Eastern part of Ireland and UK, Northern part of the Netherlands, in the Seine basin and Aquitaine region in France, in Po valley and Adriatic coast in Italy, partially in Portugal, Castillia Leon, Andalusia and Catalunia in Spain, and in some spots in Greece (Figure 4.19). The median of the applications varies from 178 kg N/ha in the Netherlands to 34 kg N/ha in Austria (Figure 4.21), and from 14 kg P/ha in France and Belgium to 6 kg P/ha in Sweden (Figure 4.23).

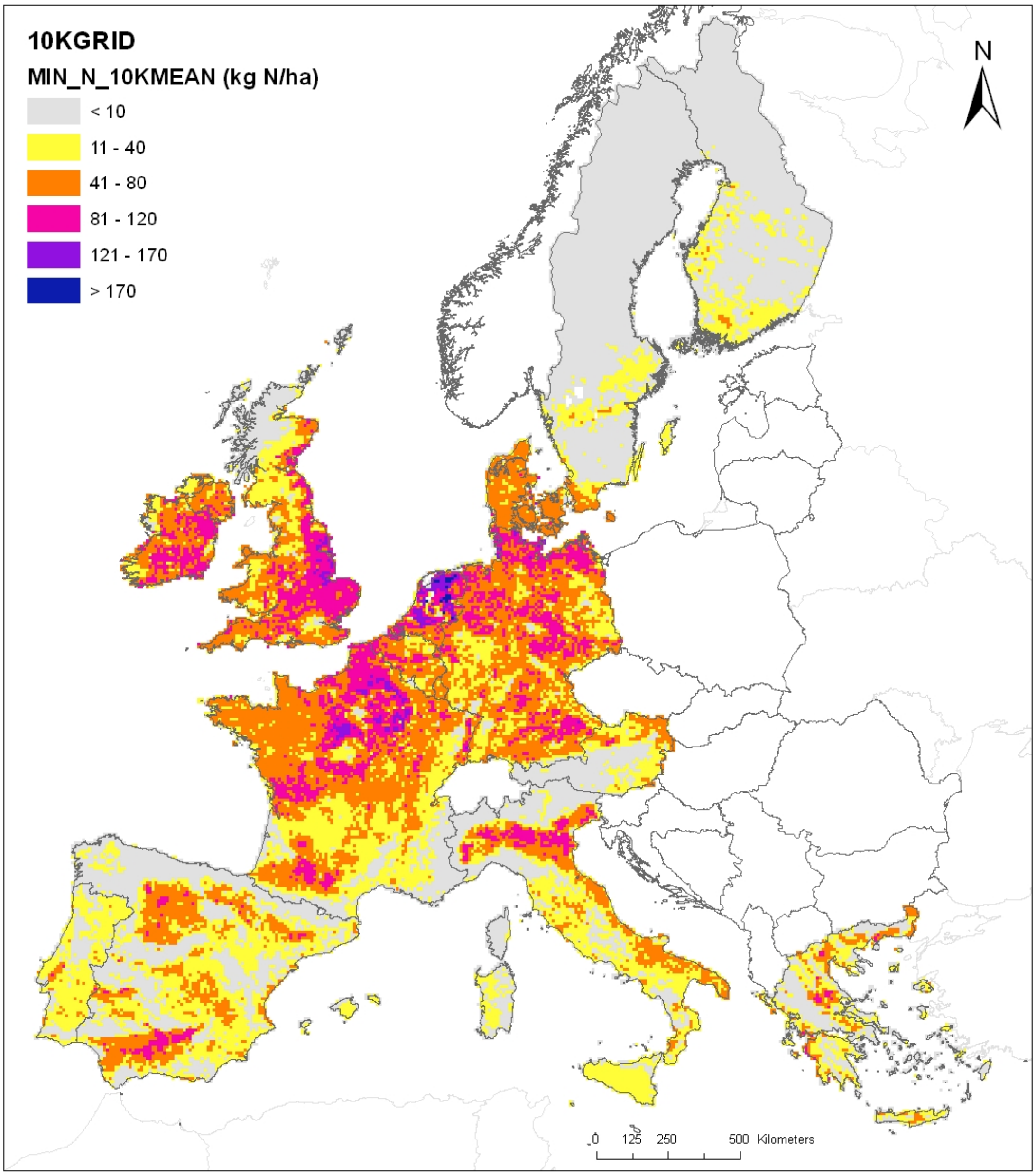


Figure 4.16 European map of nitrogen mineral fertiliser input per total surface in EU15, average on 10 km^2 area.

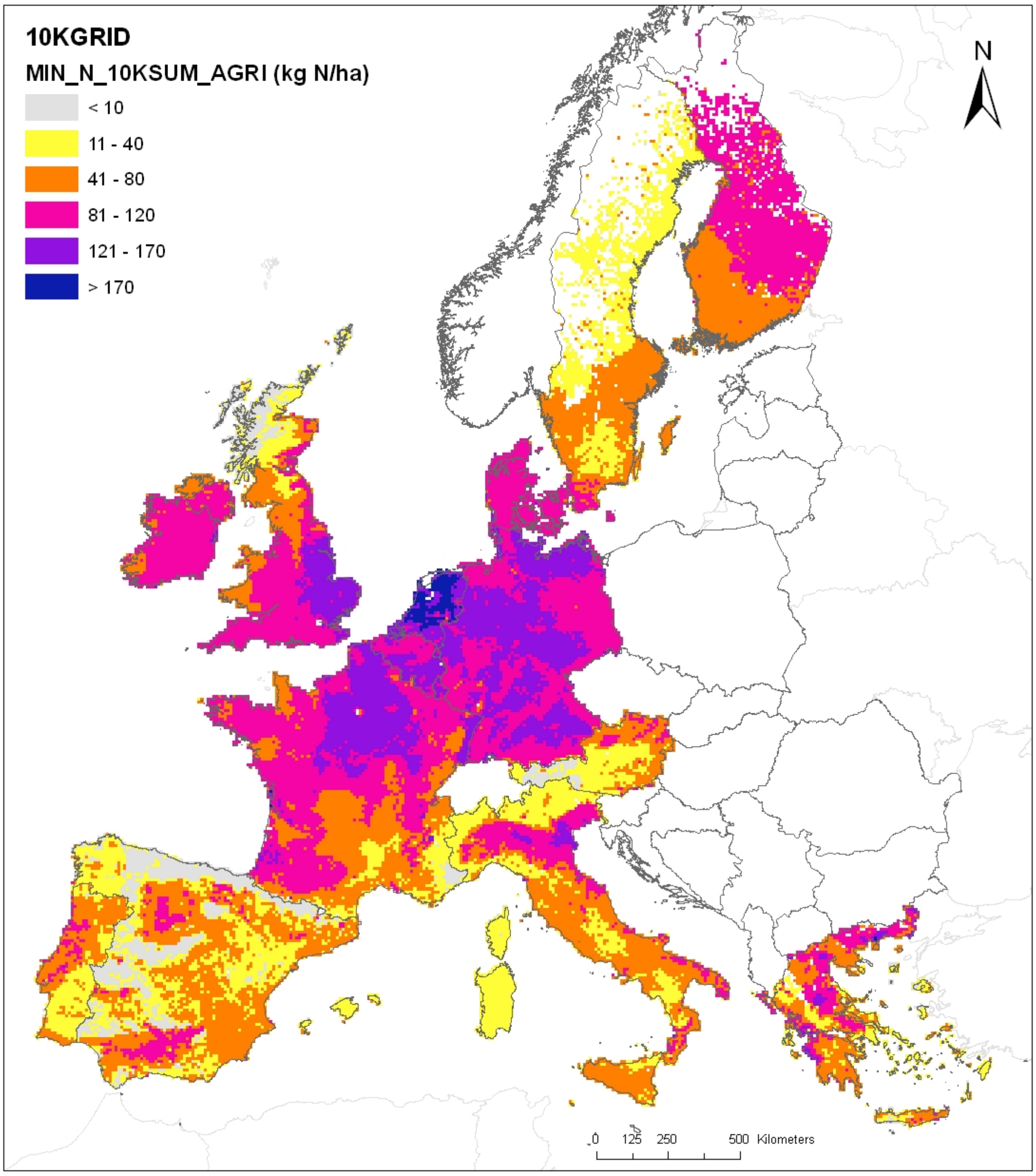


Figure 4.17 European map of nitrogen mineral fertiliser input per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

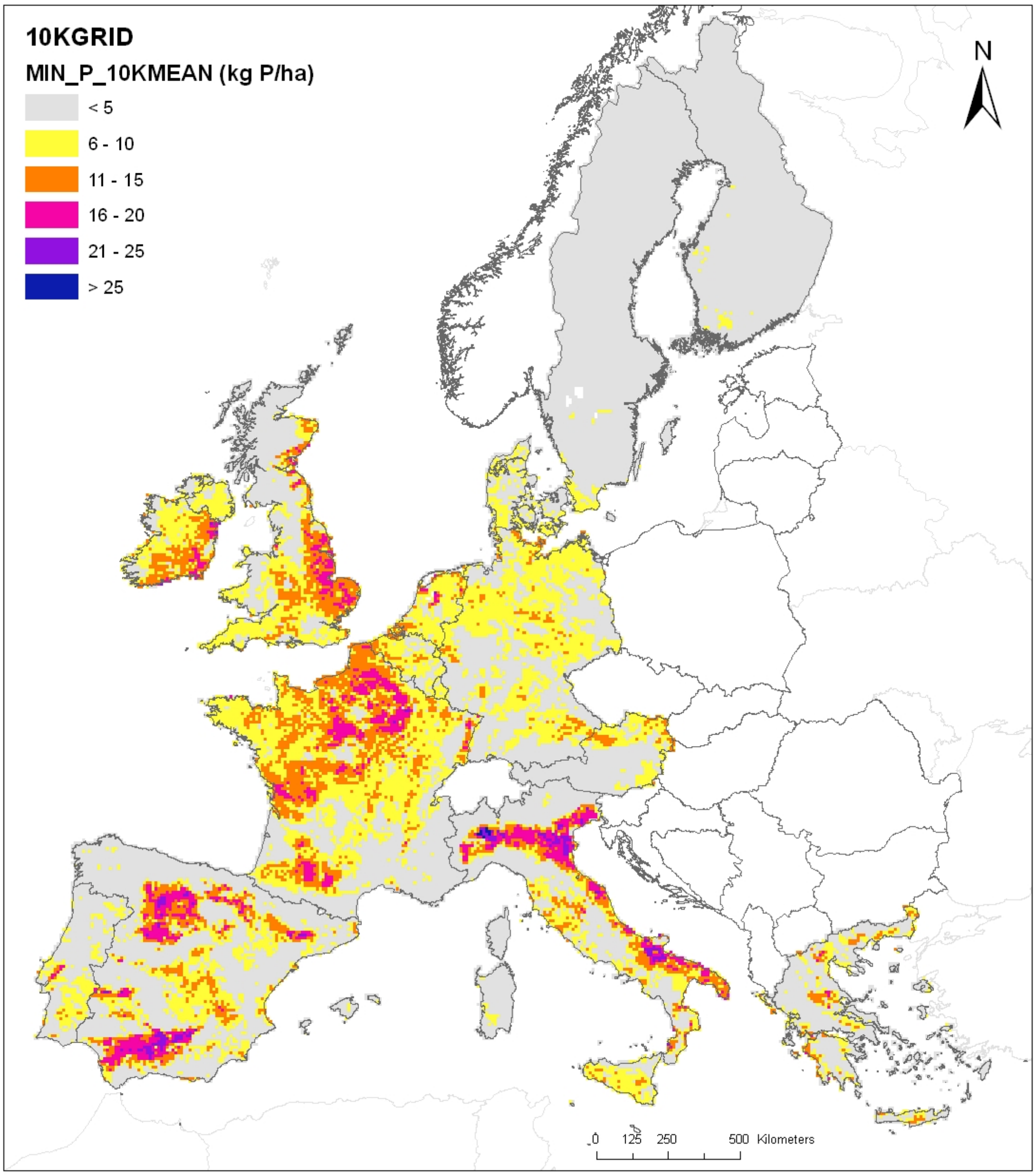


Figure 4.18 European map of phosphorus mineral fertiliser input per total surface in EU15, average on 10 km^2 area.

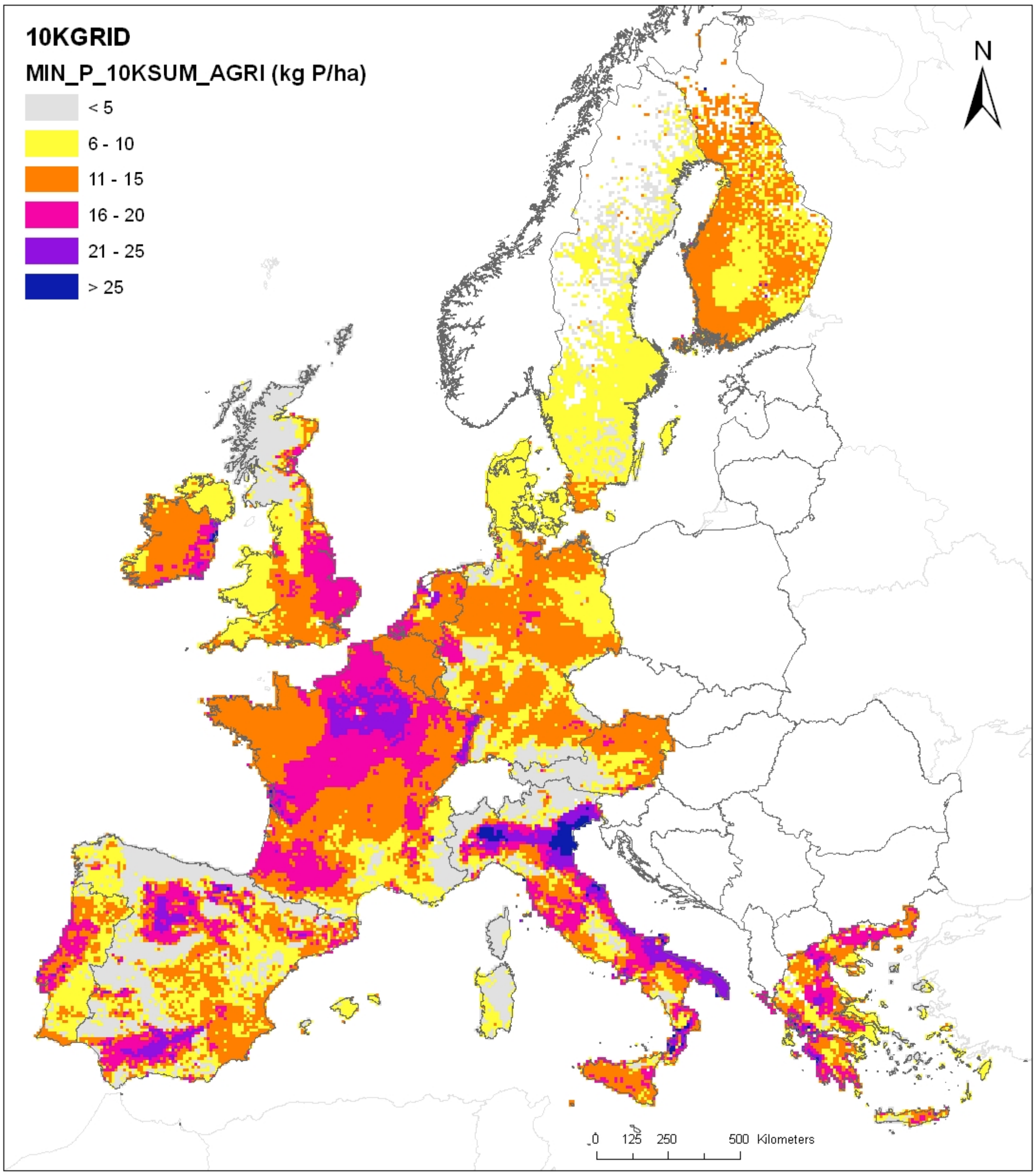


Figure 4.19 European map of phosphorus mineral fertiliser input per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

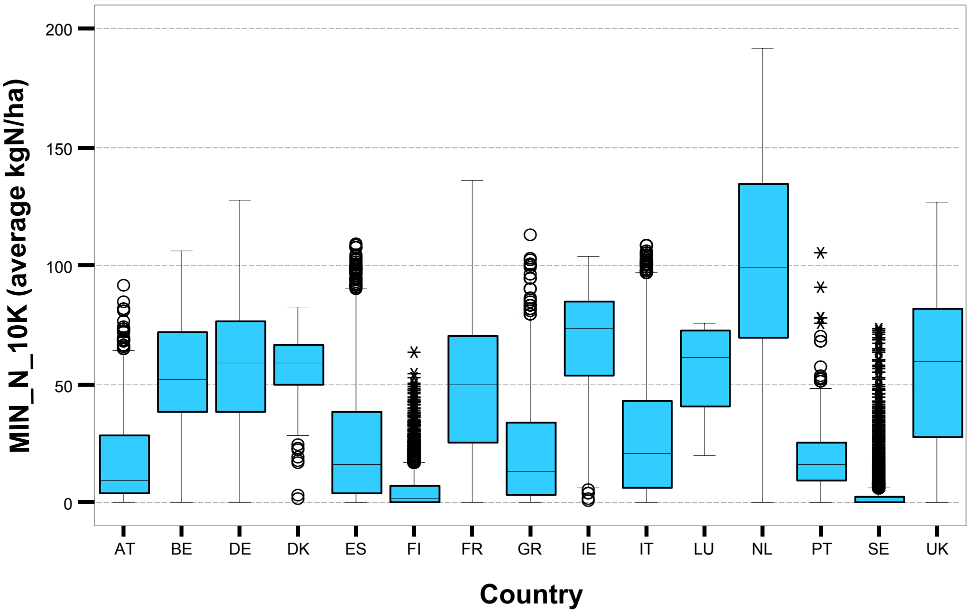


Figure 4.20 Distribution of nitrogen mineral fertiliser input per total surface for each EU15 country according to the 10 km^2 grid map.

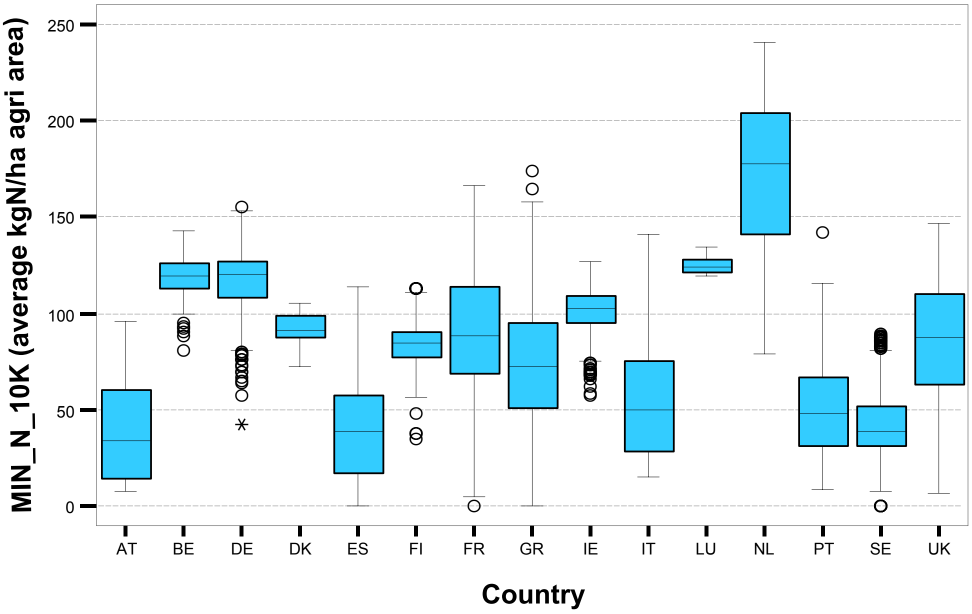


Figure 4.21 Distribution of nitrogen mineral fertiliser input per agricultural area for each EU15 country according to the 10 km^2 grid map.

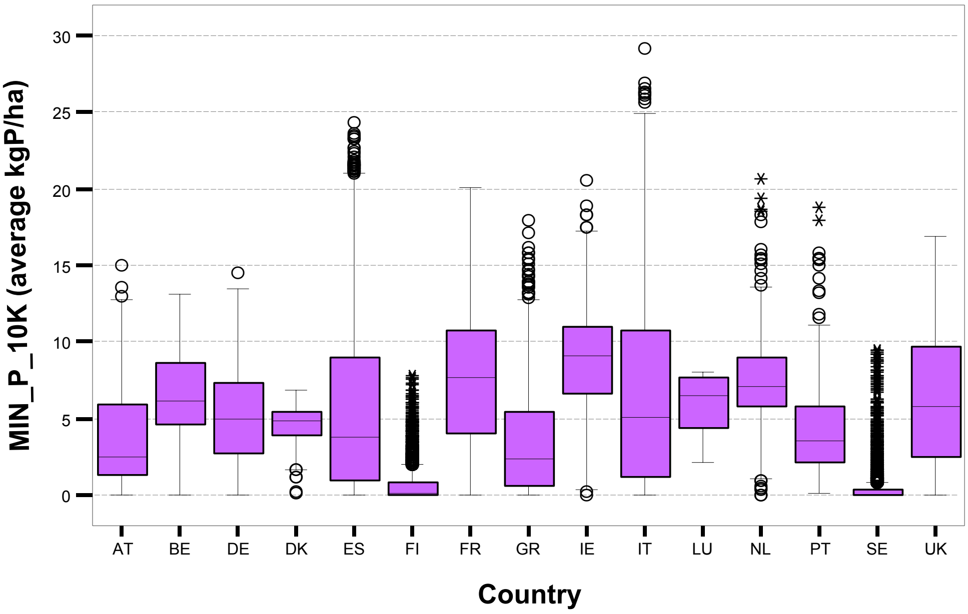


Figure 4.22 Distribution of phosphorus mineral fertiliser input per total surface for each EU15 country according to the 10 km^2 grid map.

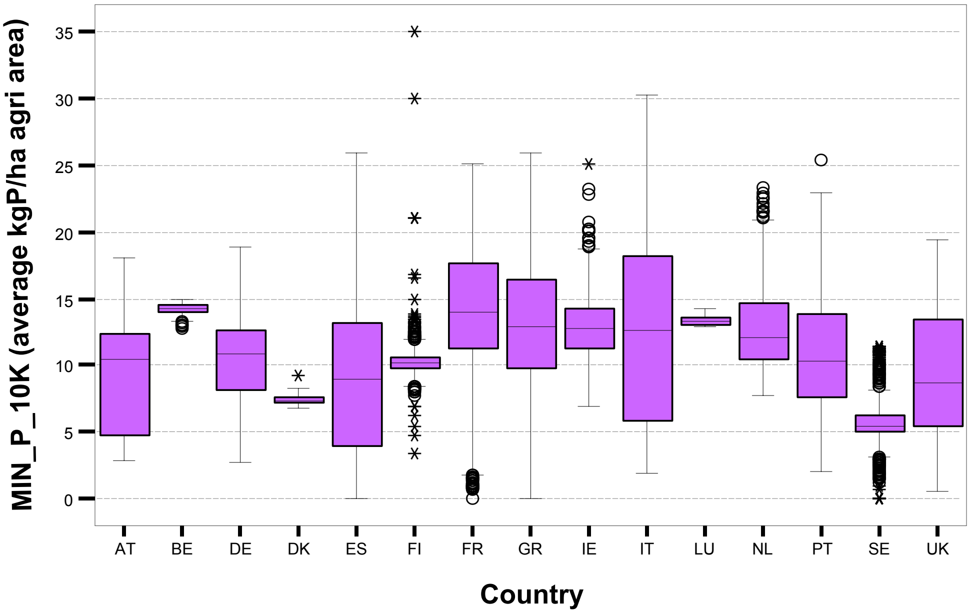


Figure 4.23 Distribution of phosphorus mineral fertiliser input per agricultural area for each EU15 country according to the 10 km^2 grid map.

4.2.2 European maps of N and P manure input

The European maps of nutrient manure input per total surface and per agricultural surface (Figure 4.24, Figure 4.25, Figure 4.26 and Figure 4.27) show that in Europe (EU15) the greater inputs are located in Ireland, western UK, The Netherlands, Belgium, Denmark, South and North-west Germany, Brittany region in France, Northern Italy, Cataluna and Galicia regions in Spain, Western part of Portugal and of Greece, both for nitrogen and for phosphorus.

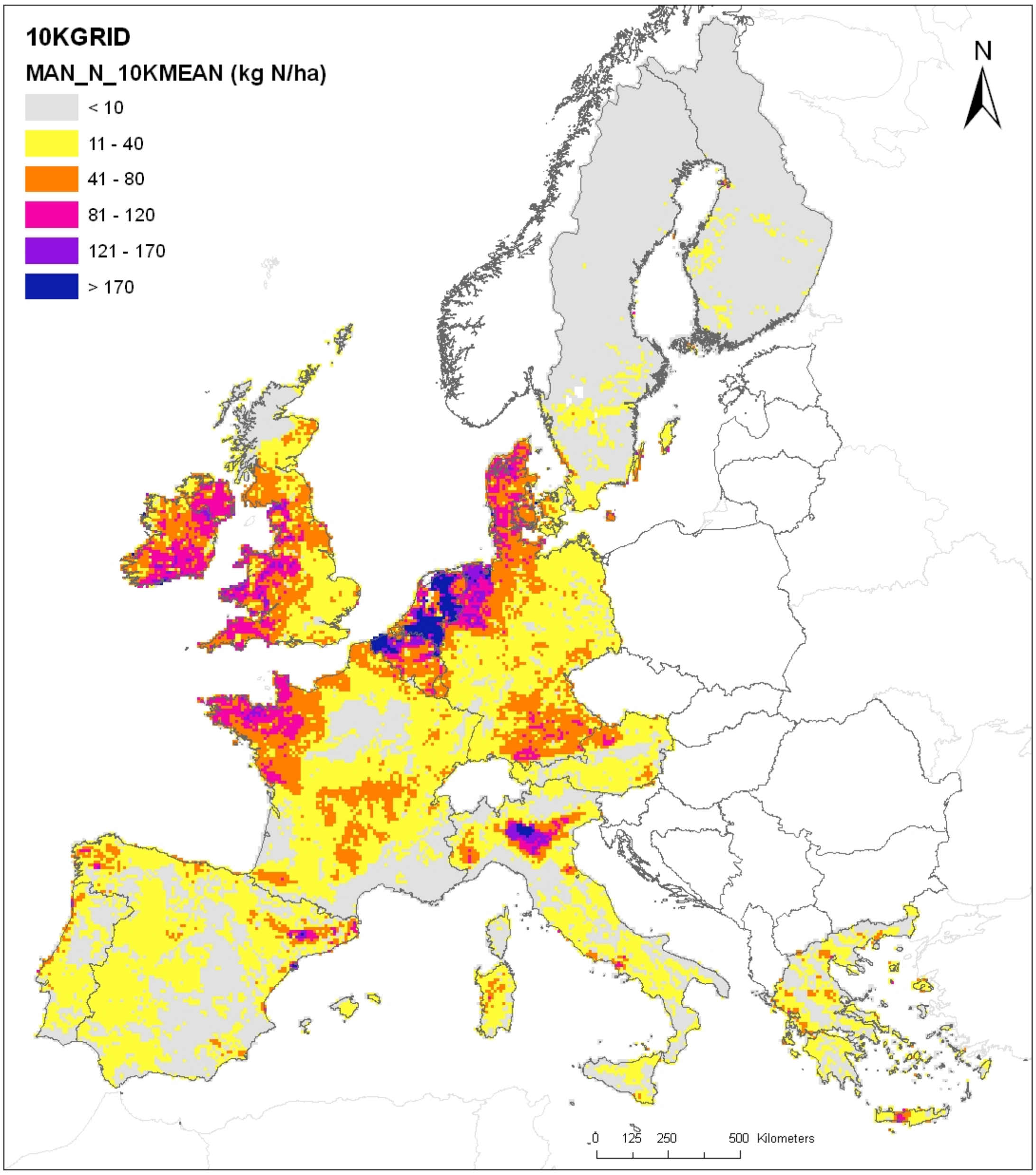


Figure 4.24 European map of nitrogen manure input per total surface in EU15, average on 10 km^2 area.

The average manure application (5% Trimmed mean) per EU15 is 58 kg N/ha per nitrogen and 12 kg P/ha per phosphorus, with higher values applied in Nederland and Belgium. The description of the distribution of average nitrogen and phosphorus manure input per total surface and per agricultural surface according to the 10 km^2 grid maps is reported in Figure 4.28, Figure 4.29, Figure 4.30 and Figure 4.31.

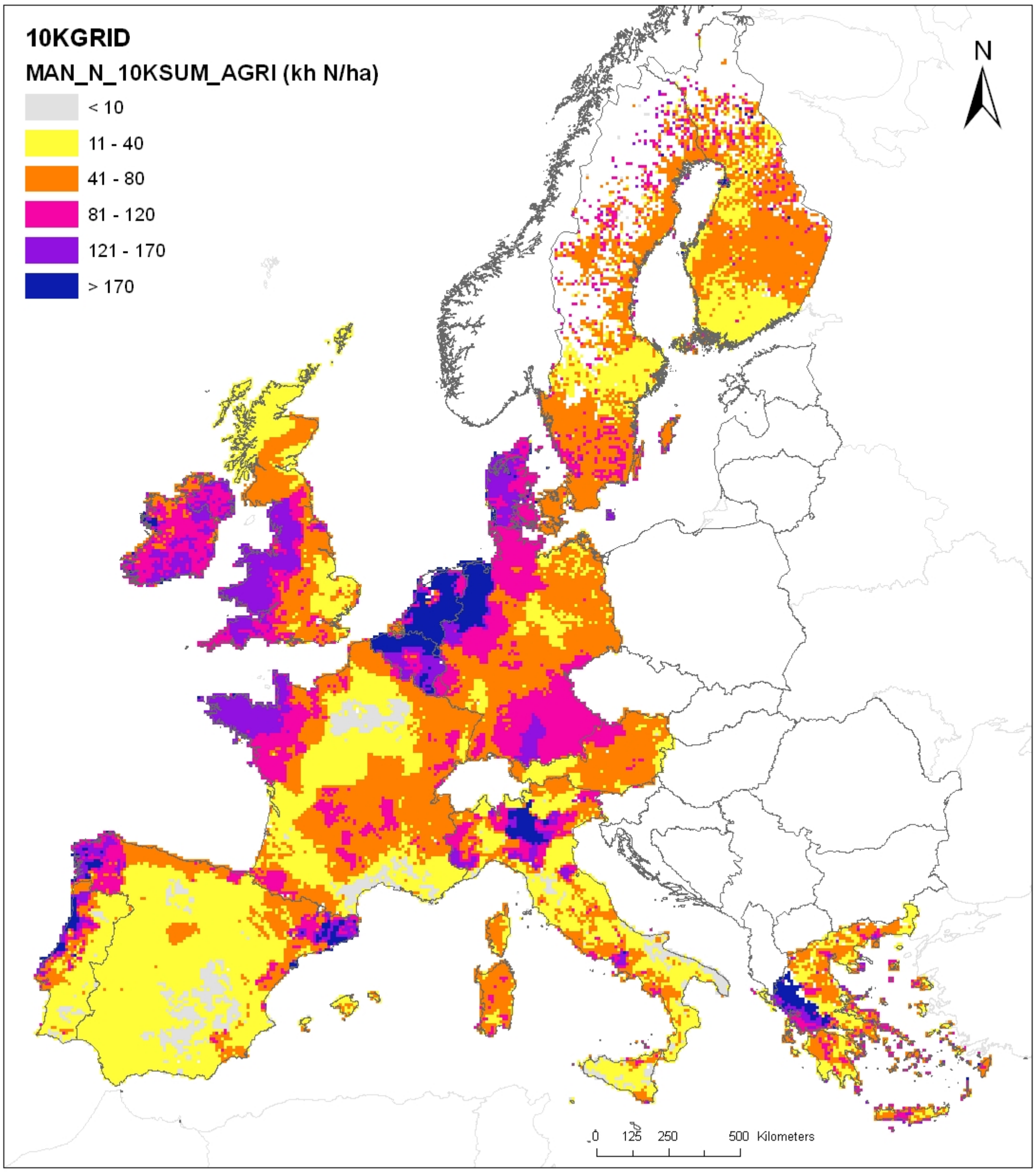


Figure 4.25 European map of nitrogen manure input per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

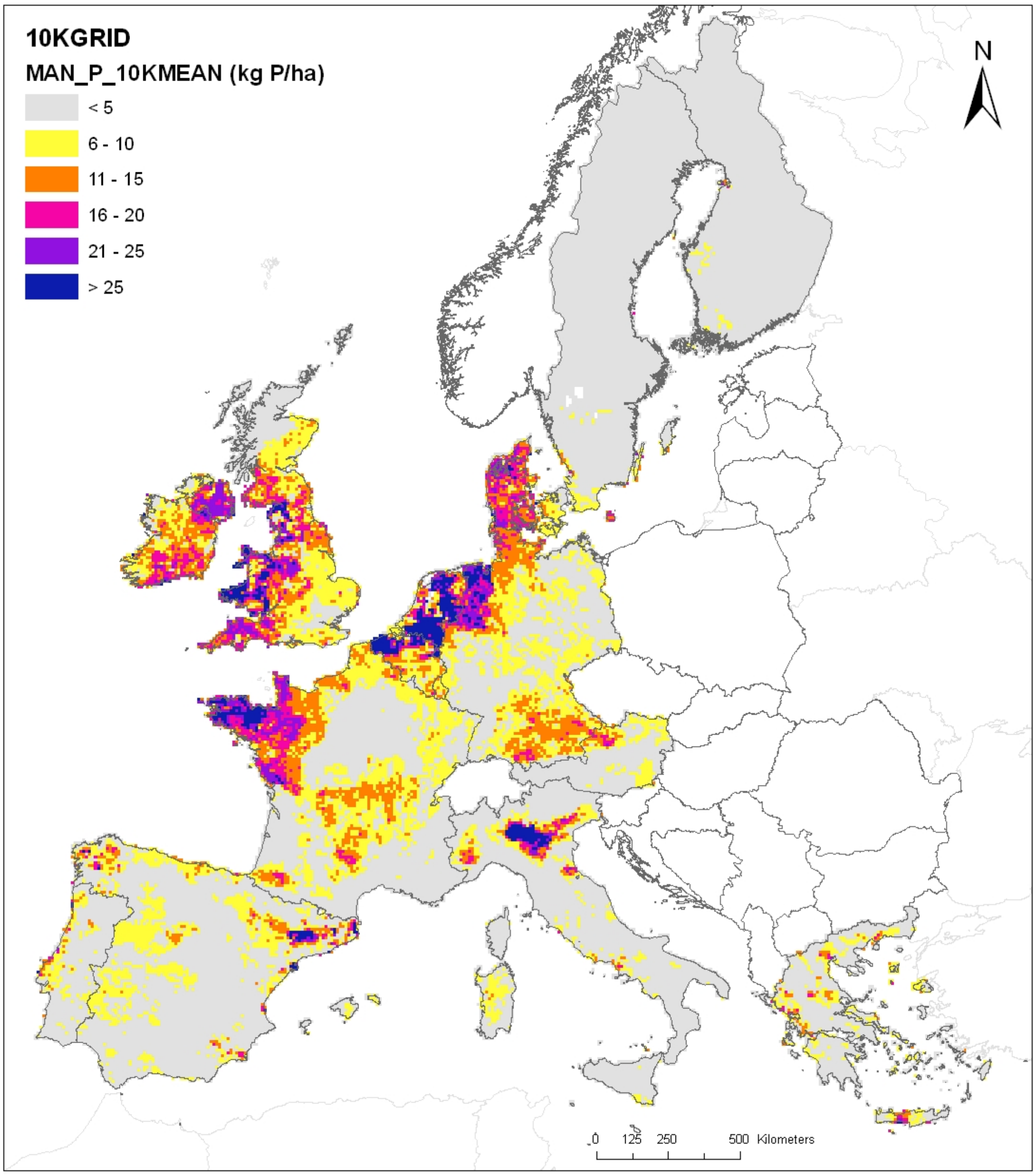


Figure 4.26 European map of phosphorus manure input per total surface in EU15, average on 10 km^2 area.

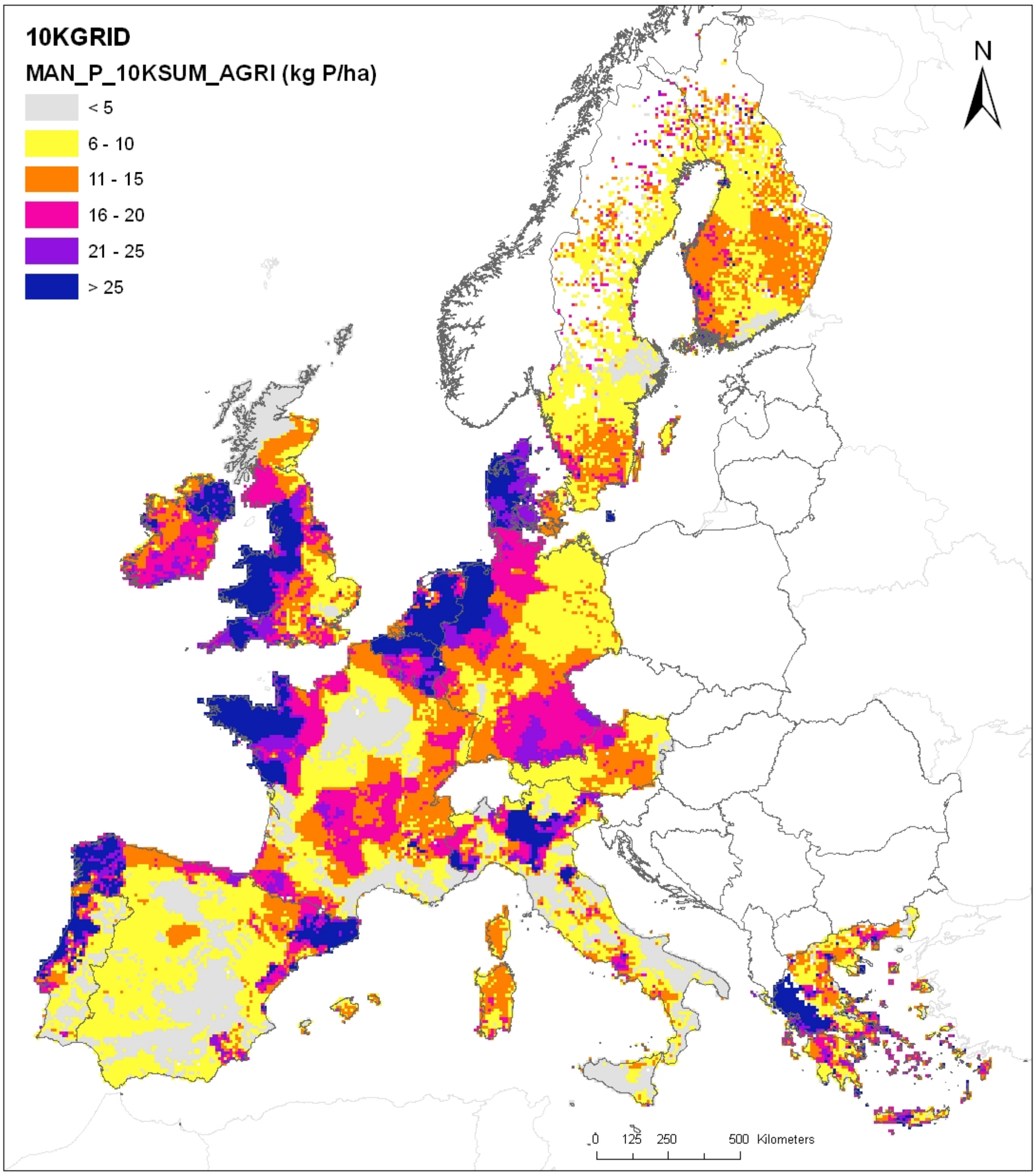


Figure 4.27 European map of phosphorus manure input per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

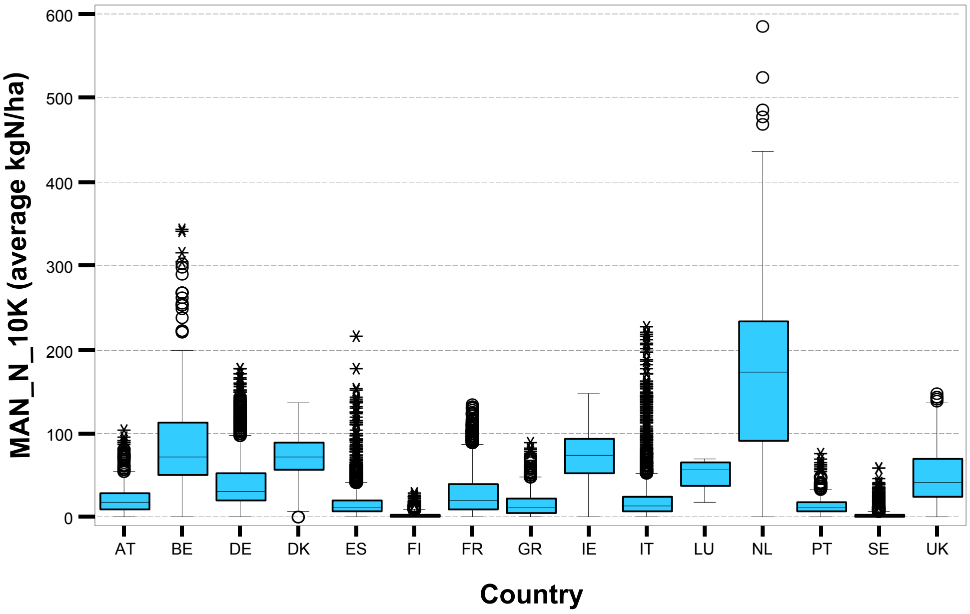


Figure 4.28 Distribution of nitrogen manure input per total surface for each EU15 country according to the 10 km^2 grid map.

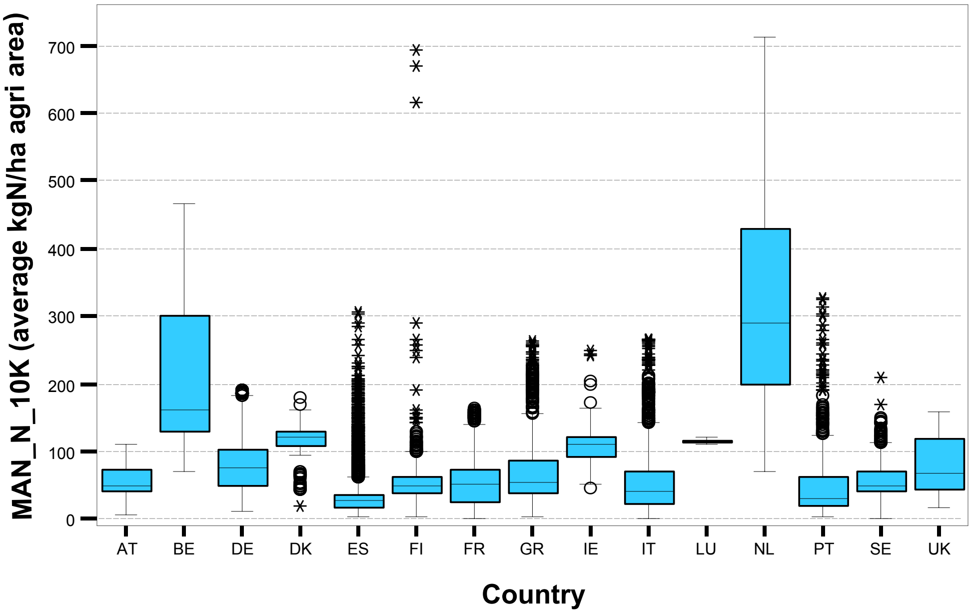


Figure 4.29 Distribution of nitrogen manure input per agricultural area for each EU15 country according to the 10 km^2 grid map.

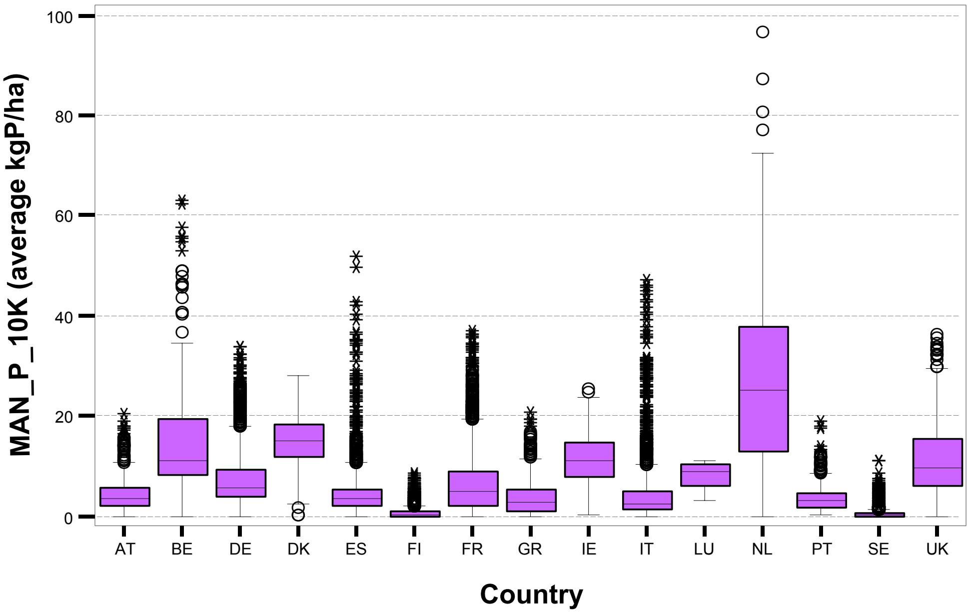


Figure 4.30 Distribution of phosphorus manure input per total surface for each EU15 country according to the 10 km^2 grid map.

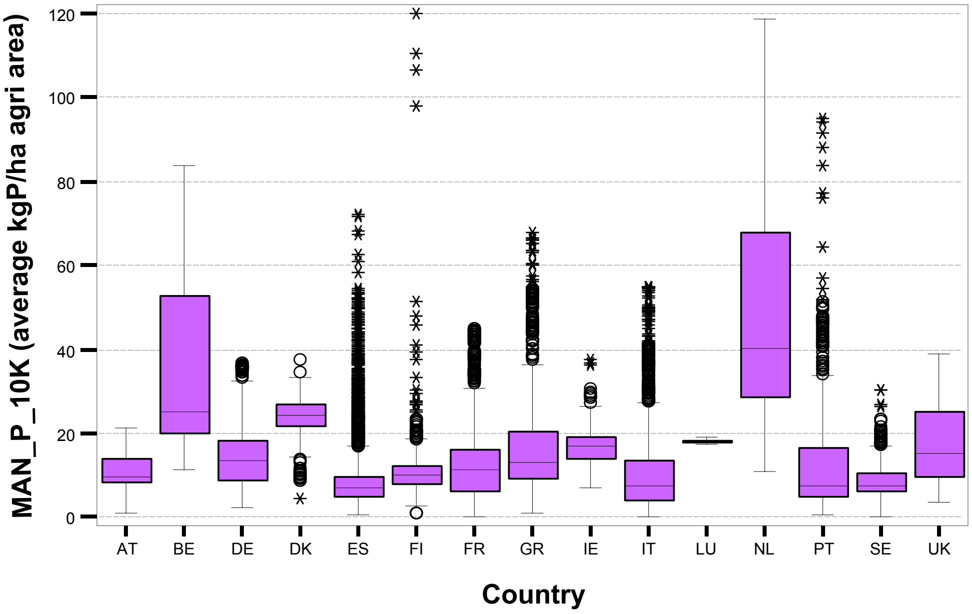


Figure 4.31 Distribution of phosphorus manure input per agricultural area for each EU15 country according to the 10 km^2 grid map.

4.2.3 European maps of N and P agricultural input

Combining the maps of mineral fertiliser and manure input allows to estimate the nitrogen and phosphorus input from agriculture (except nitrogen fixation and deposition) (Figure 4.32, Figure 4.33, Figure 4.34 and Figure 4.35). Maps of input from agriculture per total surface (Figure 4.32 and Figure 4.34) may be use as a proxy for estimating the nutrient pressure on waters in the different European regions. However, these maps indicate areas that are subject to high nutrient input but not necessarily that are characterised by high nutrient pollution. In fact, also other factors must be considered to assess the nutrient losses into soils and waters, such as soils, sub-soils, topography, aquifer characteristics, climate conditions (precipitation, temperature, humidity, wind, etc.), and agricultural management practices.

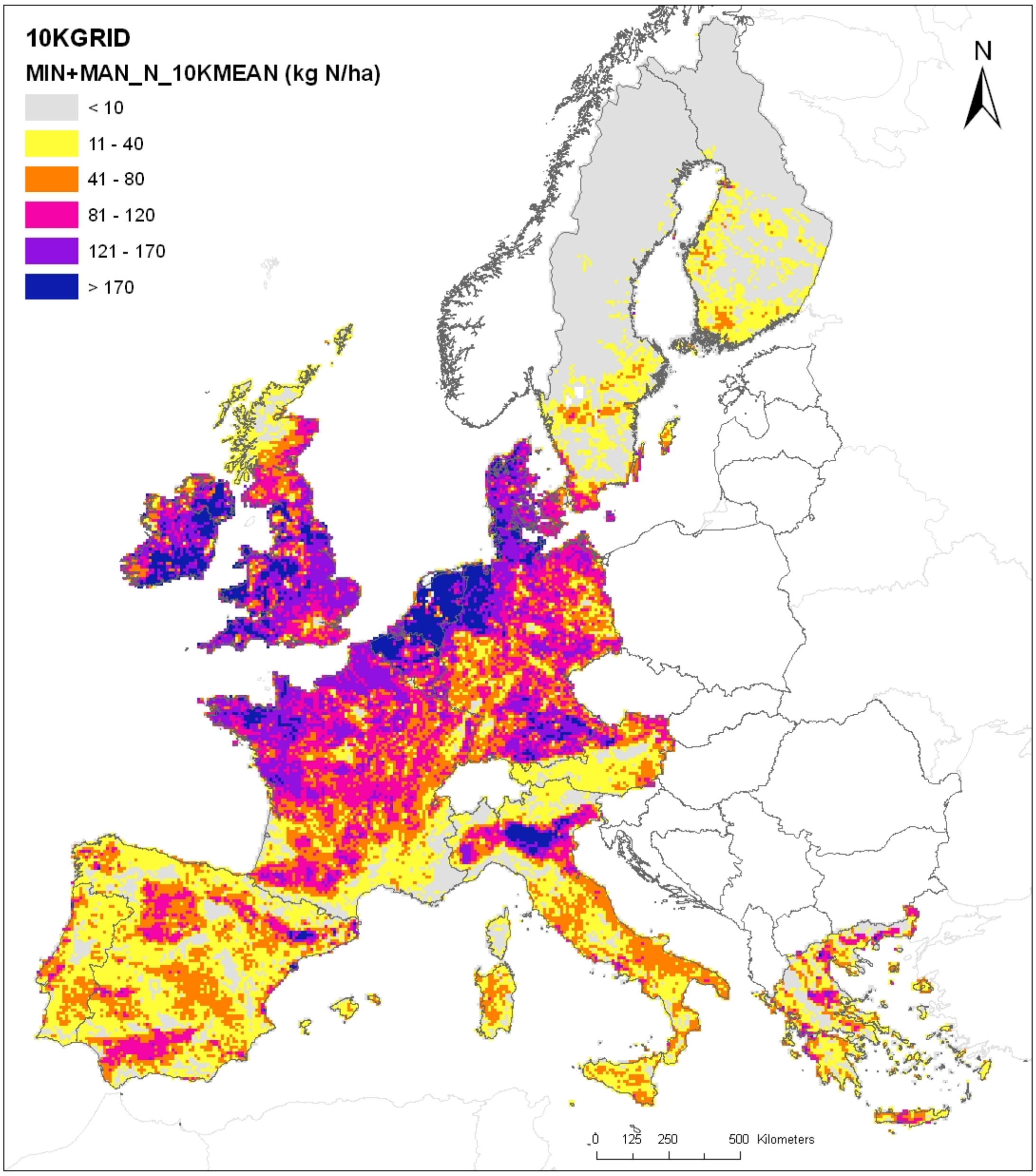


Figure 4.32 European map of nitrogen total agricultural input (mineral fertiliser + manure) per total surface in EU15, average on 10 km^2 area.

High nutrient inputs from agriculture are present in Ireland, England and Wales, Nederland, Belgium Denmark, North-Western and Southern Germany, Brittany region and Seine basin in France, Po valley in Italy, Cataluna, Castilia Leon, Andalusia and Galicia region in Spain, Tejo valley in Portugal, Tessalia and other small spots in Greece.

Except for Netherlands, Belgium and Italy, where higher input can locally occur, in the other countries the inputs from agriculture per total surface are lower than 300 kg N/ha and 75 kg P/ha, for nitrogen and phosphorus, respectively, and lower than 150 kg N/ha and 25 kg P/ha when considering the inter-quartile values (values between the 25th and the 75th ranked value) (Figure 4.36 and Figure 4.38). Obviously, input values increase when referring to agricultural area (Figure 4.37 and Figure 4.39).

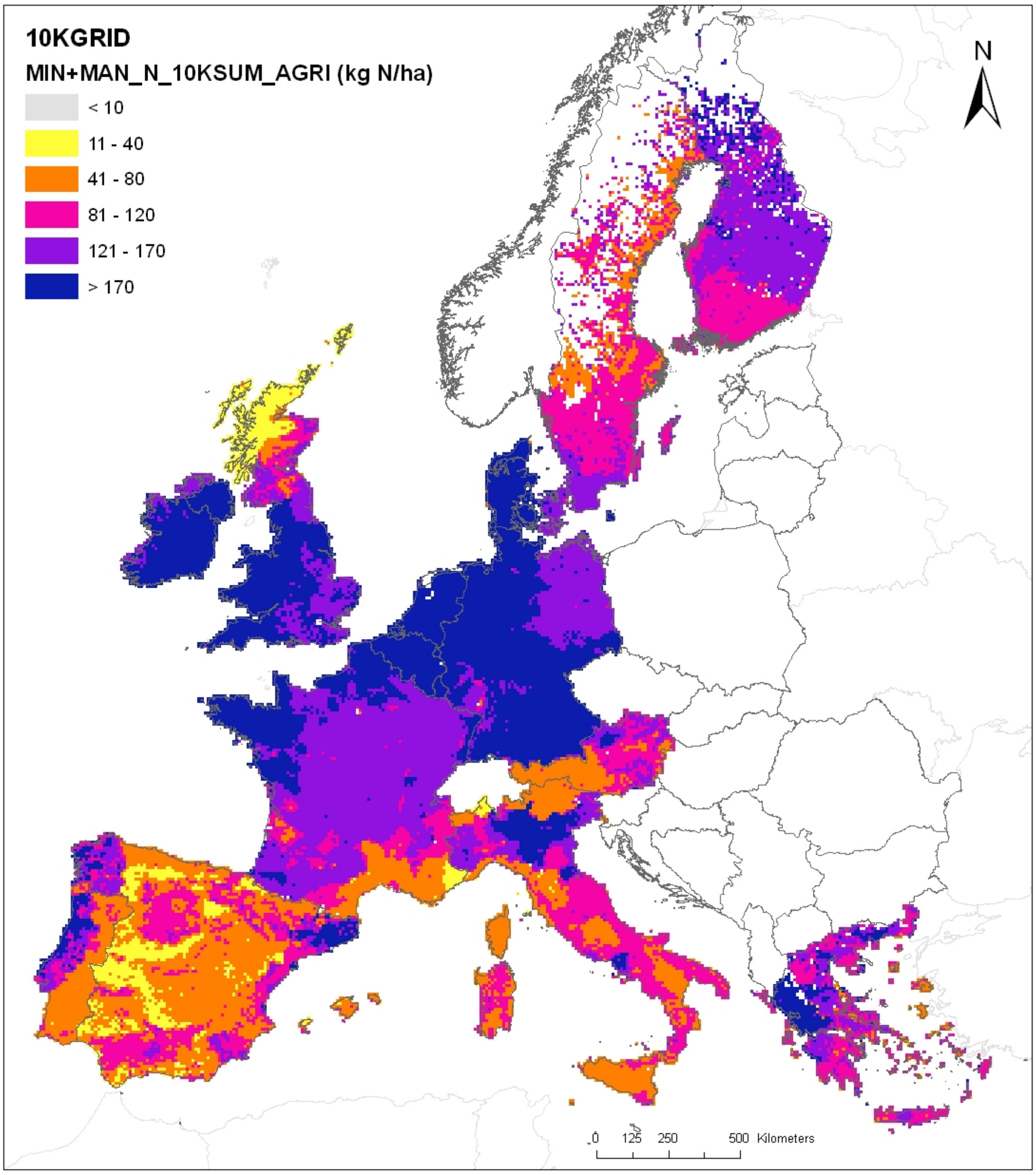


Figure 4.33 European map of nitrogen total agricultural input (mineral fertiliser + manure) per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

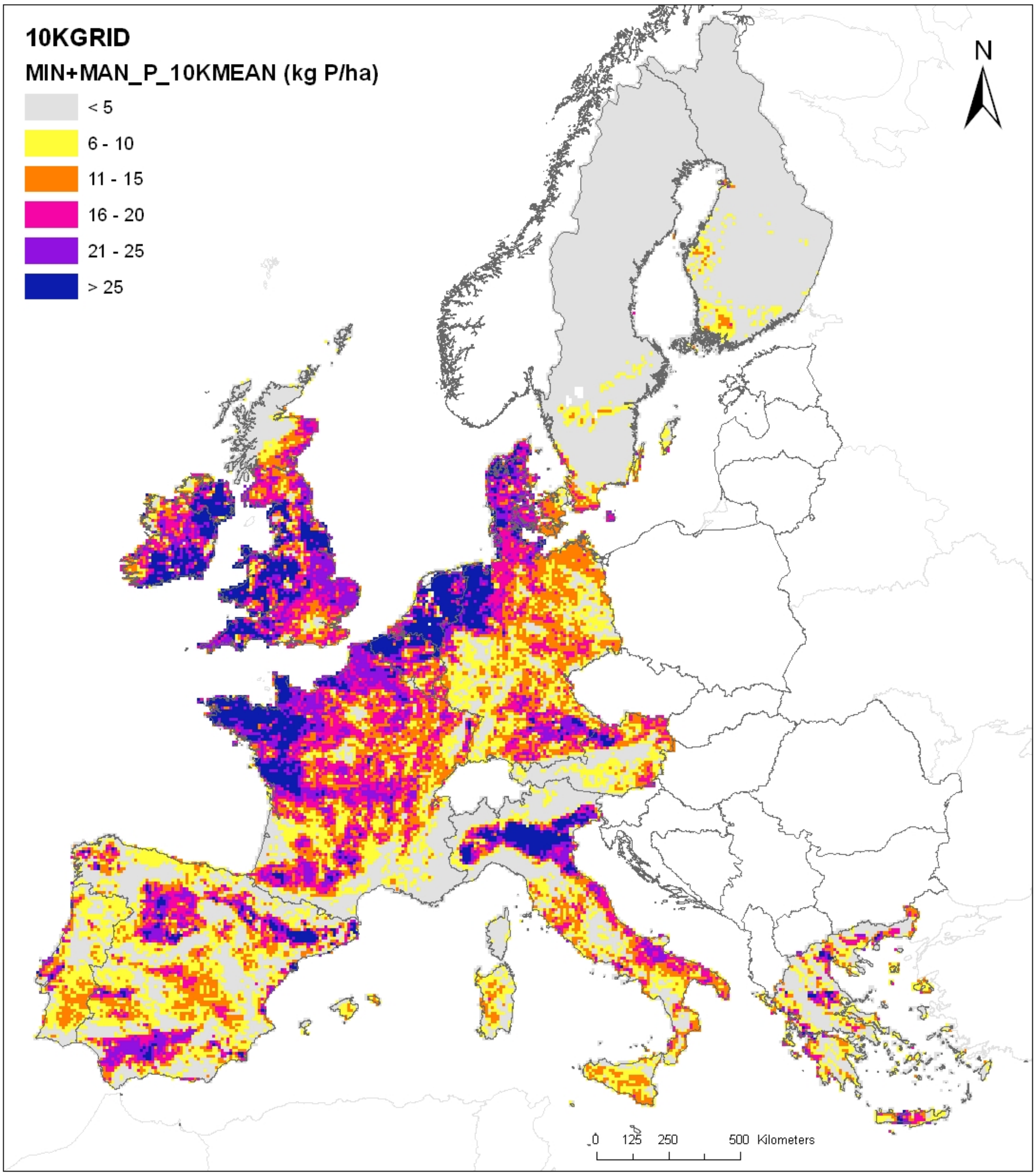


Figure 4.34 European map of phosphorus total agricultural input (mineral fertiliser + manure) per total surface in EU15, average on 10 km^2 area.

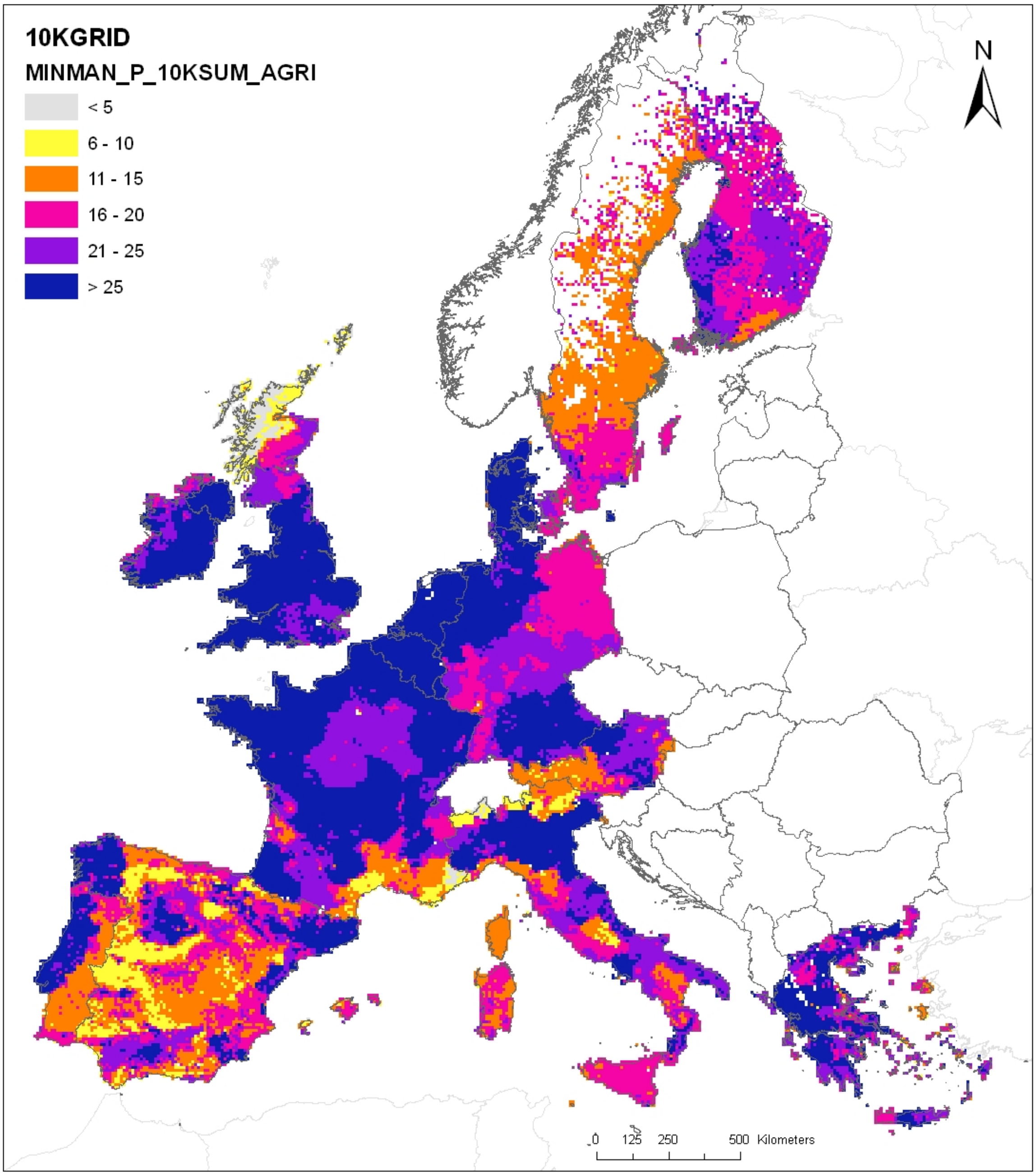


Figure 4.35 European map of phosphorus total agricultural input (mineral fertiliser + manure) per agricultural area in EU15, average on 10 km^2 area. (In Sweden and Finland the white colour indicates the absence of agricultural land within the 10 km^2 area).

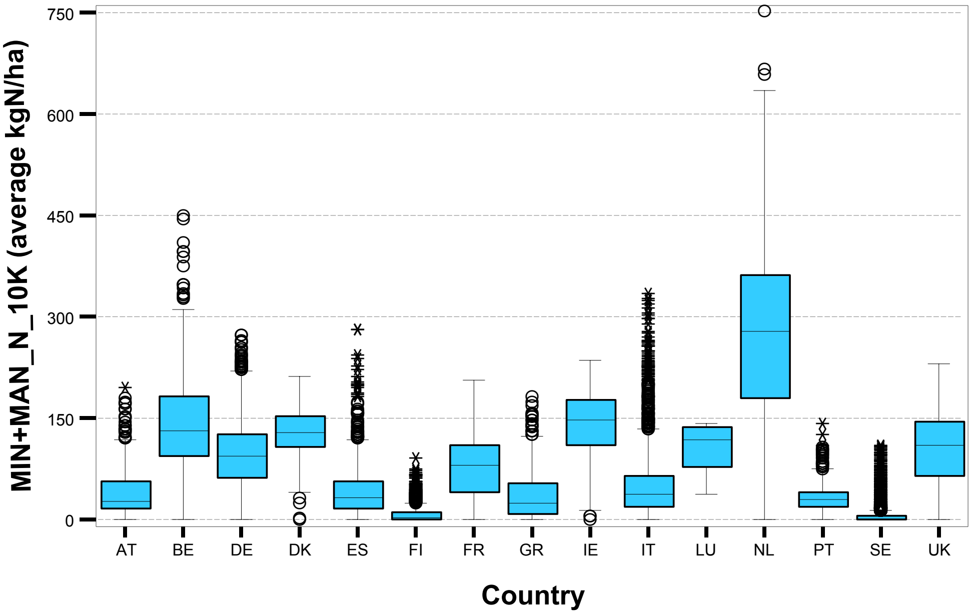


Figure 4.36 Distribution of nitrogen total agricultural input (mineral fertiliser + manure) per total surface for each EU15 country according to the 10 km grid map.

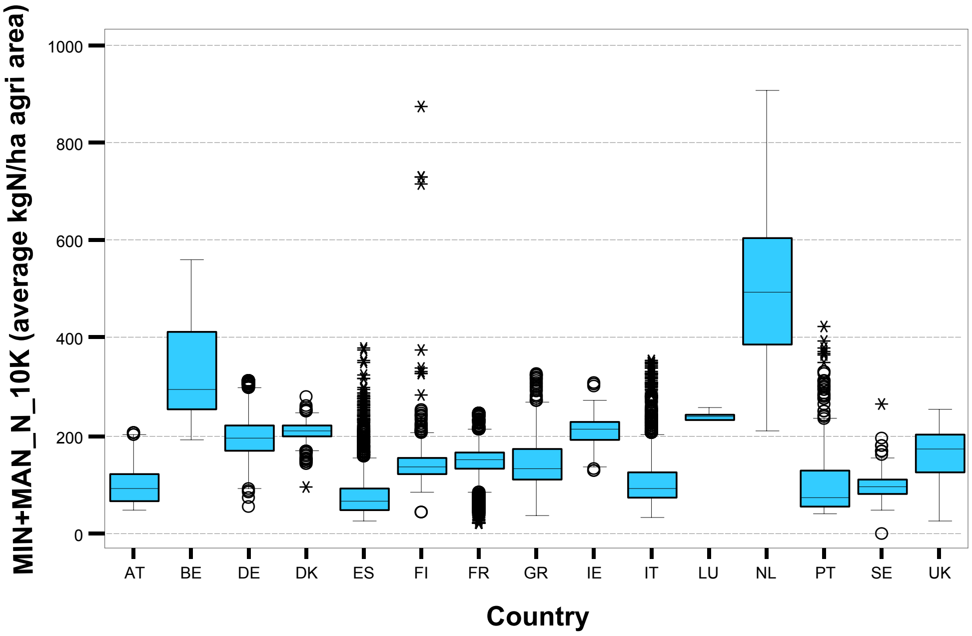


Figure 4.37 Distribution of nitrogen total agricultural input (mineral fertiliser + manure) per agricultural area for each EU15 country according to the 10 km grid map.

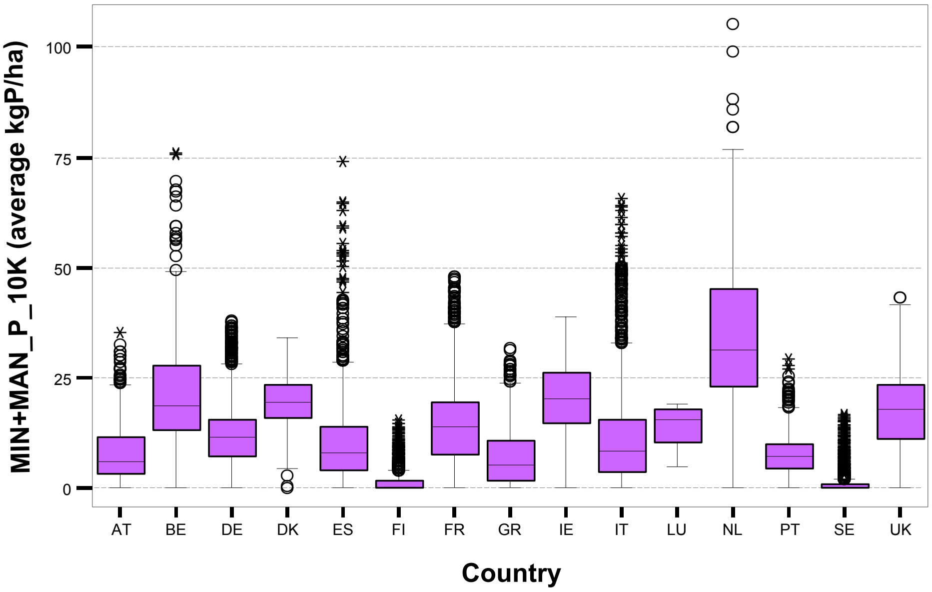


Figure 4.38 Distribution of phosphorus total agricultural input (mineral fertiliser + manure) per total surface for each EU15 country according to the 10 km grid map.

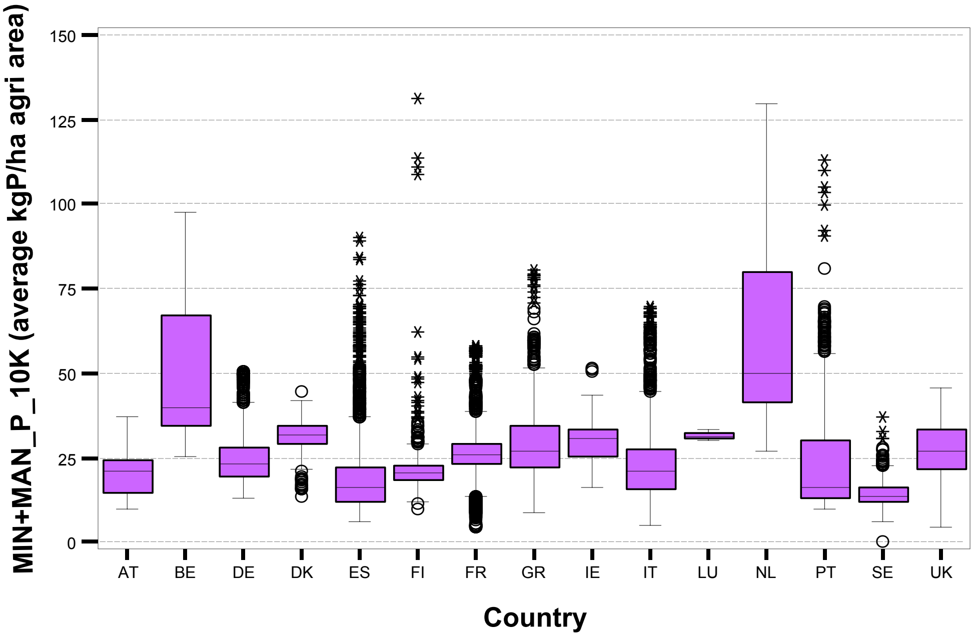


Figure 4.39 Distribution of phosphorus total agricultural input (mineral fertiliser + manure) per agricultural area for each EU15 country according to the 10 km grid map.

4.2.4 European maps of N and P gross balance

The European maps (EU15) of spatialised nitrogen and phosphorus gross balance were computed overlaying the maps (1 ha grid) representing the different terms of the Equation 9 and Equation 10. Then the values were recalculated at the 10 km^2 grid. The maps are shown in Figure 4.40 and Figure 4.41.

Higher surplus of nitrogen and phosphorus are located in the Eastern and central part of Ireland, in England and Wales, in The Netherlands, Belgium, Denmark, in North-western and Southern Germany, in the Oberoesterreich region in Austria, in the Brittany region and in the Seine basin in France, in the Po valley in Italy and in the Cataluna region. Moreover, spots are present in Thessalia region in Greece, in the Murcia, the Galicia and Castilia Leon regions in Spain and in the Lisboa vale do Tejo region in Portugal.

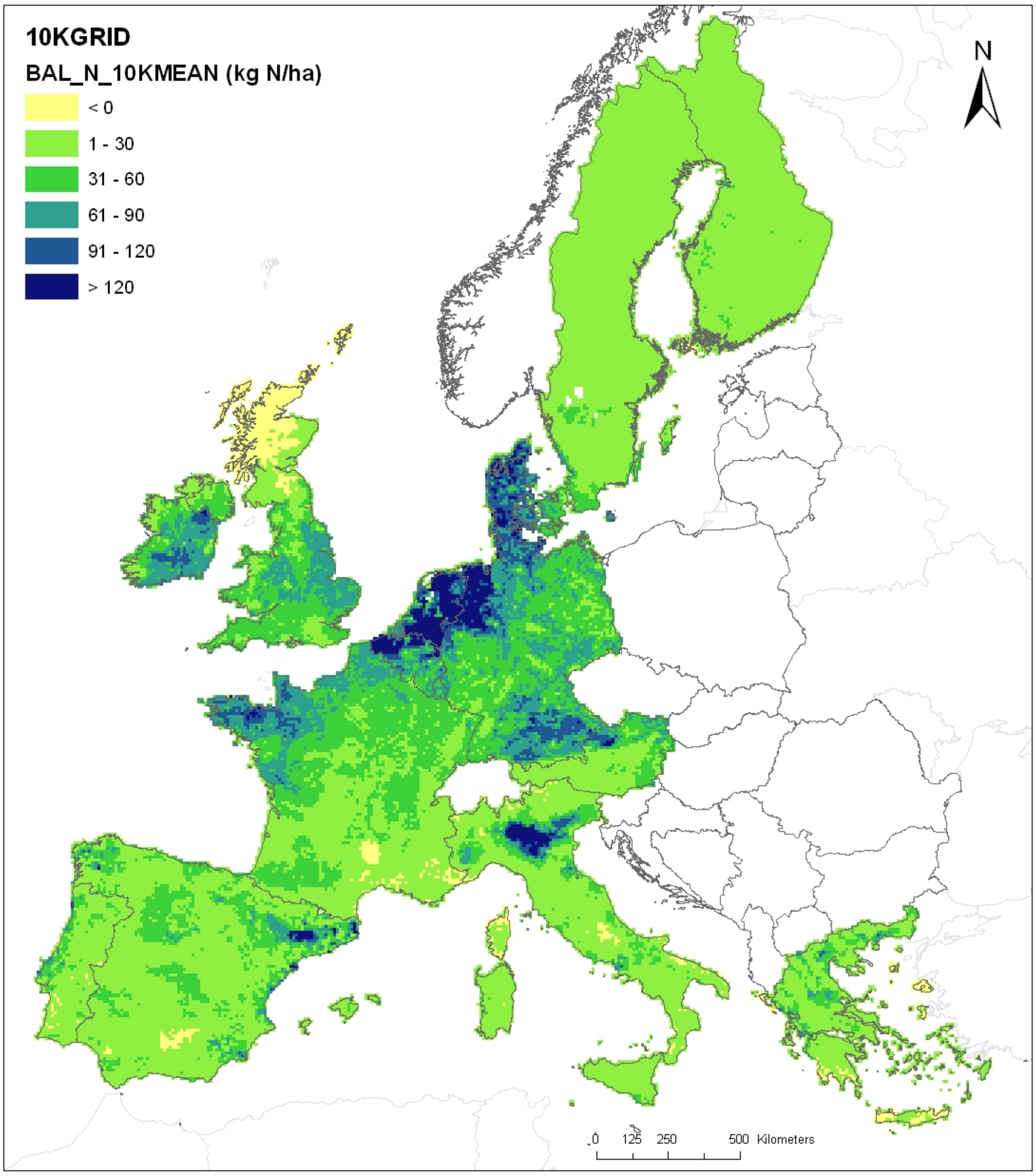


Figure 4.40 European map of nitrogen balance per total surface in EU15, average on 10 km^2 area.

Considering the balance recalculated at the 10 km^2 grid per total surface area, the nitrogen values range from –165 to 569 kg N/ha with an average value of 29 kg N/ha (35 kg N/ha standard deviation), while phosphorus values vary from –20 to 74 kg N/ha with an average value of 3 kg N/ha (5 kg N/ha standard deviation). A description of the distribution of nitrogen and phosphorus gross balance values across the different countries is provided in Figure 4.42 and Figure 4.43.

Maps of nutrient gross balance per total surface have been used as a proxy of nutrient pressure on waters in the different European regions (EEA report), as they provide the amount of nitrogen and phosphorus in excess, which could be lost by leaching or runoff towards water bodies or stored into soils. However, as for the maps of input from agriculture, these maps indicate areas of potential risk of pollution for waters and soils, and additional information on other factors, such as soils, sub-soils, topography, aquifer characteristics, climate conditions and agricultural management practices, should be included to assess the actual pollution.

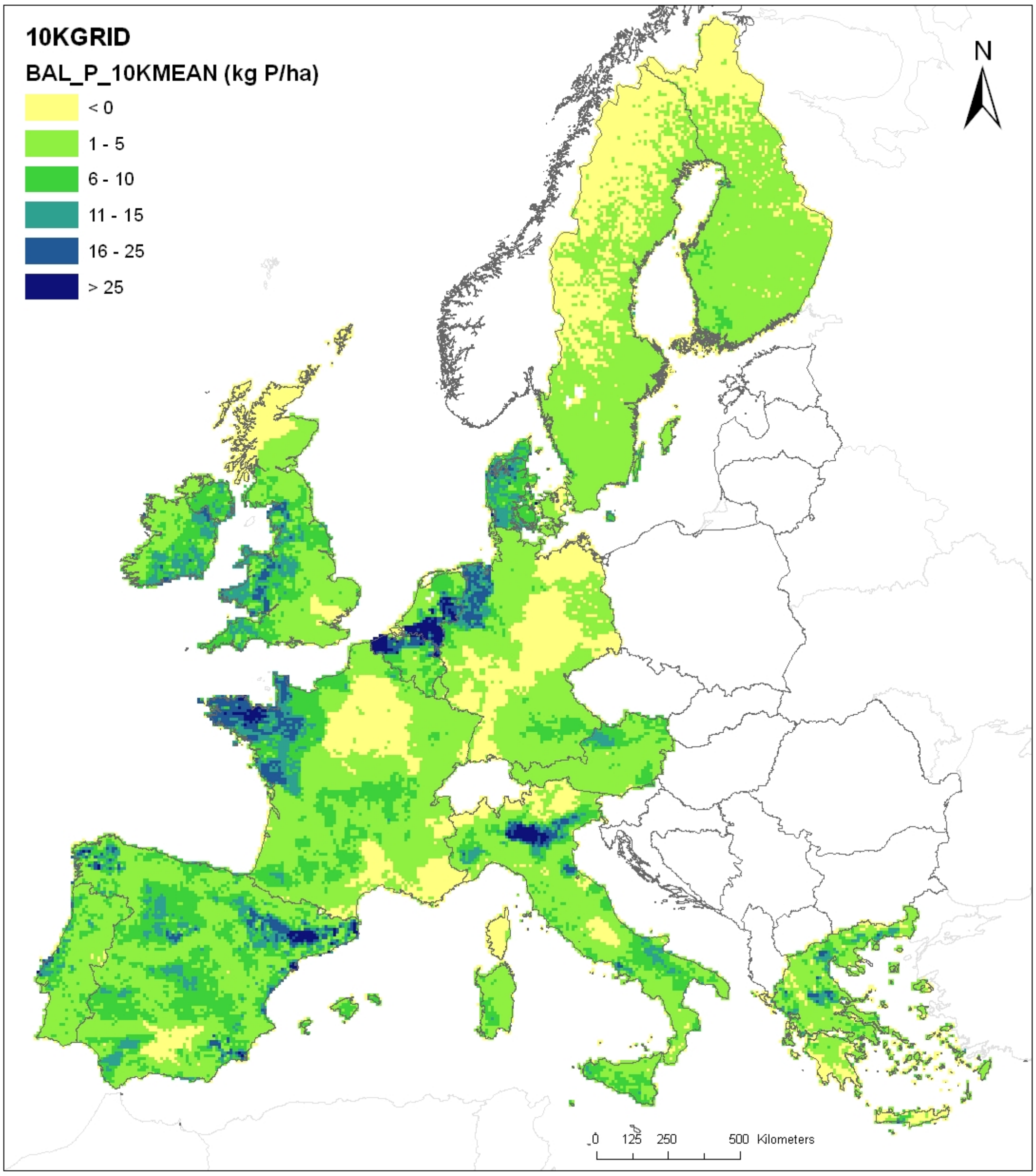


Figure 4.41 European map of phosphorus balance per total surface in EU15, average on 10 km^2 area.

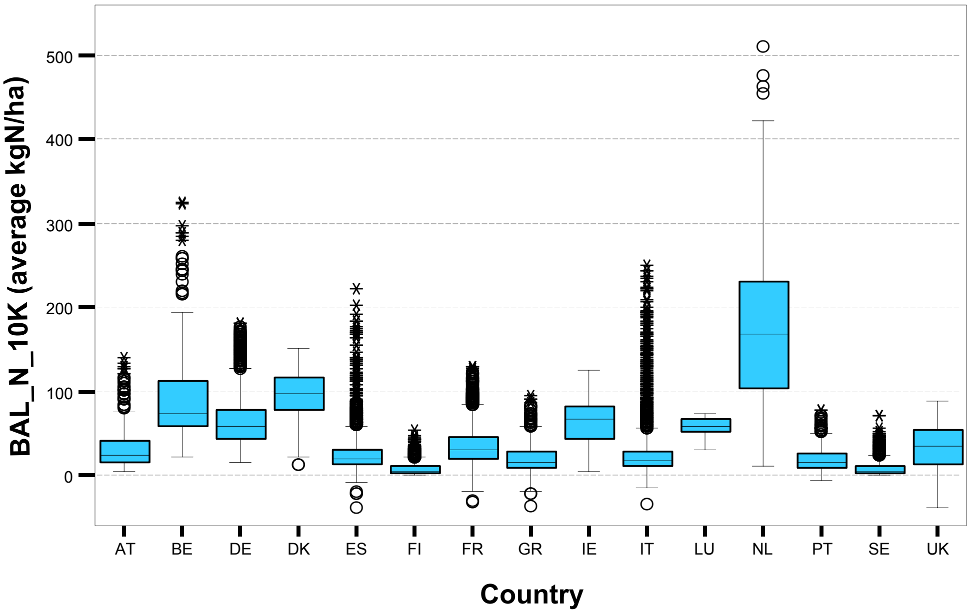


Figure 4.42 Distribution of nitrogen balance per total surface for each EU15 country according to the 10 km grid map.

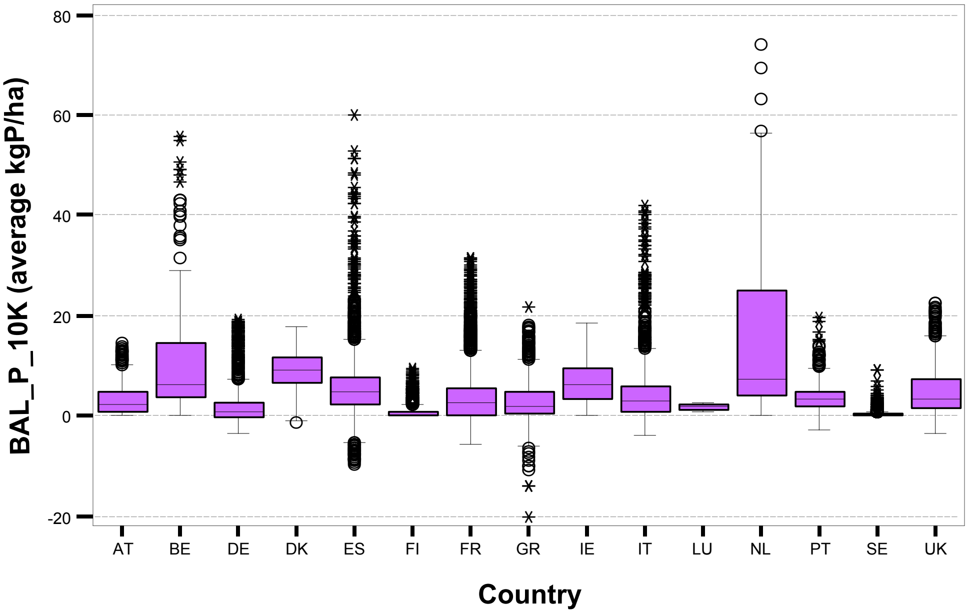


Figure 4.43 Distribution of phosphorus balance per total surface for each EU15 country according to the 10 km grid map.

5 Conclusion and future applications

This study has deepened the analysis on the discrepancies between Farm Structure Survey and CORINE Land Cover databases in reported agricultural areas, showing their correlation with the landscape characteristics.
A European map (EU15) of land use including the crop spatial distribution, consistent with the official crops areas reported by FSS, has been provided.
Nitrogen and phosphorus inputs on soils originating from agriculture have been estimated for EU15, together with their spatial distribution. The study has provided a national estimation of nitrogen and phosphorus gross balance for EU15 countries, and European maps of nitrogen and phosphorus mineral fertiliser input, manure application and gross balance at 10 km^2 resolution.

The study made available statistical agricultural data (directly linked to economic data) originally referring to administrative units, at the river basin scale, which is the natural frame for studying and managing water resources, contributing to the integration of economic and the environmental studies.

The European maps of spatialised input from agriculture and gross nutrient balance produced in this study provide a direct assessment of nutrient pressures originating from agriculture and constitute a reliable data layer for risk analysis and for process-based models, addressing water and soil quality.

The maps may be use directly as a proxy for estimating the nutrient pressures on waters at local scale in the different European regions, as they provide the amount of nitrogen and phosphorus in excess, which could be lost by leaching or runoff towards water bodies or stored into soils. However, the maps indicate areas of potential risk of pollution for waters and soils, and additional information on soils, sub-soils, topography, aquifer characteristics, climate conditions and agricultural management practices, should be included in the analysis to assess the actual pollution.

The maps were already used as basic data layer for studying the fate of nutrients in the ecosystems within the FATE project. In particular, to estimate the nutrient diffuse emissions into waters and the nutrient source apportionment in large European river basins (Grizzetti and Bouraoui, 2006) and to evaluate the impact of climate change on agriculture production (Bouraoui and Aloe, 2007).

The European maps of spatialised input from agriculture and gross nutrient balance will be further used within the FATE project as data layer in risk analysis and modelling to deepen the analysis of impacts of agriculture on water resource in Europe and to continue the research in support of Nitrate Directive, Water Framework Directive and Groundwater Directive.

6 References

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Abstract

This report describes the estimation of the spatialised nutrient inputs from agriculture and nutrient surplus at the soil surface. Statistical agricultural data from the Farm Structure Survey (FSS) were linked to the spatial information of the CORINE Land Cover 2000 map, producing a European map (EU15) of land use including the crop spatial distribution, consistent with the official crops areas reported by FSS. Nitrogen and phosphorus inputs on soils originating from agriculture were estimated for EU15, and then spatialised based on the land use map, providing European maps of nitrogen and phosphorus mineral fertiliser input, manure application and gross balance at 10 km^2 resolution. These maps allow the assessment of nutrient pressures originating from agriculture and constitute a reliable data layer for risk analysis and for process-based models, addressing water and soil quality.

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