FERTIMANURE
Innovative nutrient recovery from secondary sources – Production of high-added value **FERTI**lisers from animal **MANURE**

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D1.1. REPORT ON **FLOW ASSESSMENT, LOGISTICS** AND **CHARACTERISATION** OF MANURE AND BY-PRODUCTS.

FERTIMANURE

This project has received funding from
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Deliverable

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D1.1. Report on flow assessment, logistics and characterisation of manure and by-products.

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Executive summary:

This study was carried out as part of the European demonstration project FERTIMANURE funded by the H2020 Programme (project number 862849) titled Innovative nutrient recovery from secondary sources – Production of high-added value FERTIlisers from animal MANURE.

The work carried out for this deliverable is part of FERTIMANURE work package 1 (*WP1), of FERTIMANURE framework*. This deliverable is based on the activities of *Task 1.1 Flow assessment, logistics and characterisation of animal manure and by-products.* This task and deliverable, led by LEITAT, has the main objective of identifying and quantifying current manure production in the participating European Union (EU) countries and regions.

Firstly, an overview of manure nutrient production for the whole of Europe is addressed. This is partly based on the thorough work of the Nutri2Cycle project (H2020). The FERTIMANURE project takes advantage of this valuable resource as the starting point for a more detailed analysis at the level of the participating regions, which is the special added value the present deliverable 1.1.

The following sections provide detailed information about the amounts and nutrient flows of manure resources in the EU regions considered in FERTIMANURE. These sections compile data from EU countries where FERTIMANURE has pilot plants, formatted in a standardized format for unification and processing in order to have a complete vision of manure generation and management costs.

On the one hand, this has involved providing data on livestock densities in each region and the amounts of nutrients generated by the sector in each regional case. This first activity has the objective of quantifying and detecting the flows of manure resources in the project regions where livestock farming intensification is generating large amounts of manure. This is accompanied by informative maps of the animal densities and nutrient densities within each region.

Next, detailed information is given about the chemical composition of the considered livestock manures (cow, pig, and chicken). This is data provided by each partner, and helps characterize the differences between EU regions and the particularities of manure management in this regard.

Finally, data on current manure treatments and transport costs was compiled. This information can be used to contrast treatment options with transport out of nutrient hot spots and the costs of operation and business models considered in the project. Due to the inclusion of CELAC partners, information from Argentina has been collected and reported in Annex II, so that the information may be exploited in the CELAC region.

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1. Introduction

To face current challenges related to inefficient use and management of animal manure, an update on the current situation is required. For this reason, within WP1, “FERTIMANURE Framework,” the project execution plan includes task 1.1, “Flow assessment, logistics and characterisation of animal manure and by-products.” In this task, an assessment of material flow assessment is carried out with the aim of informing later activities which address the flow management of animal manure and its logistics for the countries participating in the project.

To do so, the partners involved have collected large-scale data from the participating European Union (EU) countries, and more detailed information at the regional level regarding the flows of animal manure comprising the stocks of animal manure.

Firstly, an overview of manure nutrient production for the whole of Europe is addressed. This is partly based on the thorough work of the Nutri2Cycle project (H2020). The FERTIMANURE project takes advantage of this valuable resource as the starting point for a more detailed analysis at the level of the participating regions, which is the special added value the present deliverable 1.1.

During technical meetings for task execution, the experienced involved partners discussed the various other initiatives and data sources on manure management in the EU. It was decided that this detailed information on the regional level would provide the most special added value to knowledge be the most relevant for the following activities within the FERTIMANURE project. Therefore, in the following sections, the document considers the five pilot regions – Barcelona (Spain), Achterhoek (Netherlands), Oberpfalz (Germany), Flanders (Belgium), and Grand Est and Brittany (France) - with the addition of Italy (whole country) which does not have a pilot.

In these regions, partners have obtained detailed information from their own projects or studies, regional authorities, or regional databases on the amounts and nutrient flows of manure resources:

On the one hand, this has involved providing data on livestock densities in each region and the amounts of nutrients generated by the sector in each regional case. This first activity has the objective of quantifying and detecting the flows of manure resource in the project regions where livestock farming intensification is generating large amounts of manure. This is accompanied by informative maps on the animal densities and nutrient densities within each region.

Next, detailed information is given about the chemical composition of the considered livestock manures (cow, pig, and chicken). This is data provided by each partner, and helps characterize the differences between EU regions and the particularities of manure management in this regard.

Finally, data on current manure treatments and transport costs from the participating regions was compiled. Data was compiled in a standardized manner from partners where FERTIMANURE has pilot plants in order to have a complete vision of manure generation

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and management costs. This information will be used later in the project to contrast treatment options with transport and, finally, the costs of operation and business models elaborated in FERTIMANURE. Information from Argentina as a part of FERTIMANURE project has been collected as Annex II so D1.1, results could be exploited and replicated in this CELAC country.

2. EU-scale analysis

Before delving into the detailed regional analysis of the participating FERTIMANURE regions, this section aims to put the manure generation in the proper EU context. The EU livestock sector is the largest in the world. Meat, milk and eggs make up 40% of the EU's agricultural value and it accounts for 48% of total EU agricultural activity, with an estimated €130bn output value annually and creates employment for almost 30 million people. It is estimated that total farm livestock population in Europe excretes around 1400 Mt of manure annually. The rising demand for animal products over the past five decades has been met by a rapid growth of specialised intensive livestock production. One of the main environmental problems likely to be associated with these systems are the accumulation of animal waste, leading to build up of excess nutrients and heavy metals in soils[1]. Manure nutrients are often not recycled effectively and used efficiently by plants and crops. Nutrient losses greatly depend on the system, management and regulations[2]. The description of the European livestock sector in this study can reflect a very general view on animal densities between the countries and nutrient production and provide the information required as a baseline to develop the FERTIMANURE project subsequent activities.

In this section, an overview of manure nutrient production for the whole of Europe is addressed. During technical meetings for task execution, the involved experienced partners discussed the various other initiatives and data sources on manure management in the EU, and the team arrived to the conclusion that very recent outputs from other EU projects have adequately addressed the issue of livestock nutrient generation on the EU scale. In particular, the Nutri2Cycle project – involving a group of the University of Ghent (UGENT) and Wageningen Environmental Research (WEnR) researchers who are also members of the FERTIMANURE consortium - has carried out a mapping of nitrogen (N) and phosphorus (P) flows from different sources based on the MITERRA-Europe model. This has been an exhaustive task, based on modelling exercises from multiple modelling frameworks. For more information, see the report "Mapping and characterization of CNP flows and their stoichiometry in main farming systems in Europe"[3].

[1] Agriculture Organisation and others, 'Livestock Density and Nutrient Balances Across Europe', Uunk 1991, 2002, 2000–2003.
[2] Qian Liu and others, 'Global Animal Production and Nitrogen and Phosphorus Flows', *Soil Research*, 55.5–6 (2017), 451–62 <https://doi.org/10.1071/SR17031>.
[3] University of Gent, *Nutri2Cycle Transition towards a More Carbon and Nutrient Efficient Agriculture in Europe*, 2020.

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2.1 Overview of European livestock densities

Animal densities gives an indication of the pressure that livestock farming places on the environment. As shown in Figure 1, strong concentration of livestock in the regions in south and central Netherlands, the bordering regions in Germany and in north Belgium (Flanders). The lowest total livestock densities among the Member States are observed in Bulgaria as well as in Slovakia and the three Baltic countries.

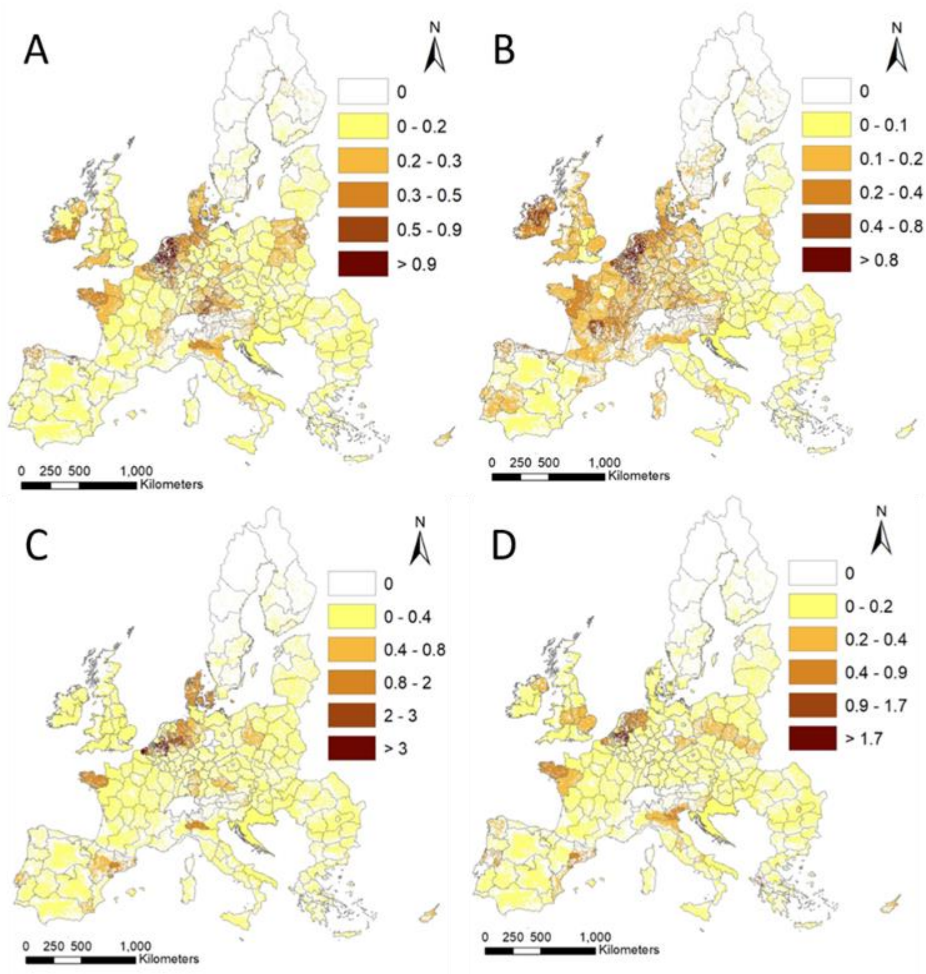

Figure 1 Animal densities per animal category: dairy cows (A), beef cattle (B), pigs (C) and poultry (D) in livestock units/ha UAA. Data source: EU project Nutri2cycle / MITERRA-Europe model.

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2.2 Overview of generation of nutrients by livestock in Europe

In fact, nutrient generation and flows from manure can be used as an indicator of animal densities, which have a large impact on overall nutrient fluxes. The most accepted nutrient flows are those concerning nitrogen and phosphorus[4].

Total N and P excreted by livestock in the EU27 are estimated at 7-9 Mt N/year and 1.8 Mt P/year. Currently, manure is applied to land, exported, used to produce valuable products (mainly bio-based fertilizers, BBFs) or incinerated. The main disposal route is land application. More than 90% of manure produced in EU27 is currently returned to agricultural fields either through the spreading of collected manure or directly by grazing. Moreover, an excess of manure is harmful to the environment and nature and in many European regions, the livestock manure produced is larger than the amount that can be used in local agriculture. Livestock excreta make an important contribution to soil nutrient inputs and in many developing countries outside Europe are the only significant input. Currently, manure

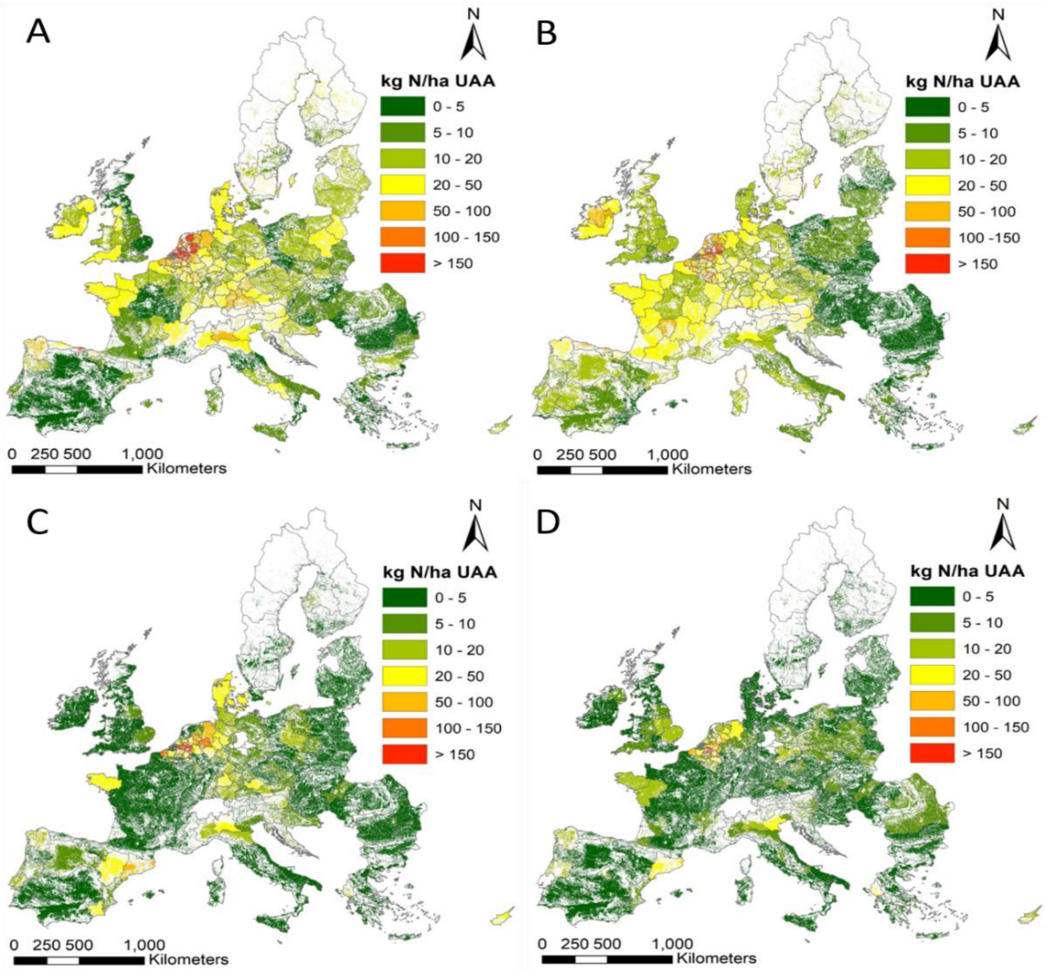

Figure 2. Nitrogen (N) excretion per animal type dairy cows (A), beef cattle (B), pigs (C) and poultry (D). Data source: EU project Nutry2cycle / MITERRA-Europe model.

[4] Basnet et al, B. B., A. A. Apan, 'Geographic Information System Based Manure Application Plan.', *Journal of Environmental Managemen*, 64 (2002), 99–113.

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management is based on the direct application of manure as fertilizer to the soil; although in some areas this management is very expensive, as areas with high livestock density are far from the nutrient demanding land likely to use the manure, thus increasing costs and transport. Figure 2 to Figure 4 shows N and P excretion as a part of the nutrient fluxes in the European Union to indicate where livestock production has an impact on these nutrient flows.

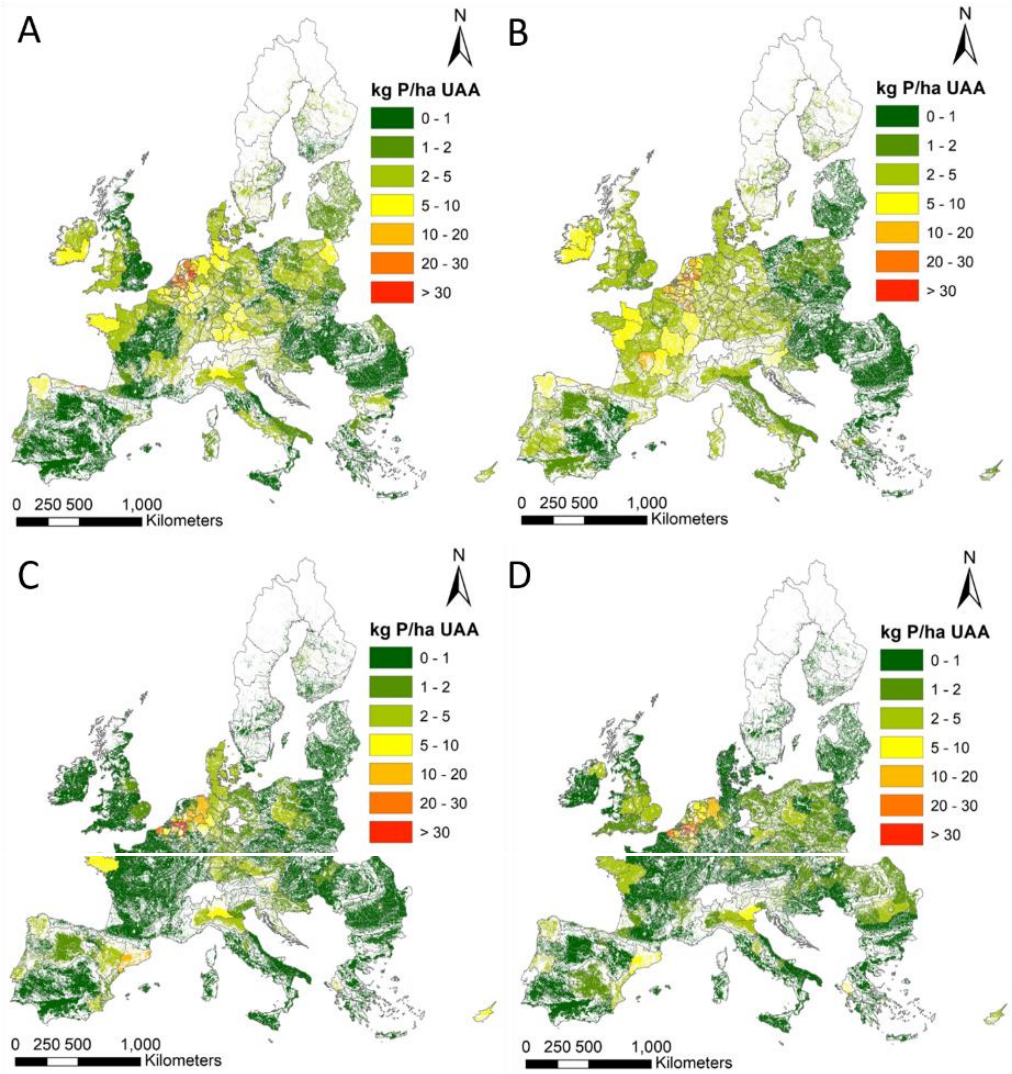

Figure 3. Phosphorus (P) excretion per animal type dairy cows (A), beef cattle (B), pigs (C) and poultry (D). Data source: EU project Nutry2cycle / MITERRA-Europe model.

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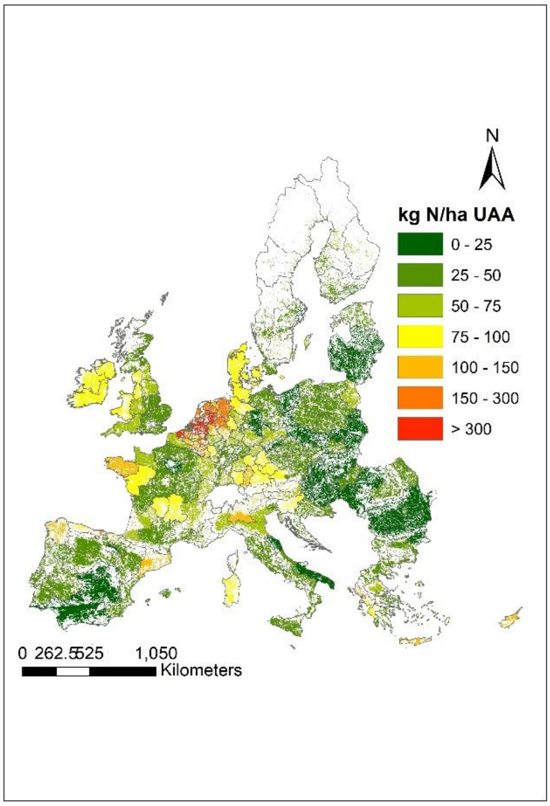

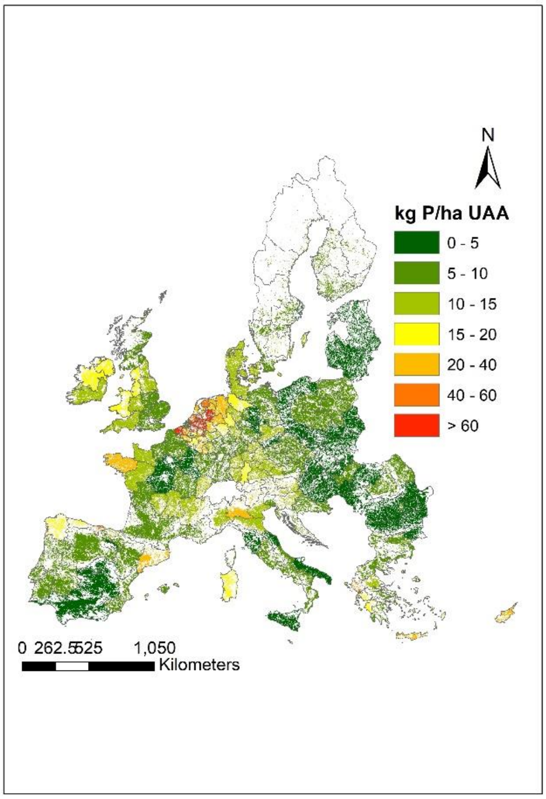

Figure 4. Total nitrogen (N) (left) and phosphorus (P) (right) excretion for all livestock animals together. Data source: EU project Nutry2cycle / MITERRA-Europe model.

2.3 Databases consulted

For the creation of the above maps generated by the Nutri2Cycle project the MITERRA-Europe model was used. It included different sources of data on animal numbers and manure production for cows, pig, cattle and poultry, based on a number of public and open databases.

Taula 1. Public and open databases consulted. Source: University of Gent, Nutri2Cycle Transition towards a More Carbon and Nutrient Efficient Agriculture in Europe, 2020.

Dataset	Source	Website
FAOSTAT	Food and Agriculture Organization of the United Nations, 1997. FAOSTAT statistical database. Rome: FAO	http://www.fao.org/faostat/en/#data
EUROSTAT	European Commission, 2019°. Eurostat statistical database. Brussels: European Comission	https://ec.europa.eu/eurostat/data/database
CAPRI	Britz, W., Witzake, P.,2014. CAPRI model documentation 2014. Bonn Institute for Food and Resource Economics	https://www.capri-model.org/dokuwiki/doku.php?id=start

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LUCAS – European Soil Data Centre	Tóth, G., Jones, A., Montanarella,L (eds.) 2013. LUCAS Topsoil Survey. Methodology, data and results. JRC Technical Reports. Luxembourg. Publications Office of the European Union, EUR26102 – Scientific and Technical Research series.	https://ec.europa.eu/eurostat/web/lucas/data/database
NIS	United Nations Framework Convention on Climate Change,2019. National Inventory Submissions. 2019. Bonn: United Nations Climate Change	https://unfccc.int/non-annex-I-NCs
FSS	European Commission, 2019b. Farm Structure Survey – Survey Coverage. Brussels, European Commission	https://ec.europa.eu/eurostat/web/agriculture/data
GAINS	International Institute for Applied Systems Analysis, 2018.the GAINS model. Laxenburg: IIASA	https://iiasa.ac.at/web/home/research/researchPrograms/Research-Programs.en.html
IPCC Reports	IPCC, 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4, Agriculture, Forestry and Other Land Use. IPCC National Greenhouse Gas Inventories Programme. Institute for Global Environmental Strategies (IGES). Kanagawa, Japan	https://www.ipcc.ch/library/

3. Regional data for FERTIMANURE pilot plant areas

As livestock farms are mostly intensive producers, there is a generation of large amounts of manure by-products in these localized areas. There, the available agricultural land for manure application is limited, leading to an excess of manure that cannot be used for local agriculture. Knowledge about the amounts of manure and nutrients generated with manure is crucial for evaluating valorisation strategies towards improved management of this valuable resource. However, information on actual management of all flows is not known (or easily obtained) or tracked in some countries. For this reason, this detailed study of each pilot region is carried out within FERTIMANURE, as it will inform later analyses of potential business models and exploitation plans. The analysis of nutrient flows between different components of the agro-ecosystem is a necessary first step for characterizing each region and understanding the particular opportunities and challenges faced within each.

FERTIMANURE counts on five regions where pilot plants will be installed to use innovative technological approaches for valorisation of manure. This deliverable thus compiles information on each of these pilot regions for the continuing analyses and case studies carried out within each zone. Within the work group participating, it was decided that the greatest added value to the project would consist of gathering data on the NUTS-3 level (municipal level) and aggregate this data to the NUTS-2 level (province, etc.). This way, nutrient flows and imbalances at the very local level can be considered for redistribution and management on a regional scale. In the case of Italy, since this country does not possess a pilot, but the imbalances and flows are to be considered anyway within the project, the whole country was included for the analysis.

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The NUTS-2 regions considered are:

1. Barcelona (Spain)
2. Achterhoek (Netherlands)
3. Oberpfalz (Germany)
4. Flanders (Belgium)
5. Grand Est and Brittany (France), and
6. Italy (whole country) which does not have a pilot

3.1 Data collected for the characterization of nutrients flow within regions

The information collected is that which is relevant for the use, management, treatment, and redistribution of manure and manure sub-products within the regions. With this basis, the following types of data were obtained:

- Nutrients generated by each animal type
- Useful agricultural land
- Number of animals and farms
- Calculations of manure nutrient flows within each region, restricted to nitrogen and phosphorus, since these are the most widely-available
- Chemical characteristics of manure, by animal type
- Regional data and management costs have been contextualized in each area. For this, pilot plants regions are analysed in terms of municipalities or regions (NUTS 3 or NUTS 2).

With all of the above, a large amount of data has been obtained with the collaboration of the partners. Much of this detailed data is included in the annexes at the end of the document.

The livestock density index gives an indication of the pressure that livestock farming places on the environment. Here, data was collected on the number of farms and number of animals per animal type. This data, along with the **livestock unit coefficients** (LSU), is required for calculating the nutrients flows per animal type and to characterise each region in terms of differences in stock density and the market structure from region to region. Importantly, this information is used to calculate total amounts of N and P contained within manure flows within each region, and therefore to understand the impact of each animal type on the total nutrient flows. All this information in each area is useful for individual or collective management plans.

Distribution of agricultural land use in each region has been compiled as a component of regional fertilizer needs and is required to improve and adapt current management systems. A characterization of regional crops and nutrient needs is necessary to characterize the "land sink", which is the traditional form of management and use of untreated manure. This is the approach used by some regional authorities in setting limitations on manure use and application, and also provides information about the potential risks to environmental quality

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faced within a given zone. Crop types are characterized, since the FERTIMANURE approach is specifically to target crop needs with tailored made fertiliser (TMF) products. Therefore, with this information, appropriate business plans for fertiliser manufacture can be devised.

The present report is focused on animal production and the associated generation of **nitrogen (N) and phosphorus (P)** as indicative nutrients from the different regions where FERTIMANURE will place pilot plants. The emphasis on N and P is made for a number of reasons: first, because of all nutrient elements, the availability of N and P limits global food production most. Losses of N and P to the wider environment also have significant human health and ecological effects and animal production accounts for a relatively large share of N and P losses from agriculture to the environment[5]. Finally, these nutrients are most linearly related with animal production, and are those which are most often quantified, measured, and monitored by regional, national, and EU authorities at this time. But it is important to note that manure contains many more nutrients and also potential contaminants that should be managed in a sustainable way as well.

[5] Steinfeld H; Gerber P; Wassenaar T; Castel V; Rosales M & Haan CD, '"Livestock's Long Shadow: Environmental Issues and Options".', *FAO.Rome, Italy*, 2006.

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3.2 Manure nutrient flows within FERTIMANURE regions

3.2.1 Barcelona – pilot plant in Folgueroles, VIC

Figure 5. Pilot plant location in Spain.

Within Catalonia, the NUTS-2 region corresponds to the Provincial administrative regions, and the NUTS-3 to counties. These are the two administrative units consulted for the purposes of this study.

The Spanish pilot is located in the municipality of Folgueroles (see Figure 5), within the province of Barcelona. The farm where the pilot is installed pertains to the Cooperativa Plana de Vic (CPV) which was founded in 1966 by a group of livestock farmers from the Osona region (the county). The density of meat production in Osona county, located in the centre of Catalonia, is one of the highest in Spain and Europe. This sector is mainly dominated by pig production, but the meat and milk production sectors are also of high importance. The magnitude of each of these sectors is reflected in the respective amounts of nutrient-rich effluents which are generated. While animal husbandry has long been the motor of the Osona region's economy, the generation of large amounts of nutrients which cannot be absorbed locally is a decades-old problem. While Osona county is the centre of cow and pig production in Barcelona province, the data and geographic analyses in continuation in this section consider the province of Barcelona as a whole (NUTS-3 level).

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Number of farms per animal type

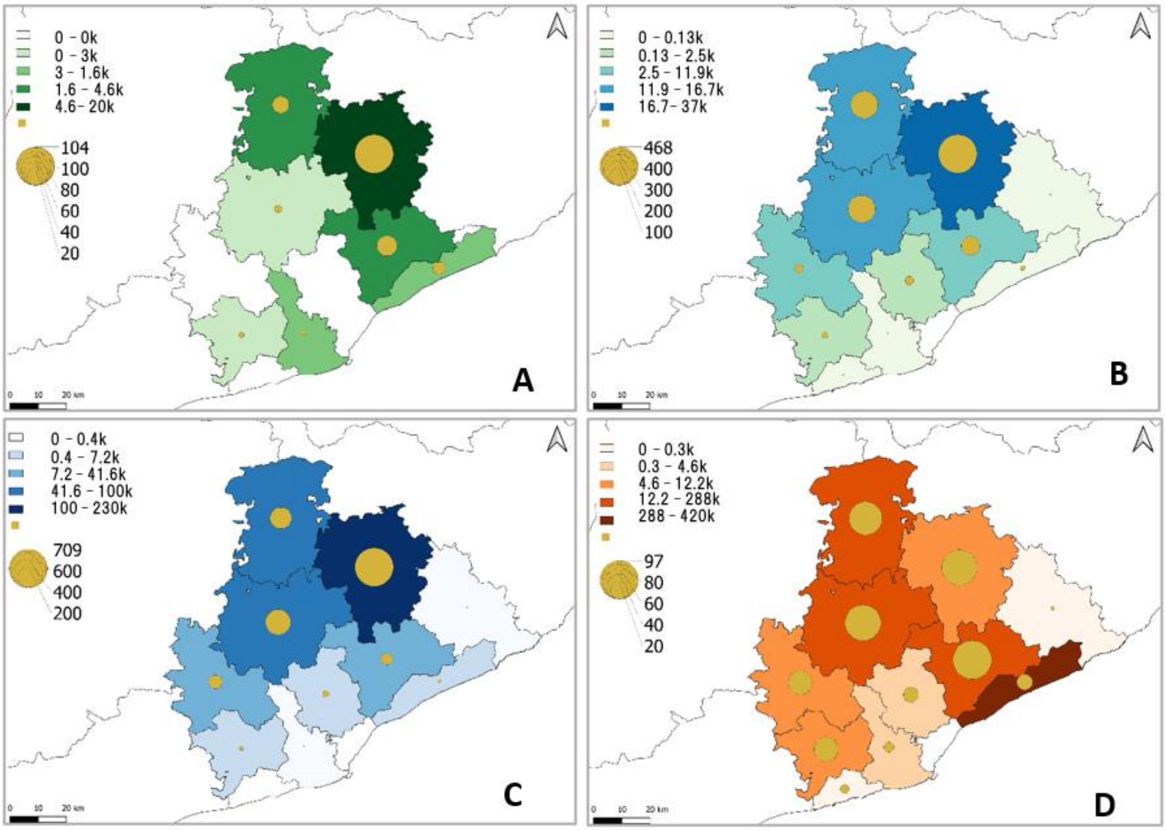

Figure 6. Number of animals (census) per animal type (LSU) per county (NUTS-3) and number of farms (Circles). Dairy cows (A) beef cattle (B), pigs (C) and poultry (E).

In the figure above (Figure 6) displaying animal and farm numbers for Barcelona province, in terms of farm number it is clearly seen is that pig rearing dominates the region. Dairy cows are also much more abundant than beef cattle. There is also some degree of regional specialization, with pigs and cattle clearly concentrated in one area, while poultry is concentrated in the coastal zone. Here, it is interesting to note that poultry animal densities do not reflect clearly the nutrient densities – this probably reflects regional differences in the farming systems, e.g. zones which specialise in chick/hen/broiler raising etc., and shall be investigated further. Detecting this difference is important for manure management since this will translate to regional differences in manure chemical properties for the same sector.

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Table 1. Table with standardized rates of nitrogen (N) and phosphorus (P) generation per animal type in the Barcelona region.

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Bovine animals under 1 year old	0.4	22	2.68
	Bovine animals 1 but less than 2 years old	0.7	40	11.92
	Bovine animals male, 2 years old and over	1	53.15	11.53
	Heifers, 2 years old and over	0.8	----	----
	Dairy cows	1	80.22	11.47
	Other cows, 2 years old and over	0.8	53.15	11.53
PIGS	Piglets having a live weight of under 20 kg	0.027	1.19	0.31
	Breeding sows weighing 50 kg and over (sows)	0.5	15	4.28
	Other pigs (fattening pigs)	0.3	7.25	1.63
POULTRY	Broilers	0.007	0.166	0.1
	Laying hens	0.014	0.263	0.14
	Ostriches	0.35	----	---
	Other poultry	0.03	-----	----

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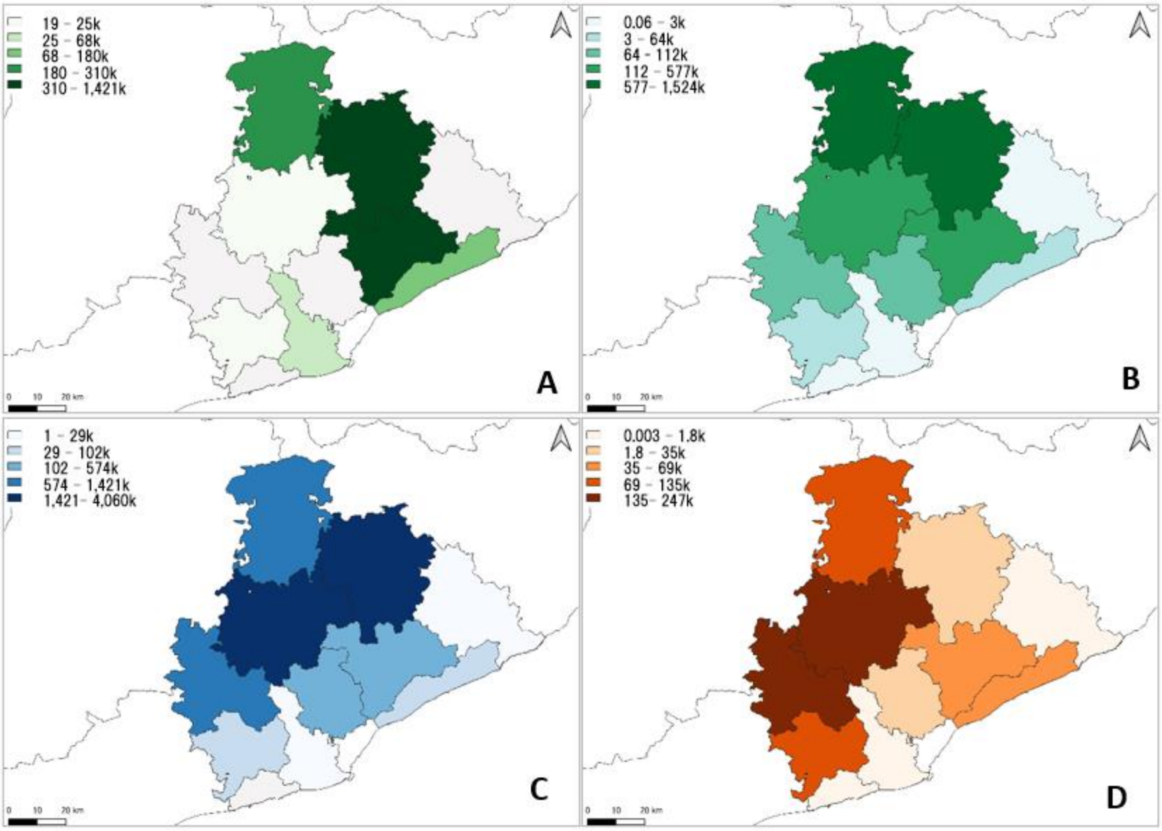

Figure 7. Quantity of nitrogen (kg N/county) per animal type per county. Dairy cows (A), beef cattle (B), pigs (C) and poultry (D). Source: Sistema de Información Geográfica de Parcelas Agrícolas (SIGPAC).

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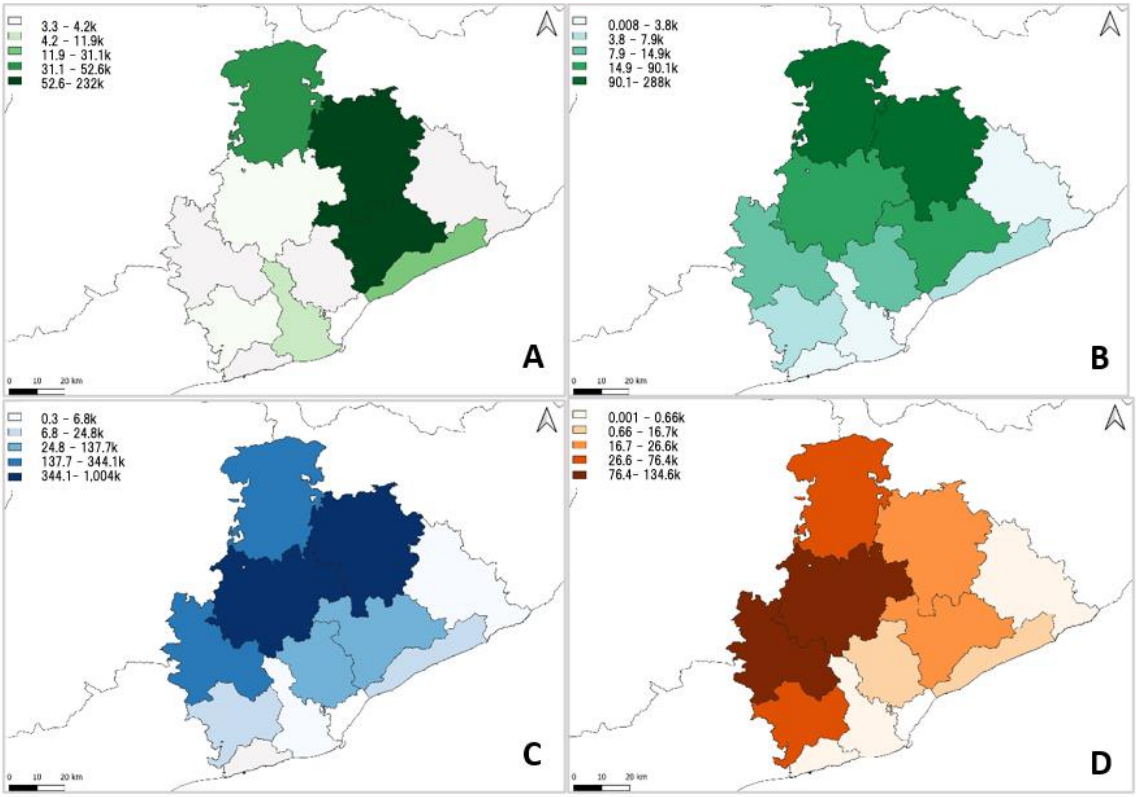

Figure 8. Quantity of phosphorus (kg P/country) per animal type per county. Dairy cows (A) beef cattle (B), pigs (C) and poultry (D). Source: Sistema de Información Geográfica de Parcelas Agrícolas (SIGPAC).

The above figures (Figure 7, Figure 8 and Table 1) show the amount of nitrogen and P generated by manure within each county (NUTS-3). As expected, the relative quantities of N and P mirror one other. In this region, manure and nutrient generation is most intensive in the interior part of the region.

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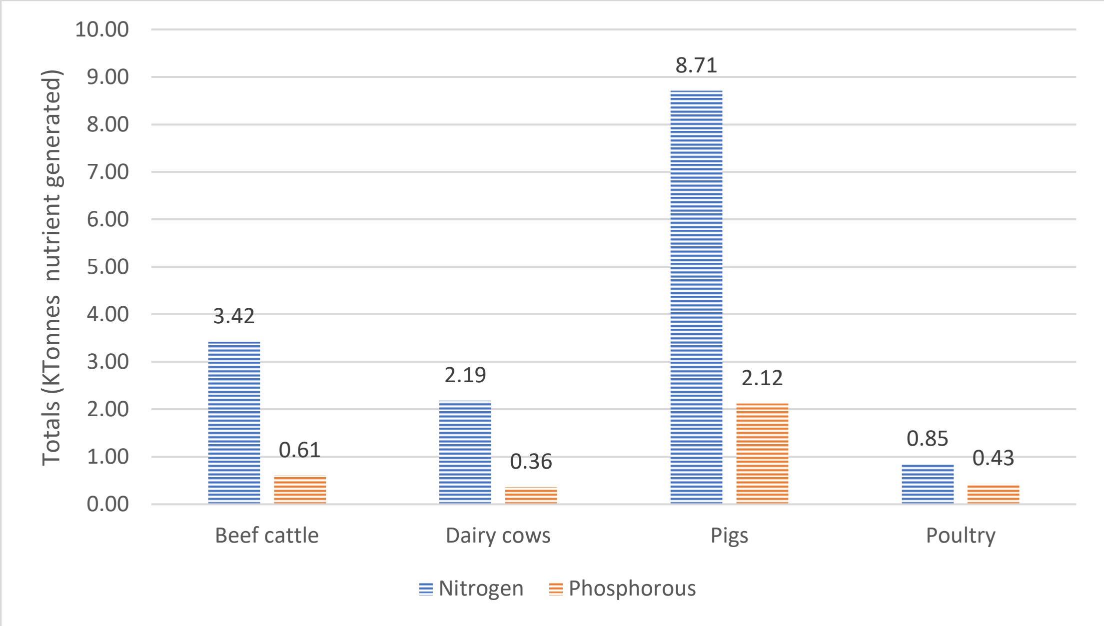

Figure 9. Total quantities of nitrogen (N) and phosphorus (P) generated per animal type. Resource: Sistema de Información Geográfica de Parcelas Agrícolas (SIGPAC).

The above graph shows the total amounts of N and P generated within the Barcelona region (Figure 9). What is seen is that nutrients from pig manures are the most abundant in this region, followed by cows, and finally poultry.

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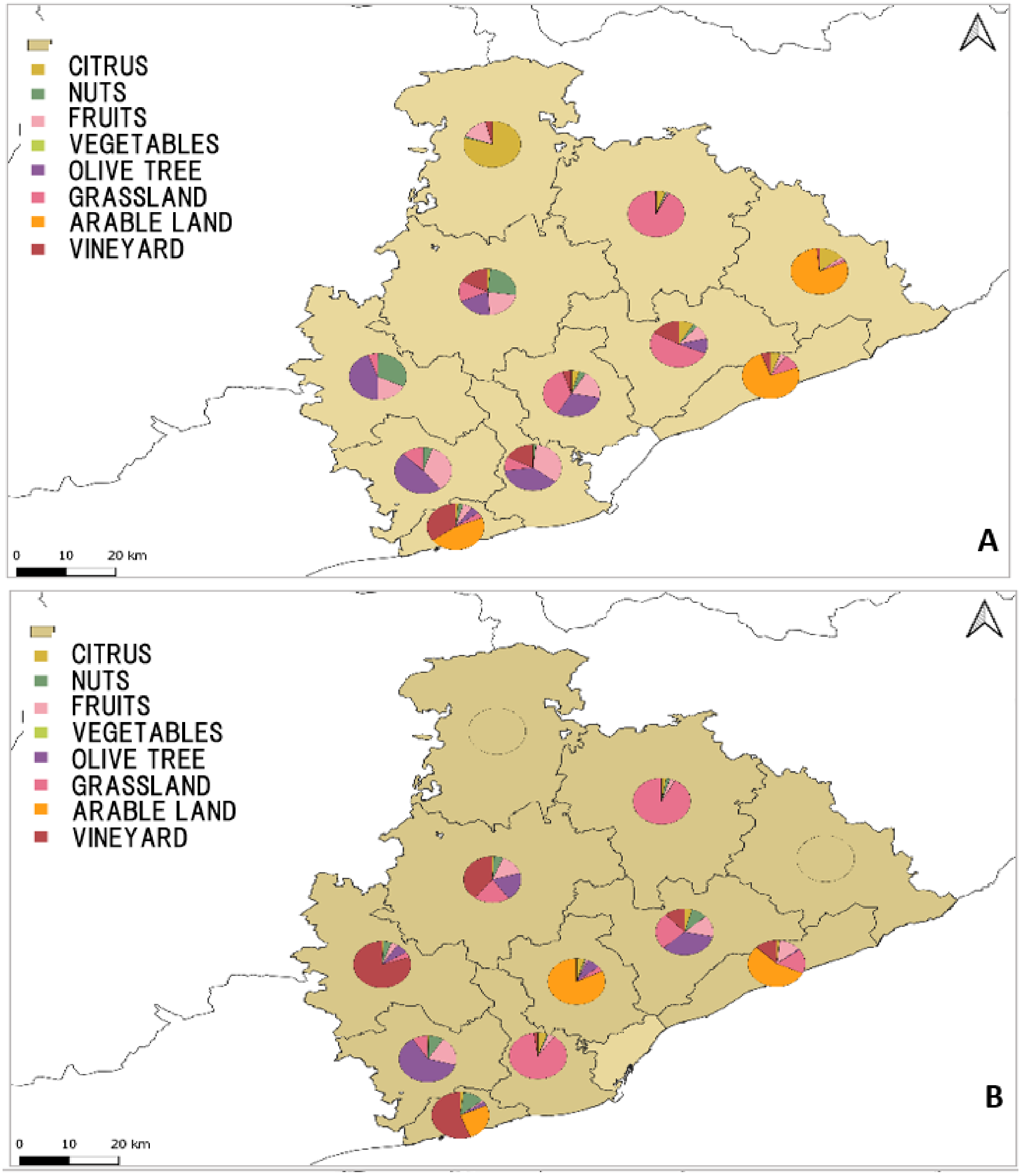

Figure 10. Crop type crossed with presence or not of irrigation: No irrigation and not nitrate vulnerable (A) and No irrigation and nitrate vulnerable zone (B).

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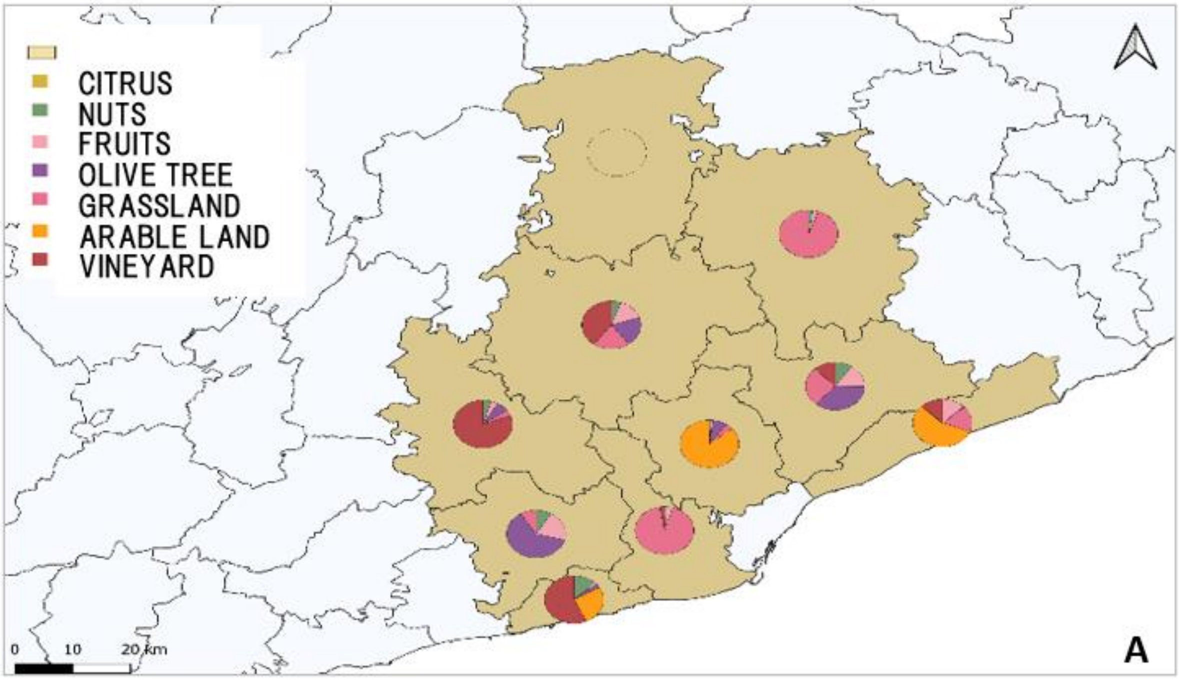

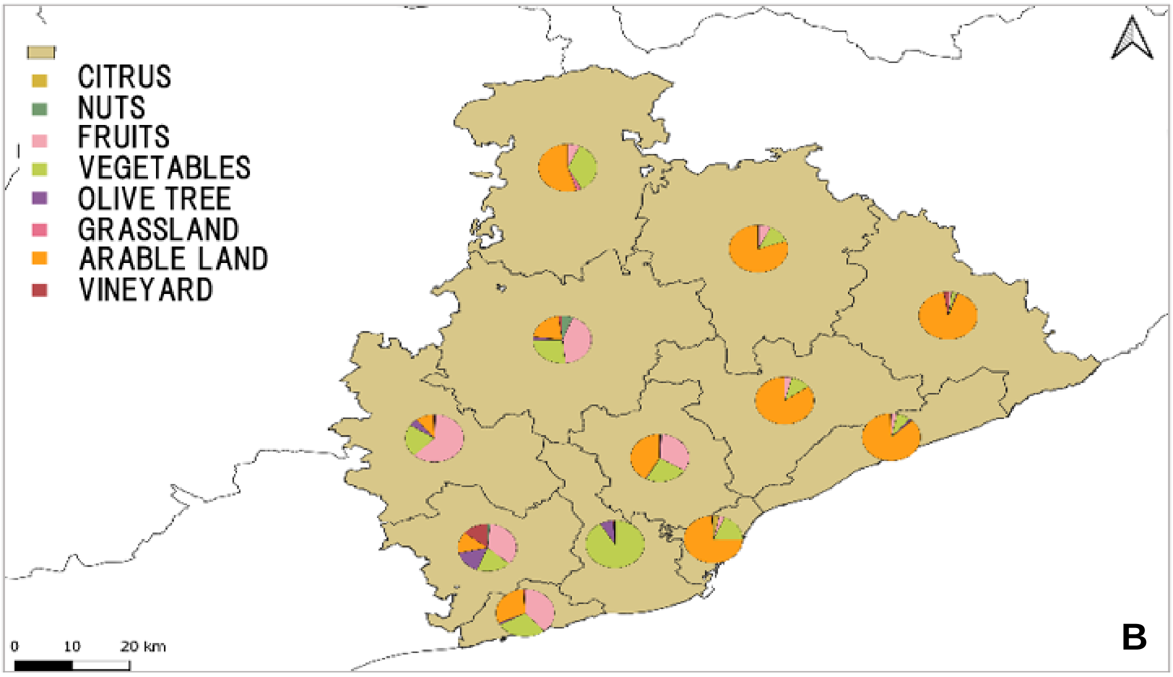

Figure 11. Crop type crossed with presence or not of irrigation: Irrigation zone and not nitrate vulnerable (A) and irrigation zone and nitrate vulnerable (B)

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The local landscape and regulations of Barcelona also influence how manure may be managed now and in the future. The densities of manure and also geology cause different management restrictions in the region, leading to different maximum rates of nitrogen which can be applied. Irrigated crops also absorb more nutrients, affecting these maximum rates. For this reason, the information on dominant crop type is presented considering these parameters in Figure 10. The areas within each county affected by nitrate vulnerable zones (NVZ) is shown in Figure 12, and these aforementioned restrictions on maximum nitrogen application rates in

Table 2.

Currently, there is no regulation in Catalonia that establishes maximum concentrations of P according to crop and agroclimatic zone, but there are maximum levels of P in the soil. For this reason, the data presented in this section is mainly focused on N rates and regulations, but not on P.

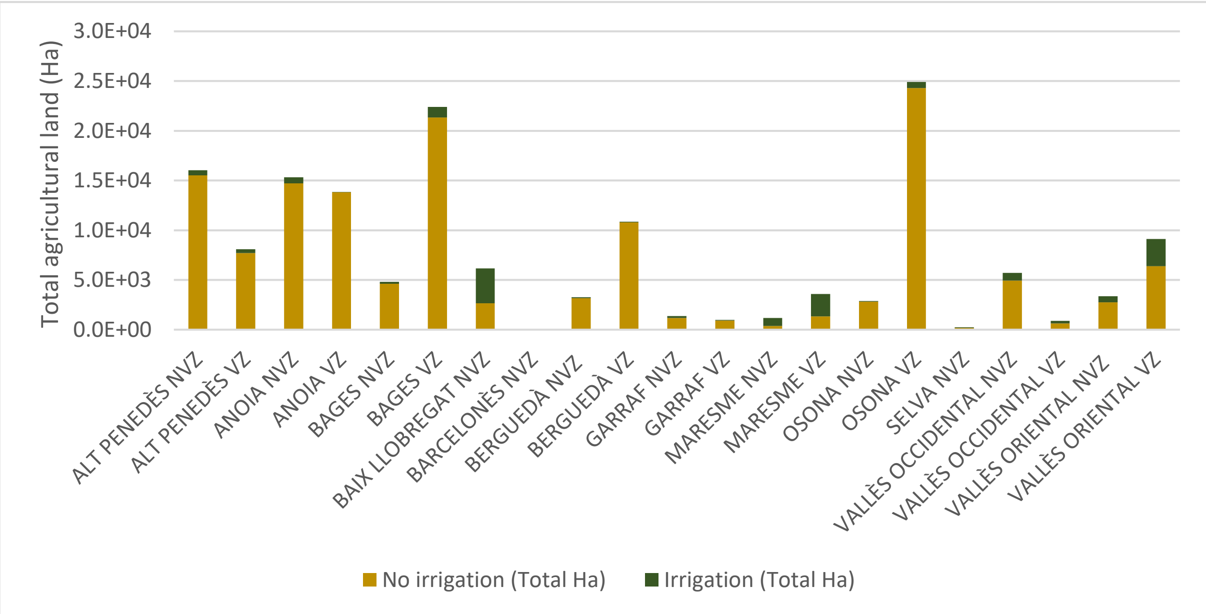

Figure 12. Total agricultural land (hectares) per region. NVZ: Non-vulnerable zone; VZ: Vulnerable zone as designated by Nitrate Directive.

Table 2. Maximum legal amounts of nitrogen (N) and phosphorus (P) which can be applied in each cropping system (kg N and P/municipality). No Irrigation:1: Municipality with more arid conditions. No Irrigation 2: remaining municipalities.

NO IRRIGATION ZONE	NITRATE VULNERABLE ZONE	NO IRRIGATION							IRRIGATION							
		CITRUS	NUTS	FRUITS	OLIVE TREE	GRASSLAND	ARABLE LAND	VINEYARD	CITRUS	NUTS	FRUITS	VEGETABLES	OLIVE TREE	GRASSLAND	ARABLE LAND	VINEYARD
	No	75	75	75	75	170	75	150	150	170	75	170	170	170	170	250

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No Irrigation 1	Yes	60	60	60	60	170	60	130	130	170	60	150	150	130	150	170
No Irrigation 2	No	120	120	100	120	170	100	210	190	210	100	170	170	170	170	250
	Yes	90	90	85	90	170	85	170	170	170	85	150	150	130	150	170

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3.2.2 Achterhoek region and Arijan Prinsen Farm pilot plant

The pilot plant installation at Arjan Prinsen Farm (APF) is located in the eastern part of the Netherlands in the region Achterhoek (part of the province of Gelderland) in a small village called Haarlo (Figure 13). The Achterhoek region includes the municipalities of Aalten, Berkelland, Bronckhorst, Doesburg, Doetinchem, Lochem, Montferland, Oost Gelre, Oude IJsselstreek, Winterswijk and Zutphen (Figure 13). The region (120.8 km^2) can be seen as mainly rural area because the percentage built-up area and roads is rather low (10%). The remaining area is divided in the following functions: agriculture 88%, nature 11% and water 1%, The main soil type are sandy soils (sometimes slightly loamy). The farms located in this area can be categorized as mainly dairy farms and furthermore pig farms (mostly only pig stables without land) and arable farms. It is known as an intensive agricultural production area.

Figure 13. Location of the Achterhoek region in the Netherlands (left) and the municipalities in the region (right).

Number of farms per animal type

Information of the CBS open data statistics[6] of the Netherlands has been used to calculated the current (average of 2017, 2018 and 2019) manure and NPK production based on the available data of the municipalities in the Achterhoek region. In Figure 14 an overview is shown of the number of animals of the husbandry in the region. There are about 2,100 dairy farms with 246,000 LSU (on average 116 LSU per farm). The pig and poultry farms have respectively, about 2,200 pigs and 51,500 laying hens.

[6] https://opendata.cbs.nl/statline/#/CBS/nl/

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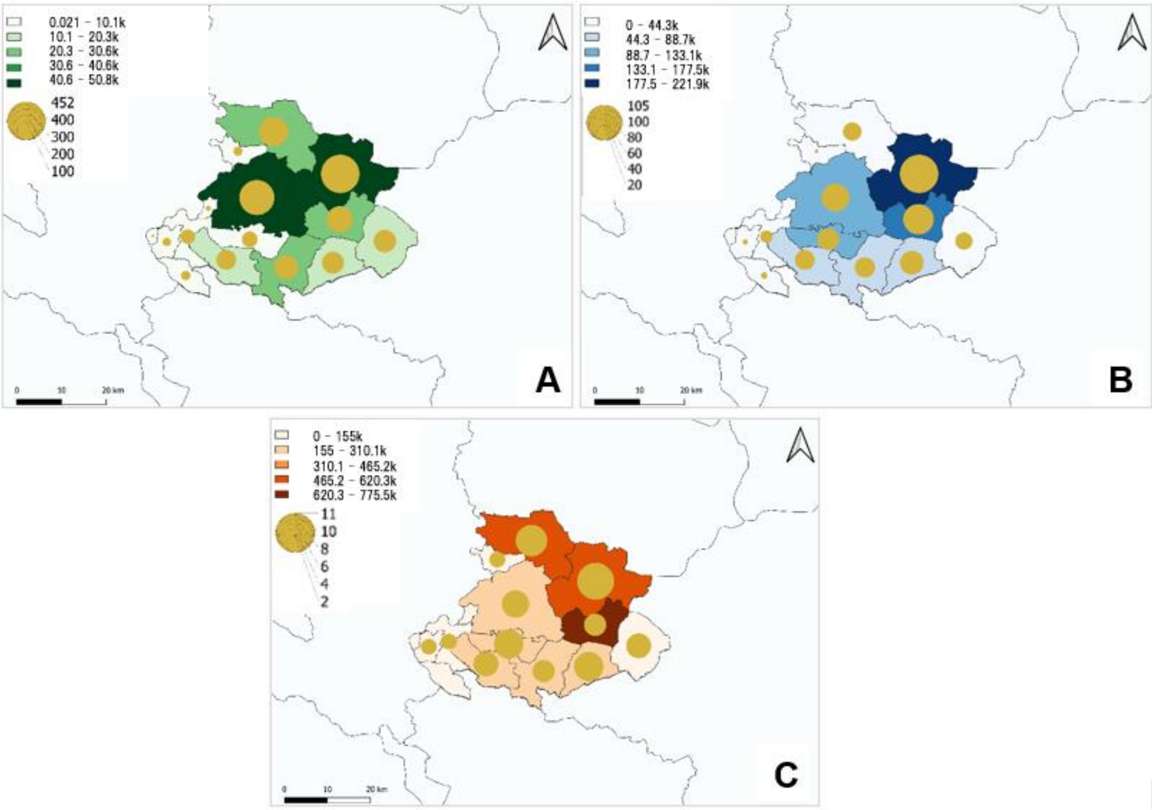

Figure 14. Number of animals (census, colored municipalities) and farms (circles) per animal type (LSU). Dairy cows & beef cattle (A), pigs (B) and poultry (E). Data are an average of three years 2017, 2018 and 2019. Data: CBS Statline 20 April 2020.

Manure production

In the Netherlands farms are obliged to have a mineral balance bookkeeping and Table 3**.** the standardised values of manure production and nitrogen and phosphorus content per animal types are shown which are used for this bookkeeping system[7].

Table 3. Standardized units manure generation for nitrogen (N) and phosphorus (P) per animal type in the Netherlands. Footnotes: (1) one year and older [no data 2 years and older], (2) included breeding sows, (3) turkeys and ducks

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Bovine animals under 1 year old	0.4	32.3	4.19

[7] https://www.rvo.nl/onderwerpen/agrarisch-ondernemen/mestbeleid/tabellen (tables 4 and 6)

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	Bovine animals 1 but less than 2 years old	0.7	66.9	9.56
	Bovine animals Male, 2 years old and over[1]	1	72.2	11.31
	Heifers, 2 years old and over[1]	0.8	66.9	9.56
	Dairy cows	1	111.5	17.73
	Other cows, 2 years old and over[1]	0.8	66.9	9.56
PIGS	Piglets having a live weight of under 20 kg[2]	0.027	n.a	n.a
	Breeding sows weighing 50 kg and over	0.5	14.5	2.79
	Other pigs	0.3	11.7	1.83
POULTRY	Broilers	0.007	0.4	0.06
	Laying hens	0.014	0.76	0.18
	Ostriches	0.35	-	-
	Other poultry[3]	0.03	1.81	0.35

Table 3 gives an overview of the total manure production and the amount of N, P, and potassium (K) minerals produced based on Information of the CBS open data statistics[8] of the Netherlands (regional facts and figures in The Netherlands). Unfortunately, the numbers cannot be linked to the animal types because in these numbers of the animal subcategories are not presented (per municipality).

The total manure production in each municipal is divided into liquid slurries and solid manure. The liquid slurries include all cattle manure (except manure production in the stable of beef cows), pasture manure from sheep, horses and ponies, all pig manure and manure from laying hens in a stable system with liquid manure. The solid manures include farmyard manure from beef cows, sheep, goats, horses and ponies, poultry manure in stable systems with solid manure and manure from rabbits and fur animals.

Table 4. Agricultural area, manure production and excretion of nitrogen (N), phosphate (P2O5) and potassium (K2O) in the Achterhoek region (as an average of three years 2017, 2018 and 2019; data CBS Statline 20 April 2020)

Municipality	Agricultural area (ha)	Manure (liquid) (Mio kg)	Manure (solid) (Mio kg)	N (Mio kg)	P_2O_5 (Mio kg)	K_2O (Mio kg)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg ha)
Aalten	6725	390	7	2.57	0.83	2.54	382	124	377
Berkelland	17756	1127	21	6.90	2.15	7.42	388	121	418
Bronckhorst	19194	978	14	5.53	1.65	6.35	288	86	331
Doesburg	532	19	0	0.09	0.03	0.13	178	50	247

[8] https://opendata.cbs.nl/statline/#/CBS/nl/

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Doetinchem	3715	237	8	1.85	0.66	1.69	499	178	456
Duiven	1388	43	1	0.30	0.10	0.33	214	71	241
Lochem	12265	616	18	3.64	1.11	4.11	297	91	335
Montferland	5596	312	10	2.08	0.67	2.09	372	120	373
Oost Gelre	7926	594	13	3.97	1.31	4.04	501	166	510
Oude IJsselstreek	8507	467	7	2.72	0.85	3.05	320	100	359
Rijnwaarden	2153	48	5	0.31	0.09	0.34	142	42	157
Westervoort	144	1	0	0.01	0.00	0.01	58	19	91
Winterswijk	7711	369	11	2.20	0.68	2.35	285	88	305
Zevenaar	4816	228	7	1.45	0.45	1.85	301	94	385
Zutphen	1469	70	2	0.43	0.14	0.47	296	94	320
Total	**99.897**	**5.498**	**125**	**34.1**	**10.7**	**36.8**	**341**	**107**	**368**

The total agricultural area (Table 4) is about 100,000 ha, while the total N, P_2O_5 and K_2O production is respectively 34.1 Mio kg N, 10.7 Mio kg P_2O_5, and 36.8 Mio kg K_2O. If the total production is divided by all agricultural land, the average mineral production is respectively 341 kg N/ha, 107 kg P_2O_5 per ha, and 368 kg K_2O per ha. But there are significant differences between municipalities (Figure 15). However. this is an overestimation because most of the poultry manure is incinerated or dried and pelleted for export and also a part of the produced pig slurry is (processed and) exported.

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Figure 15. Average mineral nitrogen (N), phosphate (P_2O_5) and potassium (K_2O) production per ha agricultural area (N and K_2O on top and P_2O_5 at the bottom).

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Crop types and agricultural systems

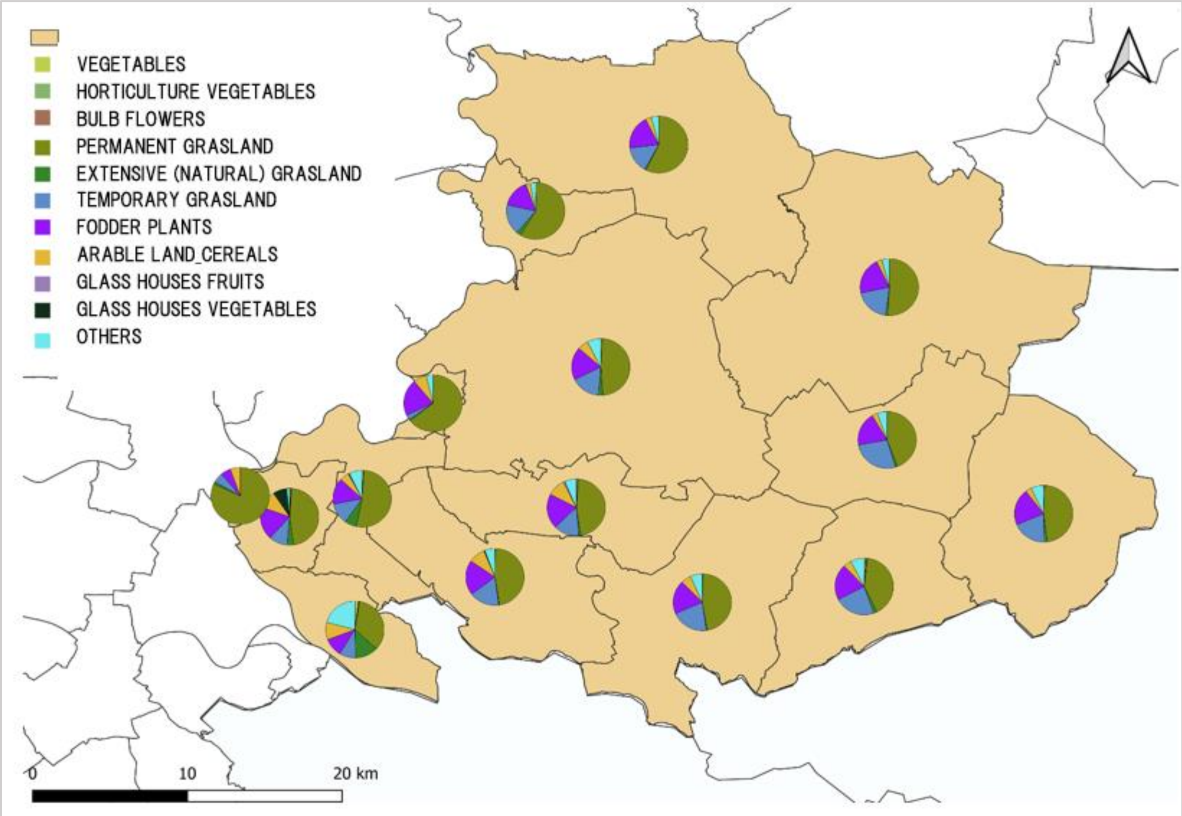

Figure 16. Crop type and systems (ha/municipality) average of the years 2017, 2018 and 2019.

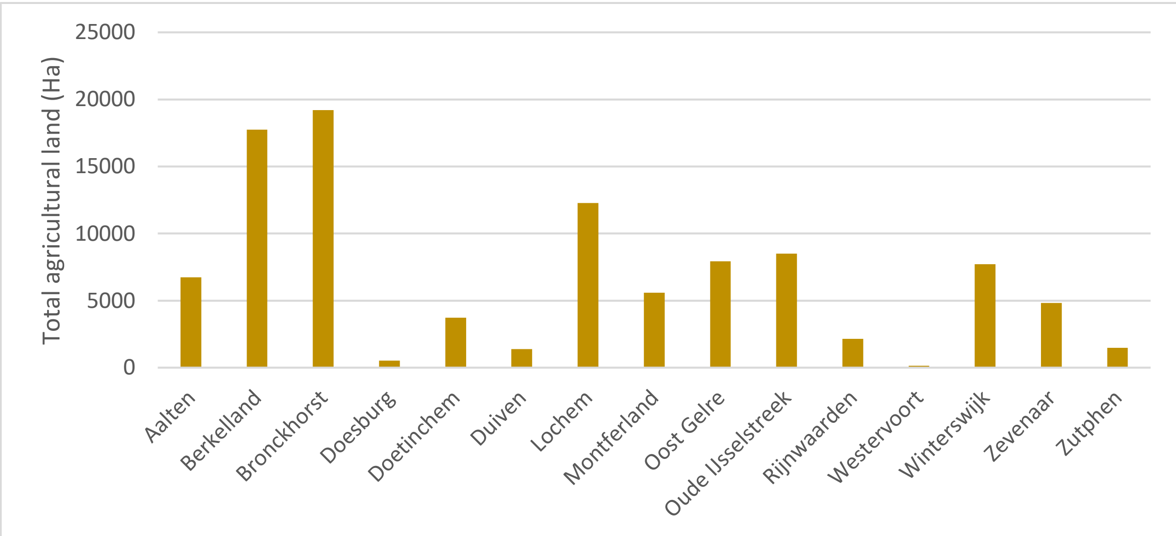

Figure 17. Total agricultural land (hectares) per municipality.

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As seen in Figure 16 the main crops are grassland (69%) and fodder crops (19%) because the dominant agricultural farms are dairy farms. On arable land mainly cereals are cultivated.

Legislation

In the Netherlands the whole agricultural area is designated as Nitrate Vulnerable Zone and in line with the Nitrate Directive the maximum application standard for manure is 170 kg N per ha. Many dairy farms with more than 80% grassland have a derogation and are allowed to apply higher application rates: 230 kg N as manure per ha on sandy and loess soils located in province of Overijssel, Gelderland, Utrecht, Noord Brabant or Limburg and 250 kg N as manure per ha elsewhere. The Achterhoek region is a sandy soil region. In the Manure Act of the Netherlands also maximum application standards for phosphate have been defined. The average phosphate application standards depend on the soil P status and crop type. If the soil P status is sufficient the phosphate application rate is 90 kg P_2O_5 per ha for grassland and 60 kg P_2O_5/ha for arable land. Both are considered as average equilibrium phosphate application rates.

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3.2.3 Oberpfalz – pilot plant in of Sulzbach-Rosenberg

The German pilot is located at the facilities of Fraunhofer UMSICHT in the municipality of Sulzbach-Rosenberg (Figure 18). which is part of the Oberpfalz administrative district in the state of Bavaria. The reference area for the pilot plant is the administrative district of Oberpfalz. In 2016 the total area used for agriculture in Oberpfalz was 391,374 ha with a total number of agricultural units (farms) of 10,458.

Figure 18. Oberpfalz administrative district (in red) of Bavaria. Germany (source: Wikipedia).

Number of farms per animal type

Oberpfalz farming is dominated by poultry, especially in Regensburg Landkreis district in the South (Figure 19). Dairy cows and beef cattle have similar farming intensities. In Oberpfalz there are some farms which have cattle with a double use (both dairy and beef). The structures in pig farming vary greatly between the different regions of Germany. In contrast to eastern Germany the farms in southern Germany are relatively small, whereas the farms in Northwestern Germany are of intermediate size. In Bavaria, pig farming can primarily be found in the southeast.

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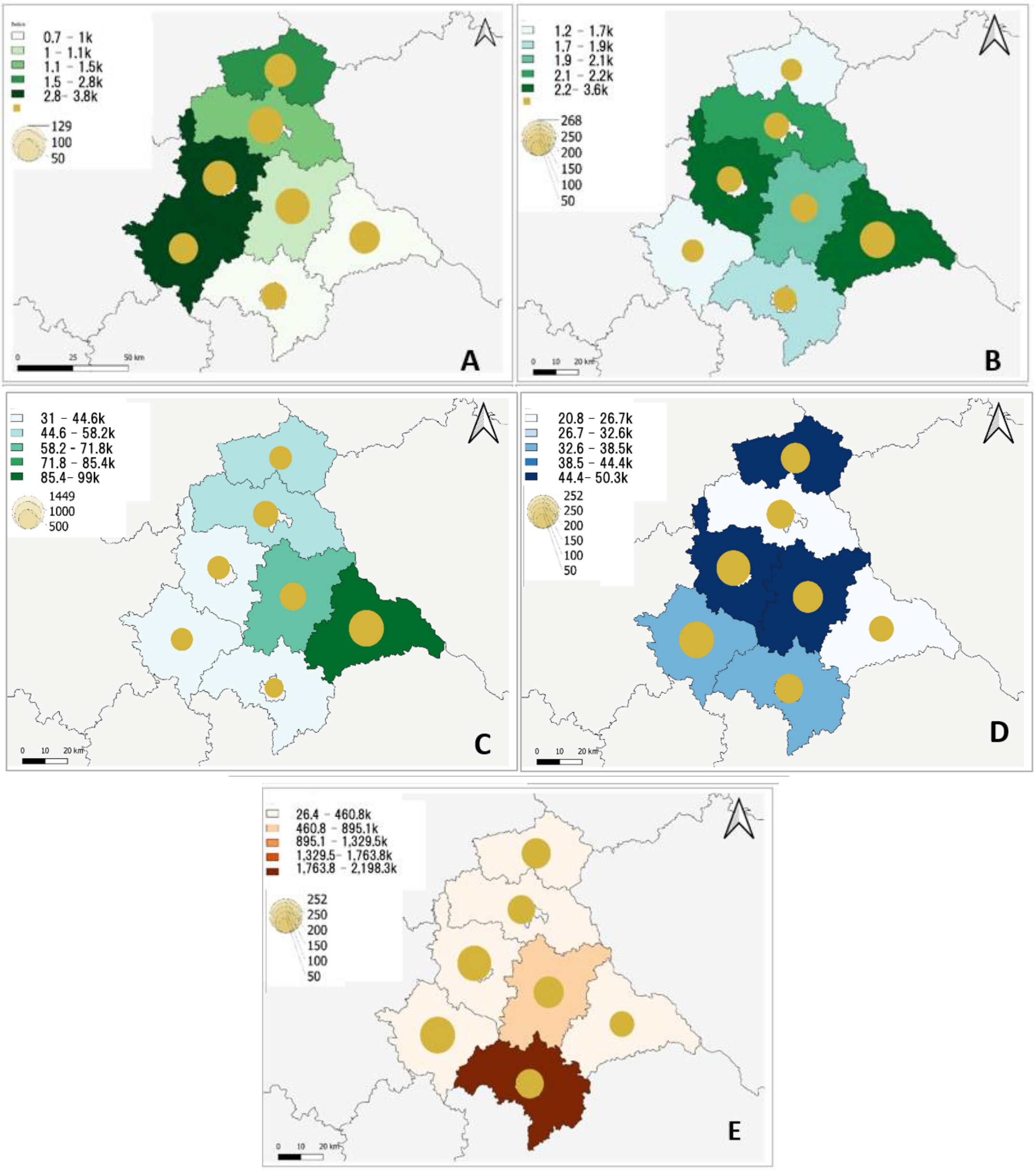

Figure 19. Oberpfalz number of animals (census, colored administrative districts) and farms (circles) per animal type (LSU). Dairy cows (A), beef cattle (B), Cattle double use (dairy & beef) (C), pigs (D) and poultry (E).

Table 5. Table with ranges of nitrogen (N) and phosphorus (P) concentrations per animal type

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Under 1 year old	0.400	11.06	2.87

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	1 but less than 2 years old	0.700	13.20	2.30
	Male. 2 years old and over	1.000	31.27	6.17
	Heifers. 2 years old and over	0.800	No data available	No data available
	Dairy cows	1.000	99.76	17.41
	Other cows. 2 years old and over	0.800	34.22	6.89
PIGS	Piglets having a live weight of under 20 kg	0.027	2.94	0.64
	Breeding sows weighing 50 kg and over	0.500	12.40	3.78
	Other pigs	0.300	9.76	2.68
POULTRY	Broilers	0.007	18.48	7.09
	Laying hens	0.014	47.2	21.12
	Ostriches	0.350	No data	No data
	Other poultry	0.030	33.36	14.64

The amount of N and P generated by manure in each district (NUTS-3) per animal type is shown in Figure 20 and Figure 21. The same patterns are observed in the relative generation of N and P (nutrient densities).

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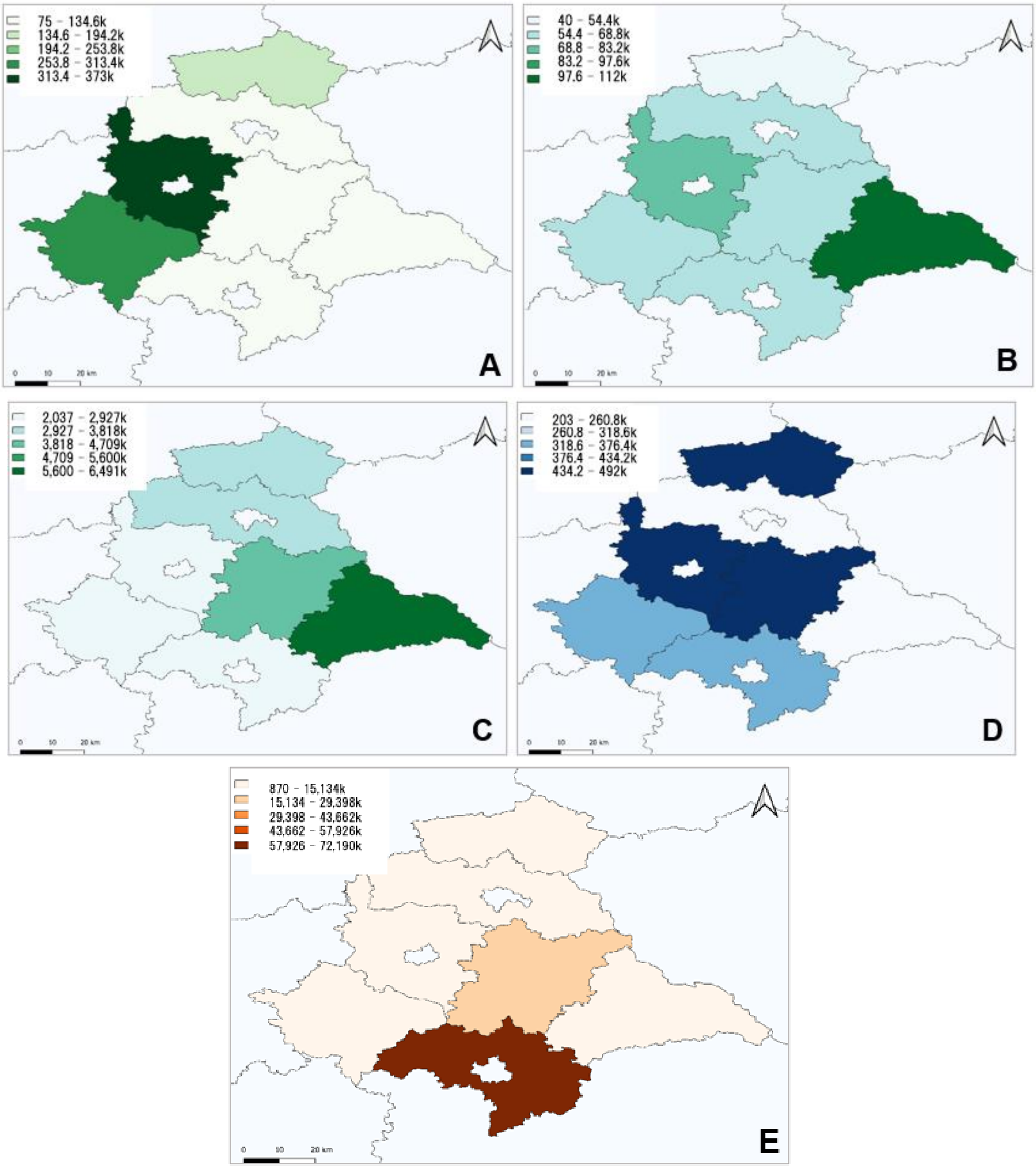

Figure 20. Quantity of nitrogen (kg/municipality) per animal type per municipality. Dairy cows (A), beef cattle (B), cattle double use (dairy & beef) (C), pigs (D) and poultry (E).

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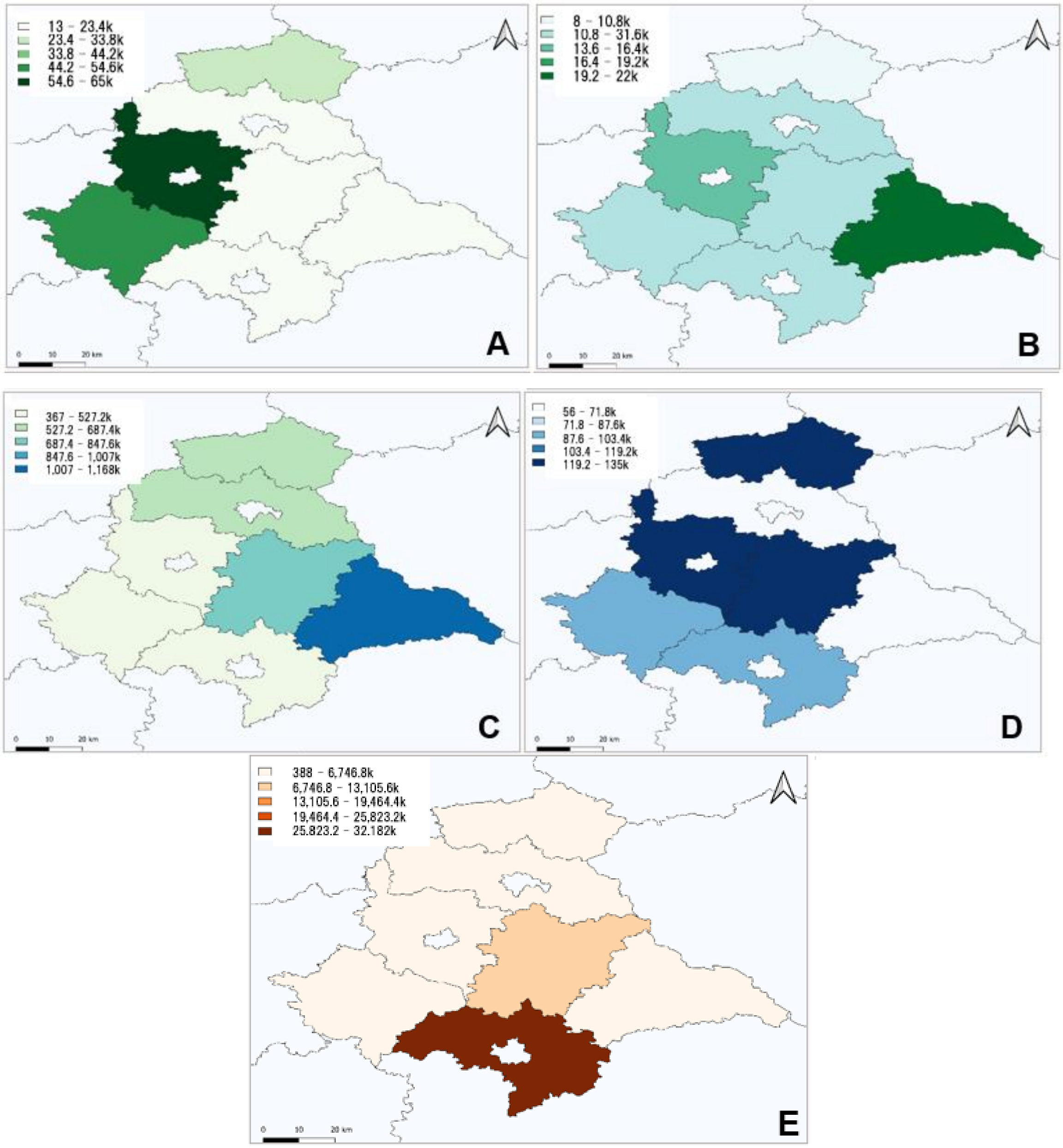

Figure 21. Quantity of phosphorous (kg/municipality) per animal type per municipality. Dairy cows (A), beef cattle (B), cattle double use (dairy & beef) (C), pigs (D) and poultry (E).

Total N and P generation in Oberpfalz are highly influenced by the impact of poultry. There are marked differences between N and P values in the nutrient generation of double use cattle and poultry (Figure 20 and Figure 21).

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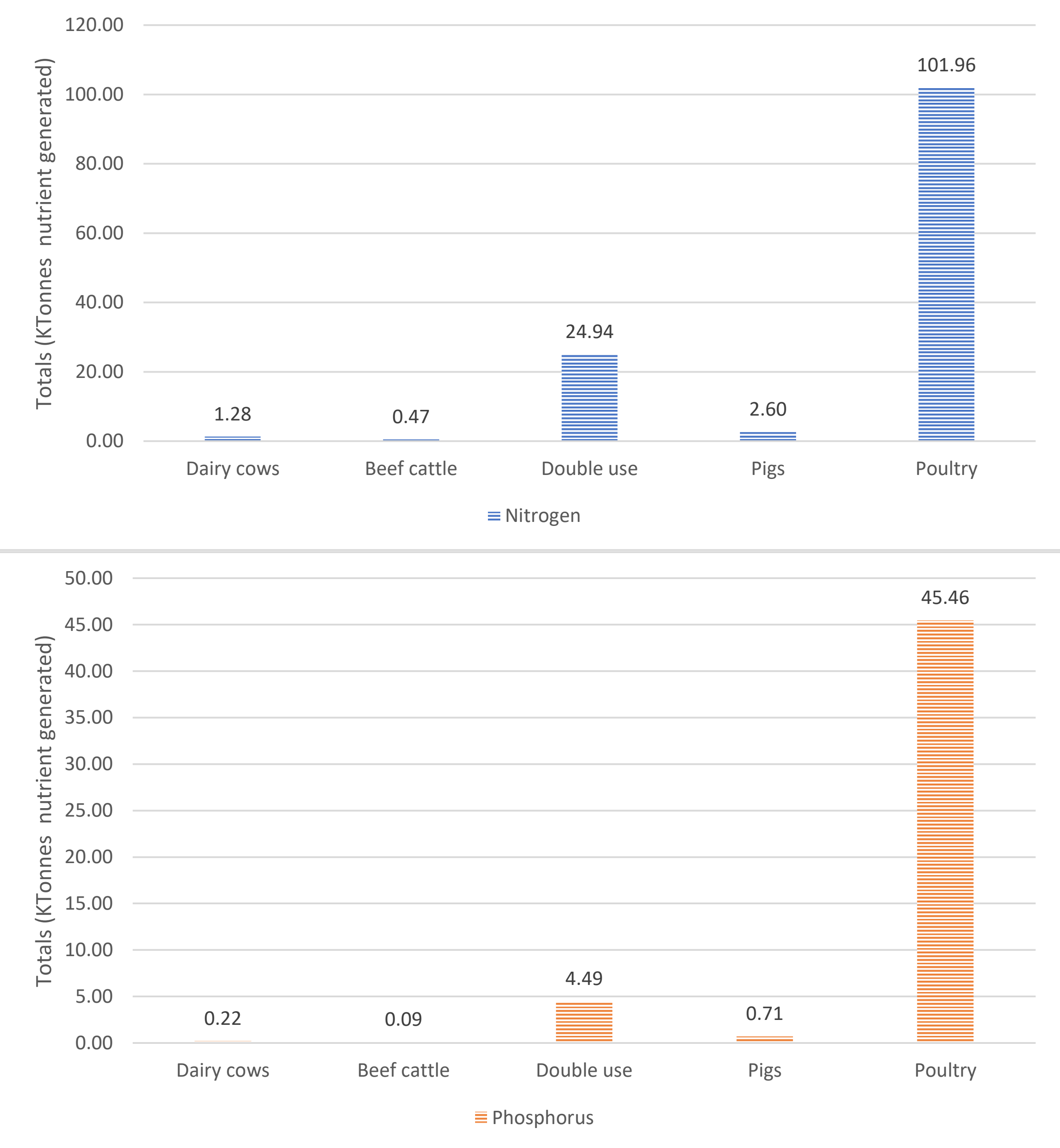

Figure 22. Total quantities of nitrogen (N) (top) and phosphorus (P) (bottom) generated per animal type.

From the above maps and graphs (Figure 22), it is evident that poultry has a disproportional impact on the nutrient generation in the Oberpfalz region. This is followed, at some length, by double use cattle rearing. This observation should be considered when planning regional management schemes, since the primary focus should be on poultry manure.

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In Oberpfalz, most of the agricultural area is used for cultivation of grain and field vegetables (i.e. potato) or is kept as green land for fodder production. Only 462 ha (0.1% of total agricultural area) were used to cultivate other vegetables like salad, cabbage or carrots and even less (about 12 ha) were used for fruit tree production (like apples) in 2012. This kind of agricultural use is negligible, for this reason only data about livestock production and arable land will be consider in the following Figure 23. The collected data were taken from the Bayrisches Landesamt für Statistik[9].

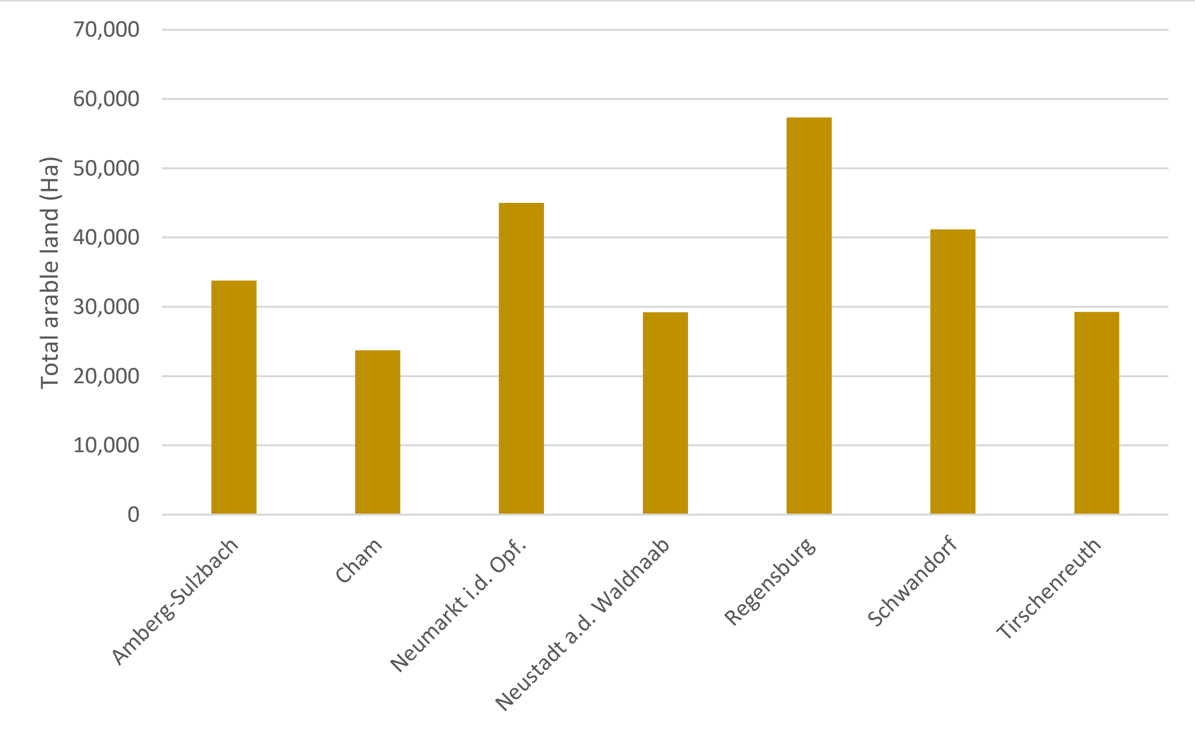

Figure 23. Arable lands in the Oberpfalz region (ha/mun) with no irrigation.

The maximum amount of phosphorus which is applied on fields depends also on phosphorus content in soil. Therefore. no general threshold is given for phosphorus application, rather it is a case-specific value. However, for nitrogen there is a general threshold for the application of manure on arable land of 170 kg N per hectare and year, this includes also the nitrogen from digestate and sewage sludge application. This reference value is based on the German state's fertilising ordinance.

3.2.4 Flanders - pilot plant in Detricon

The dairy sector is the third most important sector in Flanders (northern part of Belgium), after pig farming and vegetable production. About 50-55 % of the total Flemish agricultural area to grow grass and forage maize for this livestock industry. Most of the specialized dairy

[9] https://www.statistik.bayern.de/statistik/wirtschaft_handel/landwirtschaft/index.html#link_4

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farms are located in the province of Antwerp (Noorderkempen). There are also a lot of farms in the Flemish Ardennes (south part of the province East-Flanders) and in the Pajottenland (province of Flemish Brabant).

Flandes pilot plants are located in the following pig farms:

- Tommeleyn they have an ammonium stripper of the air, and thus can produce ammonium sulphate
- Detricon is an ammonia (stripping-)scrubbing unit installation and is the only installation that has an ammonium stripper that strips the liquid fraction (LF) of digestate and LF of manure
- Quirynen Energy Farming is a biogas installation
- Laviedor is located in Ypres. It is a composter, and basically only accepts input streams with high dry matter content

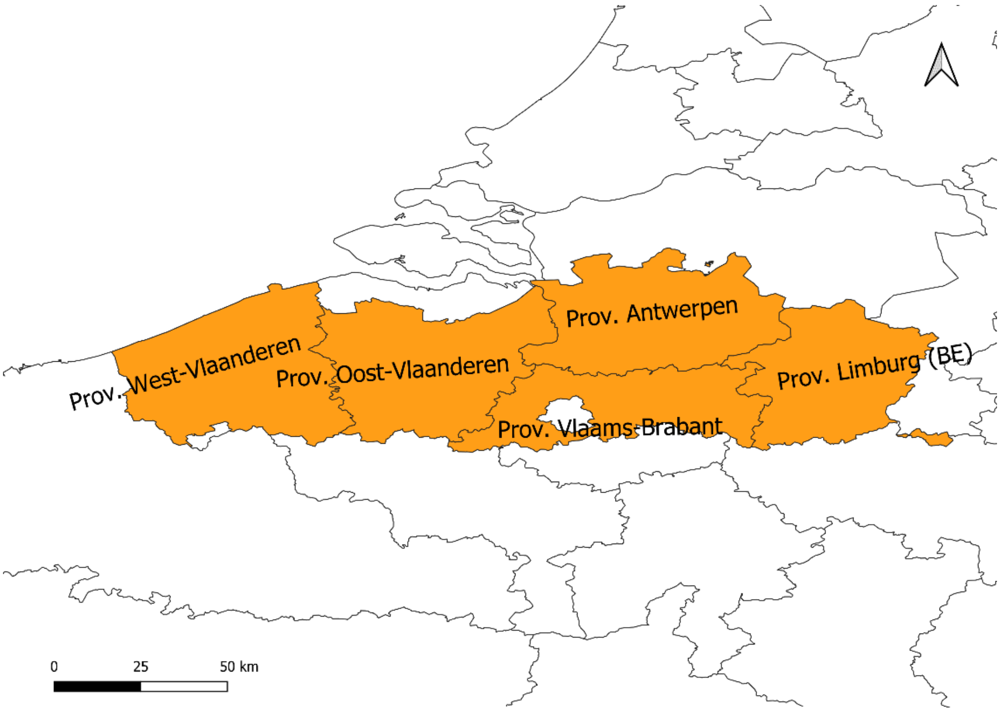

Figure 24. Provinces in Flanders.

Number of farms per animal type

Pig farming is economically speaking still the most important activity within the agricultural and horticultural sector of Flanders. In Flanders about 7,800 farms produce milk of which approximately 4,000 are specialized dairy farms. while others are mixed, most often combining dairy and arable crops[10].

[10] Instituut Voor Landbouw – en Visserijonderzoek, n.d

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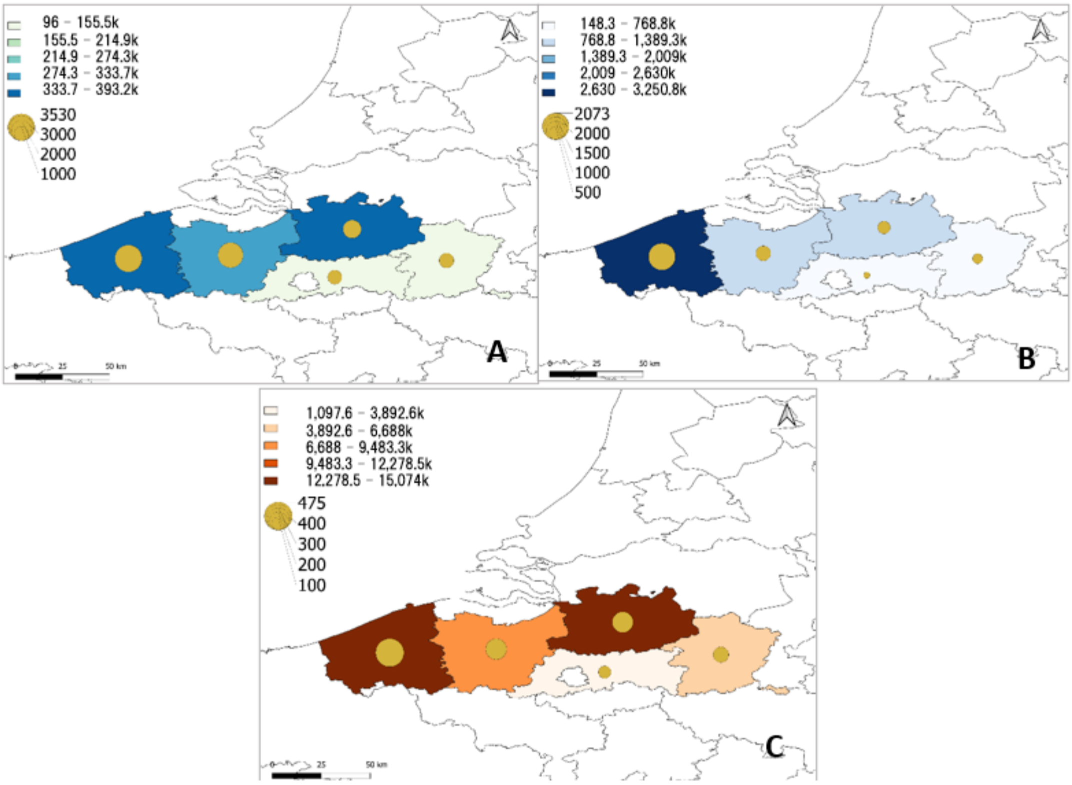

Figure 25. For Flanders region, number of animals (census colored administrative districts) and farms (circles): Beef & Dairy Cattle (A), pigs (B) and poultry (C).

It is seen in the graphics above (Figure 25) that the animal rearing activities of all three sectors – beef and cattle, pigs, and finally poultry – is mainly concentrated in north-west. This could be advantageous for the design of management schemes with collective management and could benefit from concentrating any manure upcycling activities and industries in this zone, for export to other regions with lower pressures.

Table 6. LSU for Flanders region by type of animal.

	Type	LSU
PIGS	Fattening pigs	1,165,671
	Breeding pigs	1,404,984.66
	Piglets	1,404,984.66
CATTLE	Cattle	LSU factor
	Other	630,398.4
	Milk cow	330,696
	Suckler cow	131,830.4
POULTRY	with at least 100 laying hens and pools	174,259.8
	with at least 100 broilers	166,045.3

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Flemish farms are obliged to have records on manure production and composition. Table 7 shows the standardised values of manure production and nitrogen and phosphorus content per animal types which are used for this bookkeeping system. As dairy cows are divided in different groups according their milk production, the mean manure production of all groups was used in Table 7.

Table 7. Table with ranges of nitrogen (N) and phosphorus (P) concentrations per animal type. Source: BE Flanders. Rates of manure excretion from the Action Programme Nitrates Directive 2011-2014 Flanders (region of Belgium). 2011. Footnote: NI: No Information provided

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Under 1 year old	0.400	23	7
	1 but less than 2 years old	0.700	58	19.2
	Male. 2 years old and over	1.000	77	29.5
	Heifers. 2 years old and over	0.800	58	19.2
	Dairy cows	1.000	107	34
	Other cows. 2 years old and over	0.800	58	19.2
PIGS	Piglets having a live weight of under 20 kg	0.027	2.18	1.38
	Breeding sows weighing 50 kg and over	0.500	15.25	29.61
	Other pigs	0.300	NI	-
POULTRY	Broilers	0.007	0.61	0.26
	Laying hens	0.014	0.81	0.45
	Ostriches	0.350	8.6	4.5
	Other poultry	0.030	0.24	0.19

Higher values in Nitrogen production are observed in West- Vlaanderen, followed by Oost-Vlaanderen and Antwerpen. The same pattern is observed in P_2O_5 matching with the higher animal production in these areas. As observed in **Error! Reference source not found.** in Flanders, total nitrogen production is influenced basically by beef & dairy cattle, but there are not differences in P_2O_5 production between type of animals.

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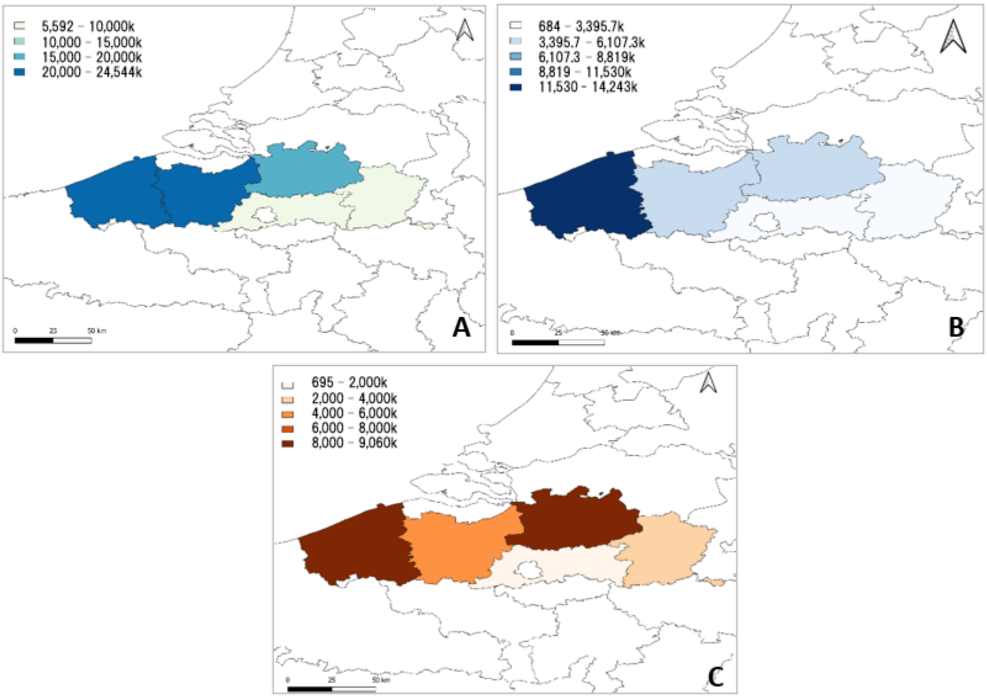

Figure 27. Quantity of nitrogen (N) in kilograms produced in Flanders region. Beef and dairy cattle (A), Pigs (B), Poultry (C).

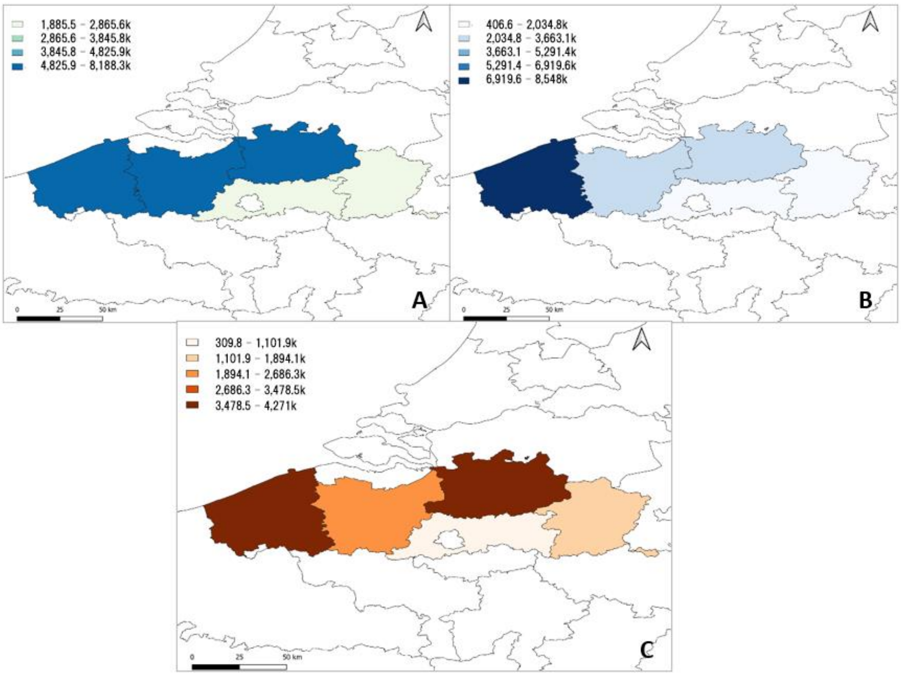

Figure 26. Quantity of P_2O_5 (N) in kilograms produced in Flanders region. Beef and dairy cattle (A), Pigs (B), Poultry (C).

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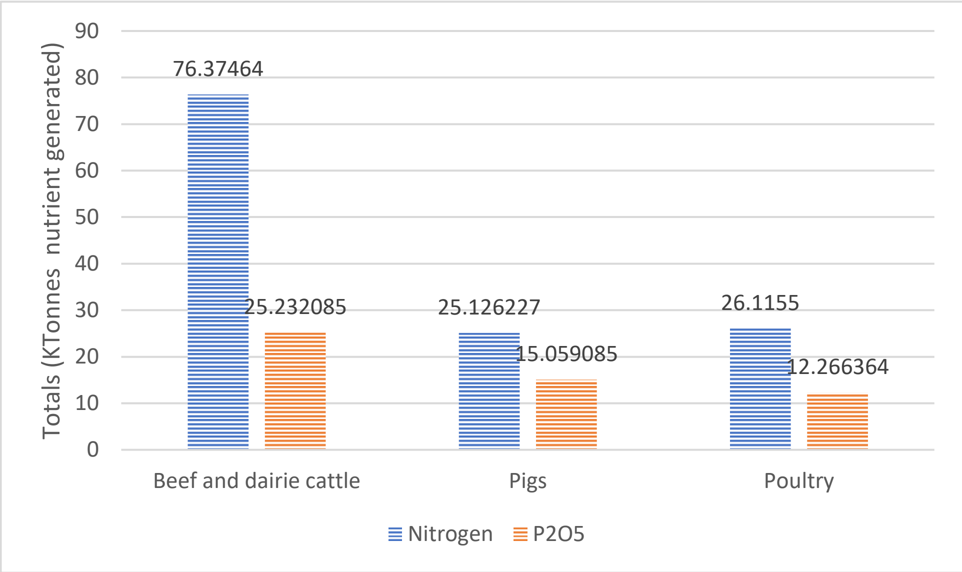

Figure 28. Total gross production of nitrogen (N) and P2O5 in terms of total kg N per animal type

The total agricultural area is about 621000 ha, while the total N and P_2O_5 production is approx. respectively 127.6 Mio kg N and 52.6 Mio kg P_2O_5. If the total production is divided by all agricultural land, the average mineral production is respectively 205 kg N/ha and 85 kg P_2O_5 per ha, but there are significant differences between municipalities.

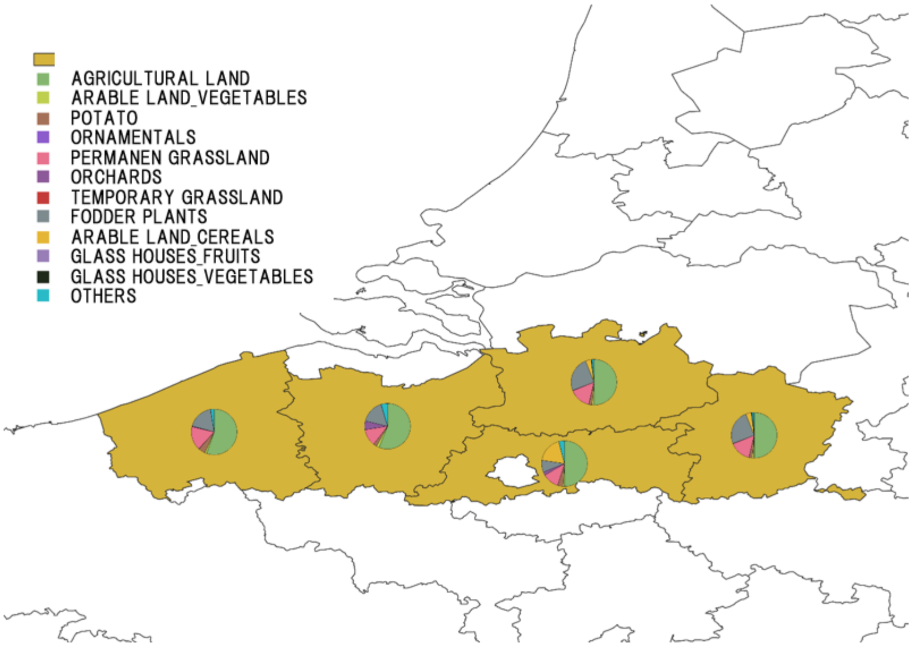

Figure 29. Crop type and systems (ha/mun) in Flanders per region in 2019

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In Flanders, 56 % of the agricultural area is covered with meadows, pasturelands and fodder crops, which is not surprising given the importance of stockbreeding in Flanders, where 35% of the surface area available is allocated to arable farming. The main crops are cereals, potatoes and sugar beet. Horticultural activities are carried out on 8% of the agricultural area, half of which is used for growing vegetables (**Error! Reference source not found.**).

3.2.5 Grand Est and Brittany – mobile farm pilot plants

The French pilot focuses on a technology able to produce secondary products from pig/cattle/poultry manures. The main technology innovations are testing on-farm mobile units for pyrolysis (on solid biomasses like poultry manures) and stripping (directly on liquid phases of slurries or after preliminary step of methanisation). Two units will be tested in Brittany and Grand-Est two leading French agricultural regions (Figure 30).

In both regions, utilised agricultural area accounts for nearly 60% of the total surface area. Moreover, the agricultural models in each of these regions have important structural differences.

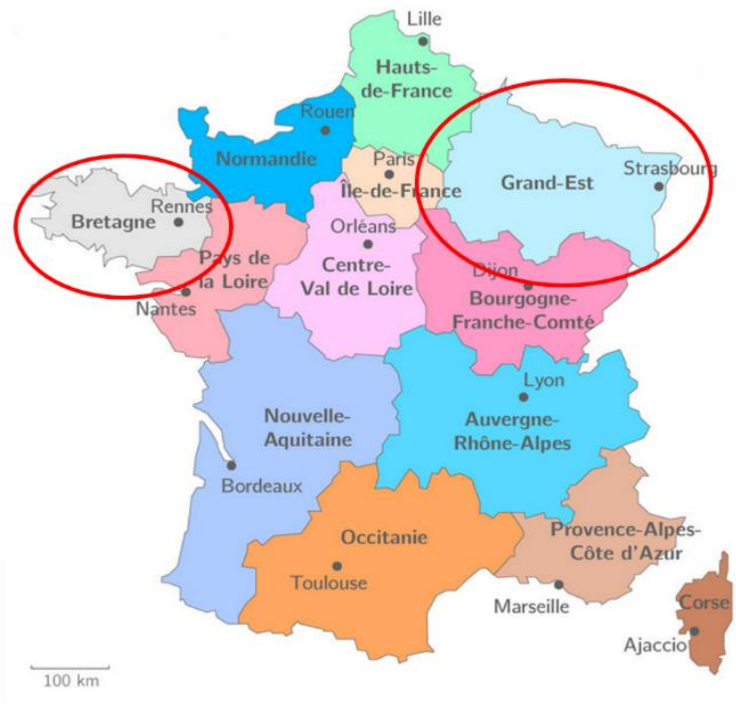

Figure 30. Location of the French regions of Grand Est and Brittany.

In Brittany, livestock breeding is the main activity (58% of French pork and 1 out of 3 French chickens are produced in Brittany). Due to its high livestock density, this region has the

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highest nitrogen and phosphorus levels in France (Figure 32). In the case of Grand East, as observed in Figure 32, broilers chicken productions are the higher in terms of animal production, but livestock productions is dispersed between municipalities.

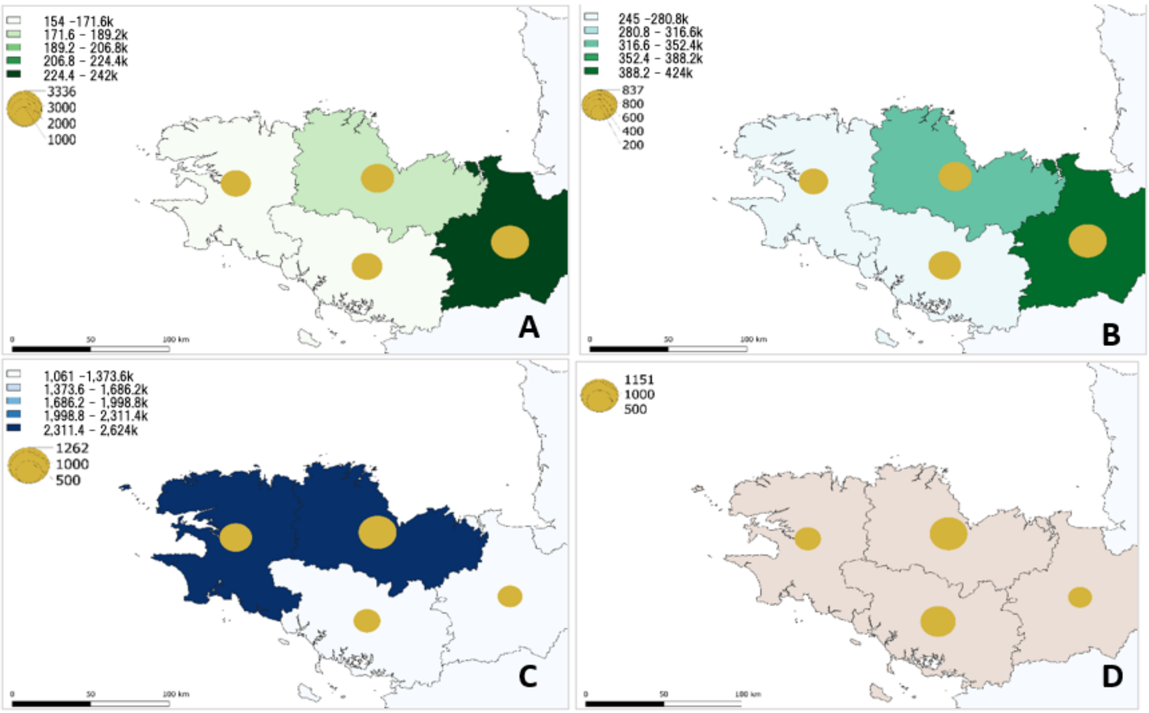

Figure 31. Brittany region number of animals (census, coloured municipalities) (in thousands) and farm number (circles) per animal type (LSU). dairy cows (A), beef cattle (B), pigs (C) and poultry (no data available in number of animals, D). Source : Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt (DRAAF), 2019; Pigs and poultry: RSA, 2010, Bretagne – N° animals: DRAAF, 2019. 2019 (Memento statistique agricole 2018 – productions animales); N° farms: RGA, 2010 (OTEX – exploitations spécialisées).

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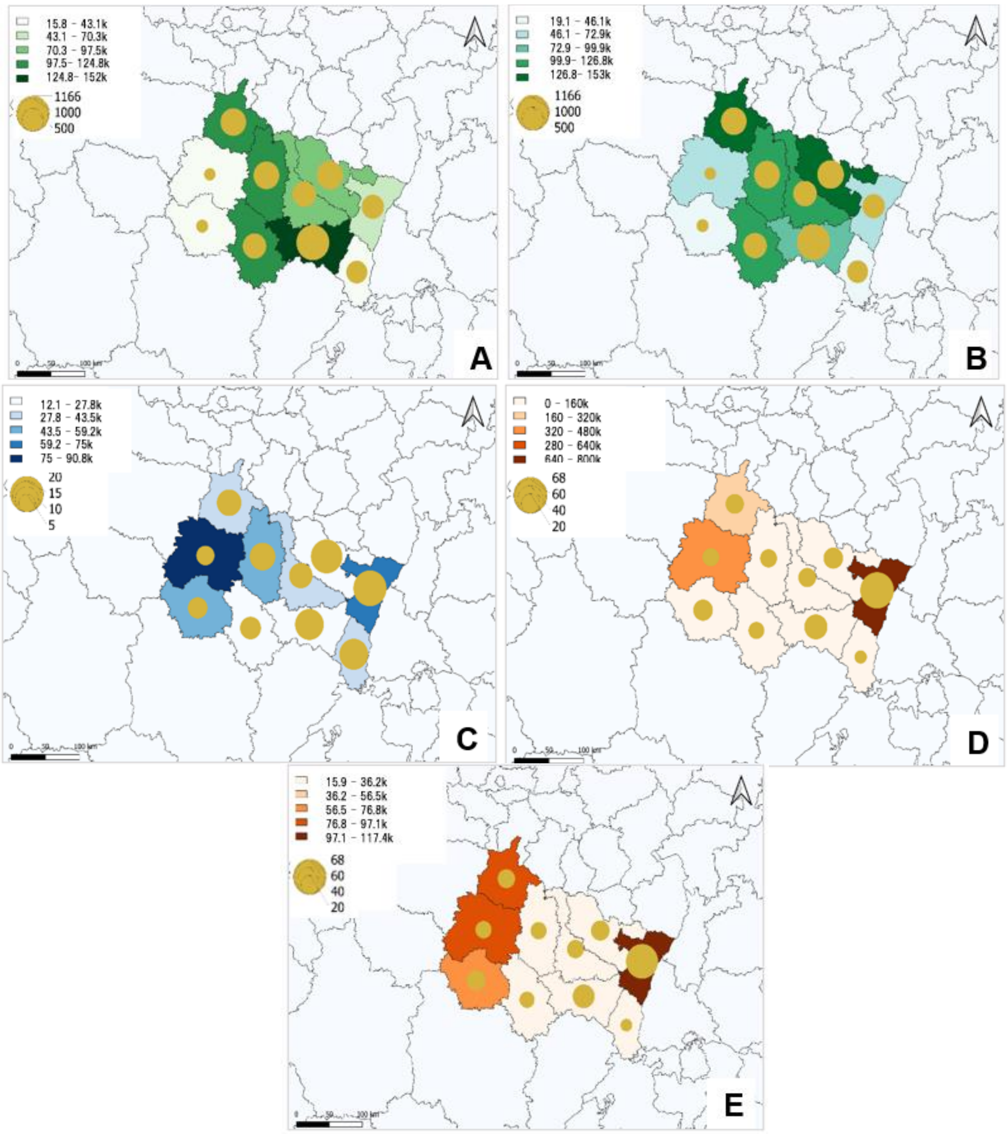

Figure 32. Grand Est region number of animals (census, colored municipalities) (in thousands) and farm number (circles) per animal type (LSU). Dairy cows (A), beef cattle (B), pigs (C), laying hen (D) and broiler chickens (E). Source : Direction Régionale de l'Alimentation, de l'Agriculture et de la Forêt (DRAAF), 2019; Pigs and poultry: RSA, 2010, Bretagne – N° animals: DRAAF, 2019. 2019 (Memento statistique agricole 2018 – productions animales); N° farms: RGA, 2010 (OTEX – exploitations spécialisées).

Table 8. Table with ranges of nitrogen (N) and phosphorus (P) concentrations per animal type.

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Bovine animals under 1 year old	0.4	25	7.00
	Bovine animals 1 but less than 2 years old	0.7	42.50	18.00
	Bovine animals Male. 2 years old and over	1	73	34

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	Heifers. 2 years old and over	0.8	54	25
	Dairy cows	1	100.5	39
	Other cows. 2 years old and over	0.8	54	25
PIGS	Piglets having a live weight of under 20 kg	0.027	0.3	0.285
	Breeding sows weighing 50 kg and over	0.5	15.9	12.50
	Other pigs	0.3	3.4	1.775
POULTRY	Broilers	0.007	0.0635	0.015
	Laying hens	0.014	0.41	0.35
	Ostriches	0.35	/	/
	Other poultry	0.03	/	/

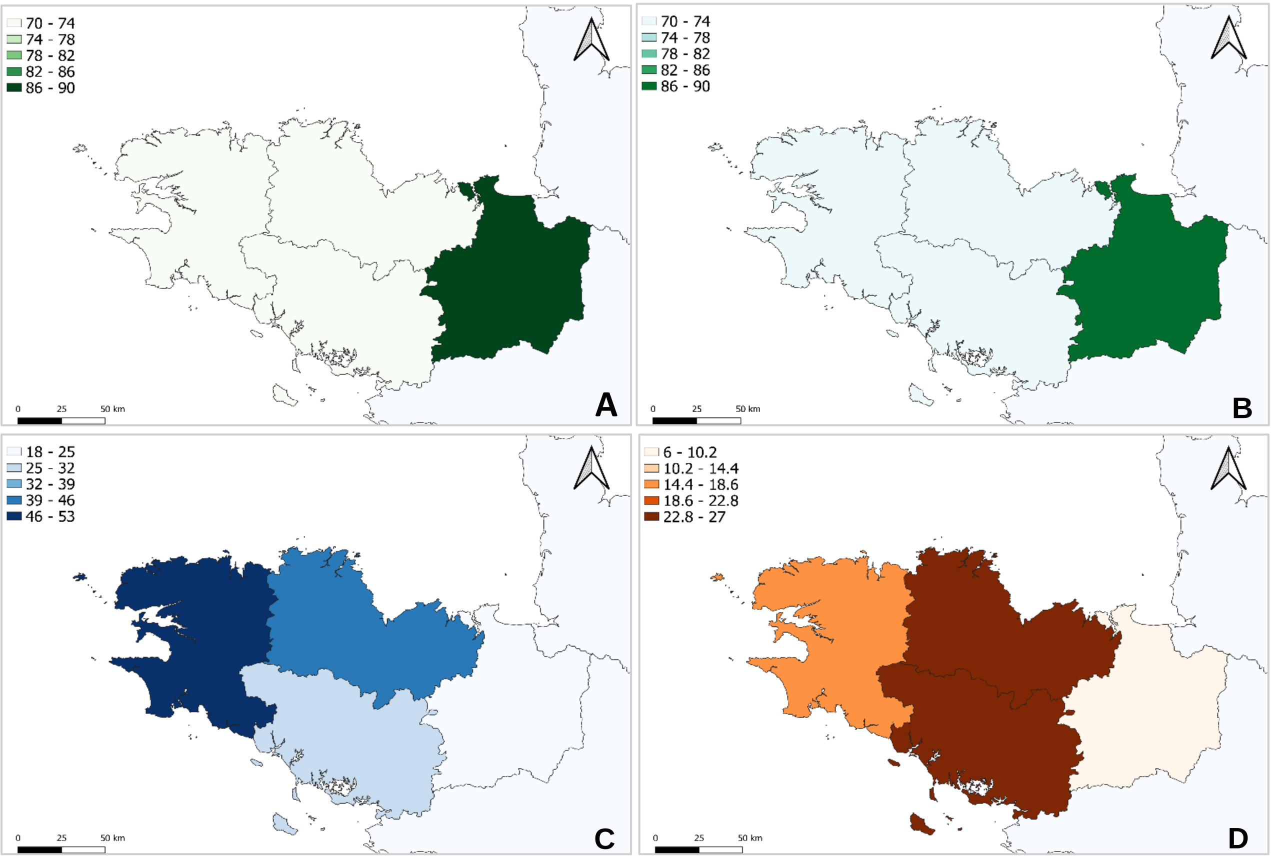

Figure 33. Brittany region quantity of nitrogen (kg N/municipality) per animal type per municipality. Dairy cows (A) beef cattle (B), pigs (C) and poultry (D) Source: Bretagne - Bilan simplifié de l'azote au sol en 2017. Note: no separate data for dairy cows and beef cattle.

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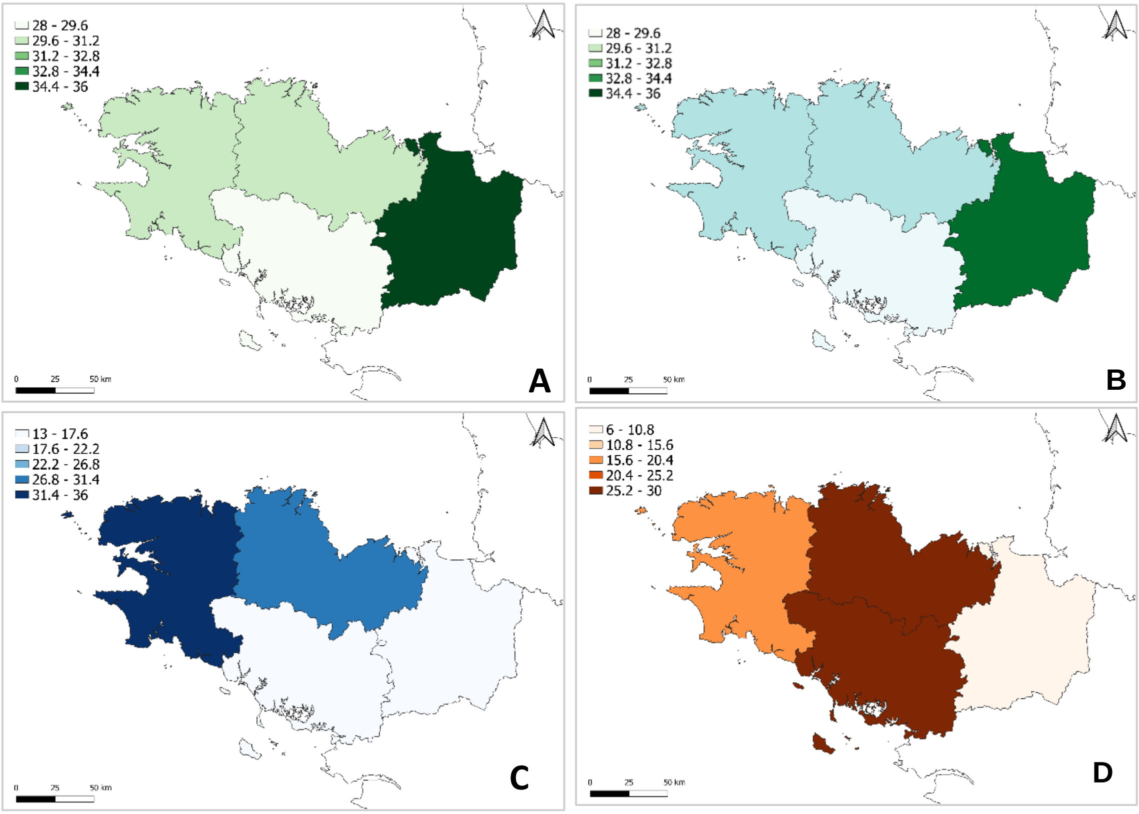

Figure 34. Brittany region Quantity of phosphorous (kg P/municipality) per animal type per municipality. Dairy cows (A) beef cattle (B), pigs (C) and poultry (D) Source: Bretagne - Bilan simplifié de l'azote au sol en 2017, Note: no separate data for dairy cows and beef cattle.

From the graphics above (Figure 33 and Figure 34), it is clear that in the livestock sectors of the French regions, cattle are the most important in terms of nutrient generation. This is particularly the case for the Grand Est region where pig and poultry farming are minimal. In Grand Est livestock breeding is mainly integrated in crop-livestock farming systems and nitrogen and phosphorus surplus are lower than in Brittany (see Figure 36 and Figure 35).

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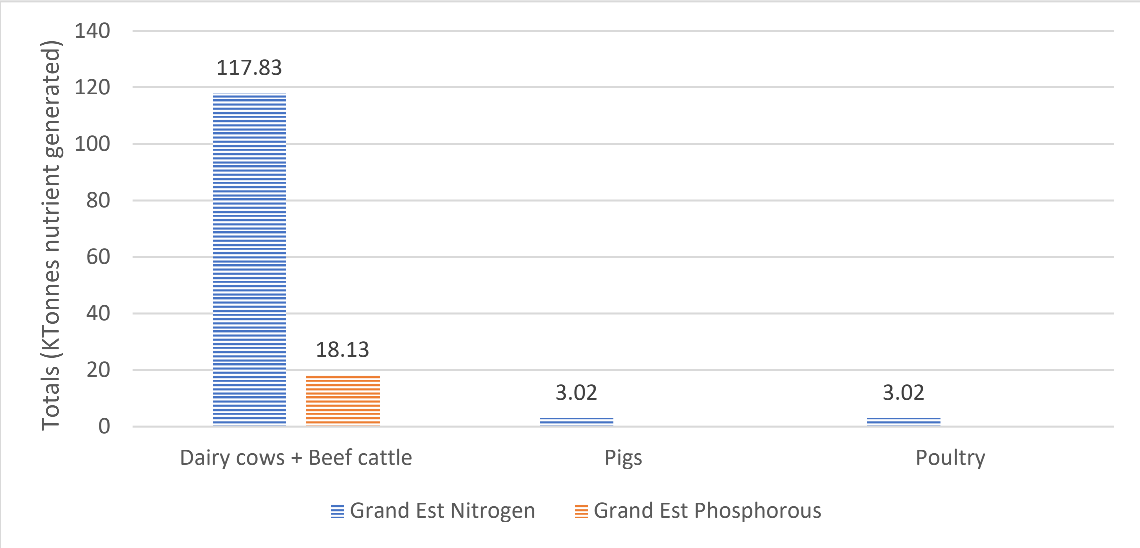

Figure 36. Grand Est region total nitrogen (N) and phosphorus (P) quantities generated per animal type.

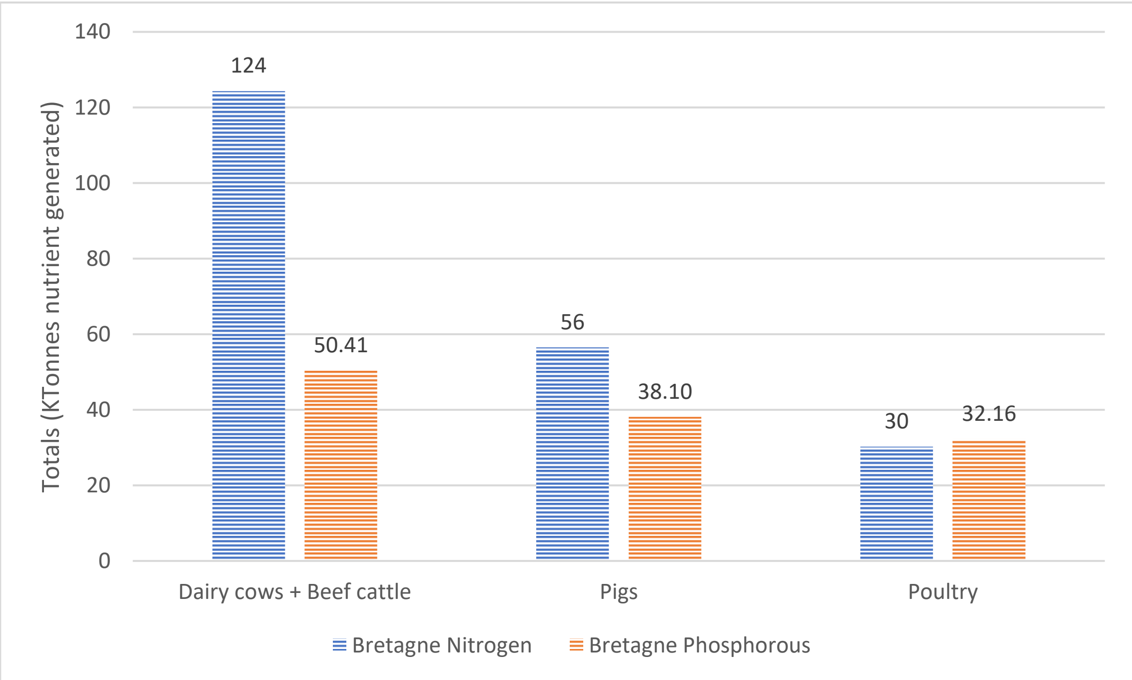

Figure 35. Bretagne region total nitrogen (N) and phosphorus (P) quantities generated per animal type.

In Grant Est region, meadow is the leading crop (see Figure 37). Besides wheat and maize for livestock feeding, Brittany is the leading region for vegetable production (mainly cauliflower, artichoke, shallot, spinach and tomato). Brittany has been designated as a nitrate vulnerable zone. Improving manure processing is the preferred strategy for dealing

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with the high quantity of manure produced, since nutrient densities are high and limited manures can be applied since all Brittany region is an NVZ area. In this region there are even some catchment areas where the limits are as low as 140 kg N (organic and mineral) for arable crops and 160 kg N (organic and mineral) crop-livestock farming systems. This is a highly restrictive situation which requires new, innovative management interventions in order to improve the economic and environmental sustainability of the sector. Grand-Est region is the leading region for cereals and oilseed crops and the second one for wheat, maize, beetroot and potatoes production. It is the first region for wine production in value. The proximity with RITTMO, based in Alsace and responsible for deploying the pilots, makes it easier to find farmers interested to try the technology locally, and then test the products on high added valued crops.

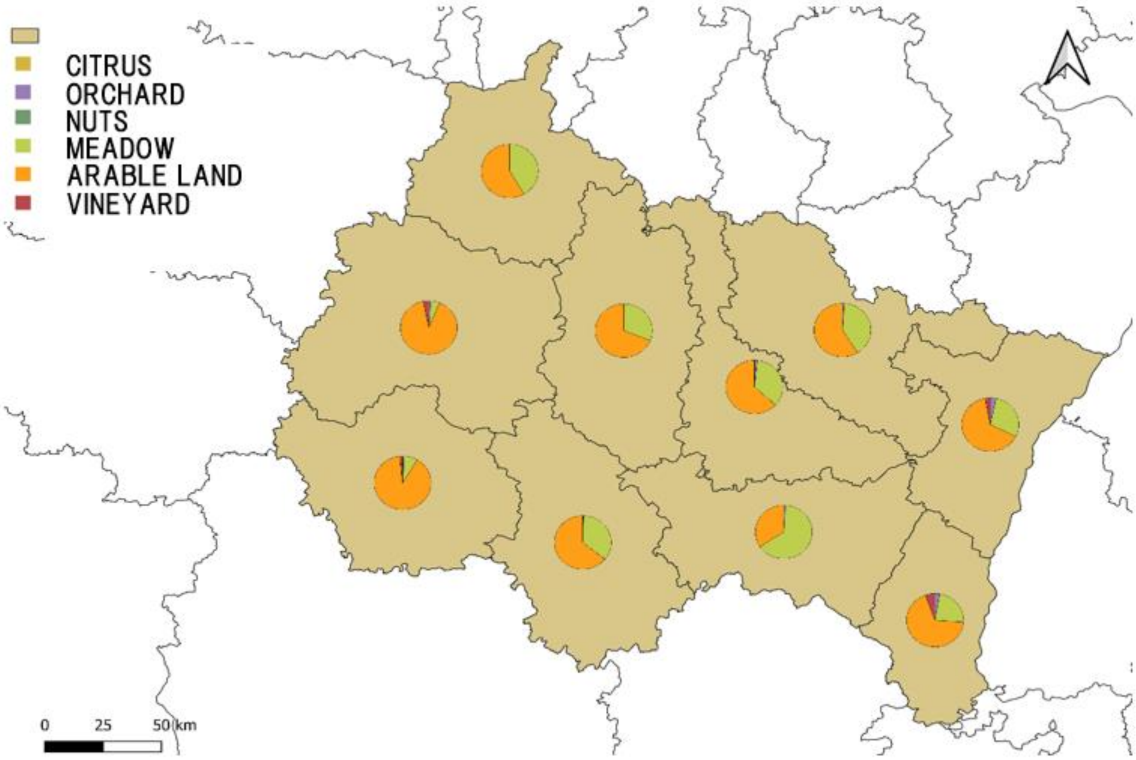

Figure 37. Area of crop types in the Grant Est region. Details : Orchard = permanent crops – vineyards. Source: Grand Est (total values for the region) - Agreste enquête TERUTI occupation du sol 2015. Grand Est departments - Draaf Grand Est-SRISE. Fiches territoriales. 2019.

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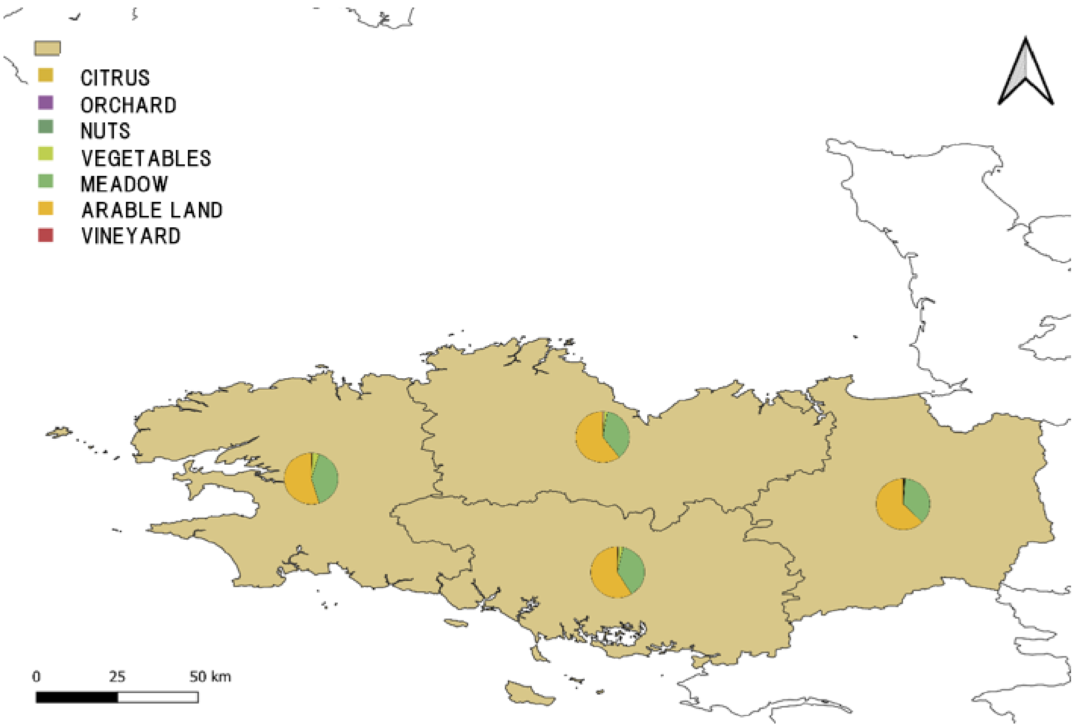

Figure 38. Bretagne region crops with no irrigation. Source: (región + departements) - Agreste enquête TERUTI occupation du sol 2015.

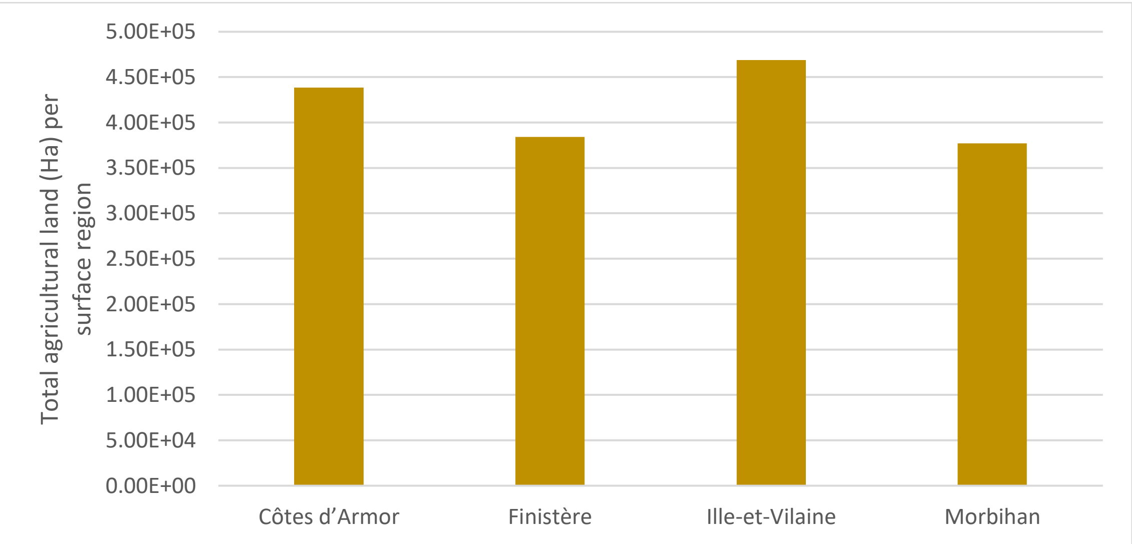

Figure 39. Bretagne region total agricultural land (hectares) per municipality with or without irrigation.

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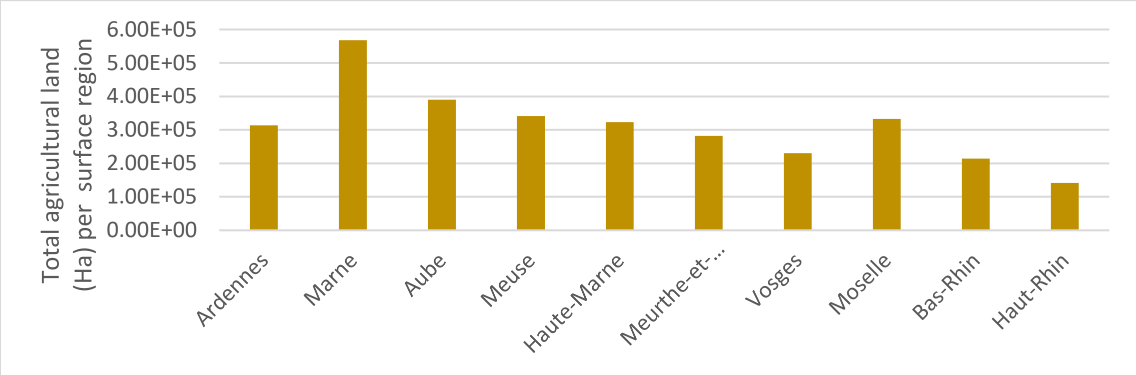

Figure 40. Grand Est region total agricultural land (Ha) per municipality with or without irrigation.

3.2.6 Italy

As mentioned earlier in this document, in Italy there is no pilot plant in FERTIMANURE, but having a significant and relevant livestock sector, the same data has been compiled to carry out the similar descriptive data tasks for the whole of Italy.

Italian agriculture is highly diversified in terms of its main characteristics, especially between northern and southern regions. This diversification ranges, for example, from the intensive, high productivity farming of the northern regions to a less productive situation in the mountain zones and the south of the country, as seen in Figure 41.

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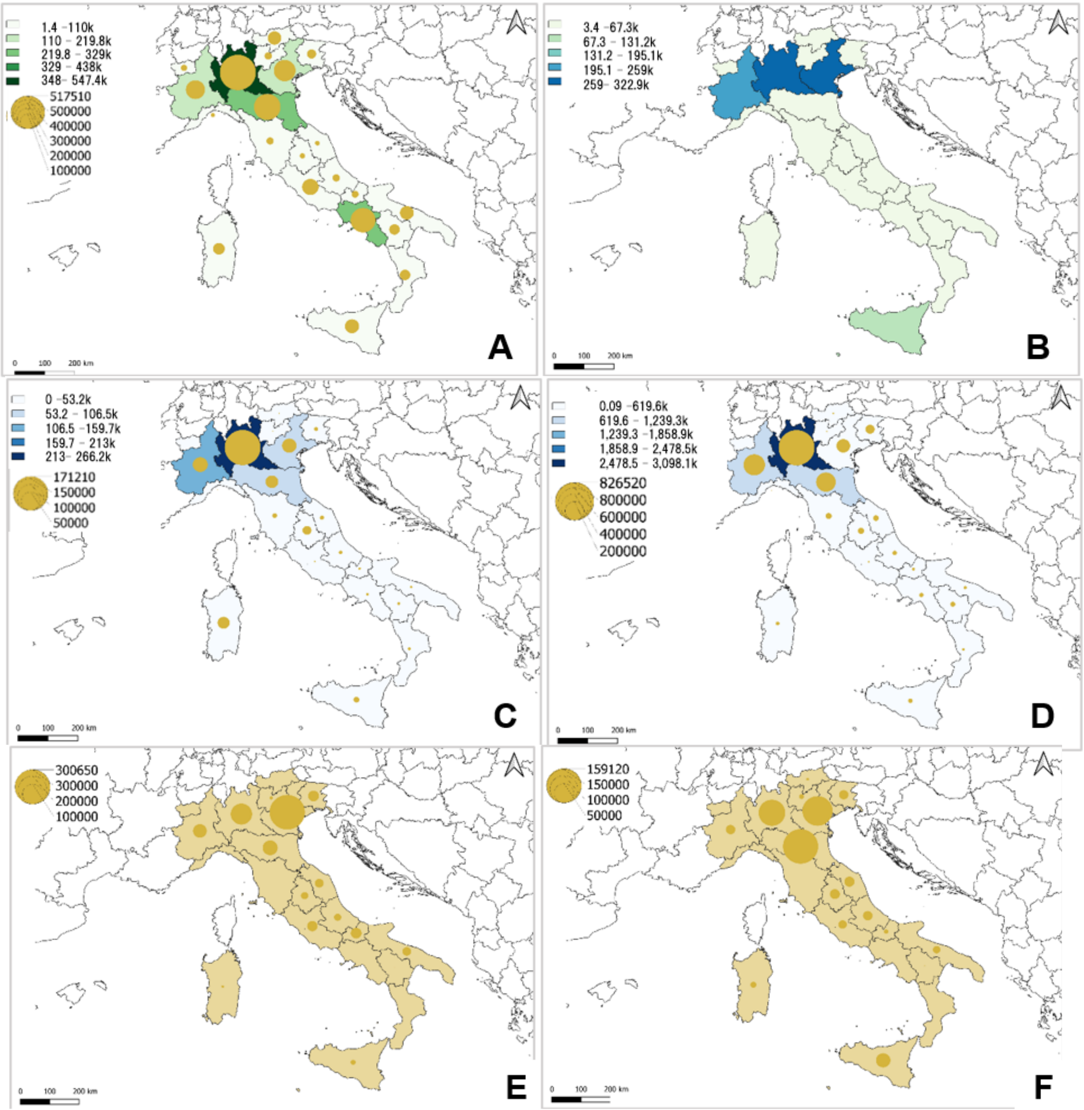

Figure 41. Italy number of animals (in thousands) (census, coloured administrative units)- and farms number (circles) per animal type (LSU). Dairy cows (A), beef cattle = no data available in Nº Farms (B), sow pigs (C), feeder pigs (D), broilers = no data available in number of animals (E) and egg-laying chickens (F).

Table 9. Ranges of nitrogen (N) and phosphorus (P) concentrations per animal type. Data: Livedate_2014_Database N excretion factors

		LSU	Kg N/head year	Kg P/head year
BOVINE ANIMALS	Bovine animals under 1 year old	0.4	15.48	2.16
	Bovine animals 1 but less than 2 years old	0.7	42	
	Bovine animals Male. 2 years old and over	1	50.16	7.49
	Heifers. 2 years old and over	0.8	55.17	7.09

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	Dairy cows	1	108.9	16.15
	Other cows. 2 years old and over	0.8	-	8.88
PIGS	Piglets having a live weight of under 20 kg	0.027	3	1.05
	Breeding sows weighing 50 kg and over (sows)	0.5	23.5	5.8
	Other pigs (fattening pigs)	0.3		
POULTRY	Broilers	0.007		
	Laying hens	0.014		
	Ostriches	0.35		
	Other poultry	0.03		

As expected, N and P production is higher in the northern regions due to the livestock production (Figure 42- Figure 44). In the south, there is only one high N and P density region, which is Campania, where dairy cow production is high. Total nitrogen production impacted by dairy cows, pigs and poultry, while total P is mainly from dairy cows (Figure 44).

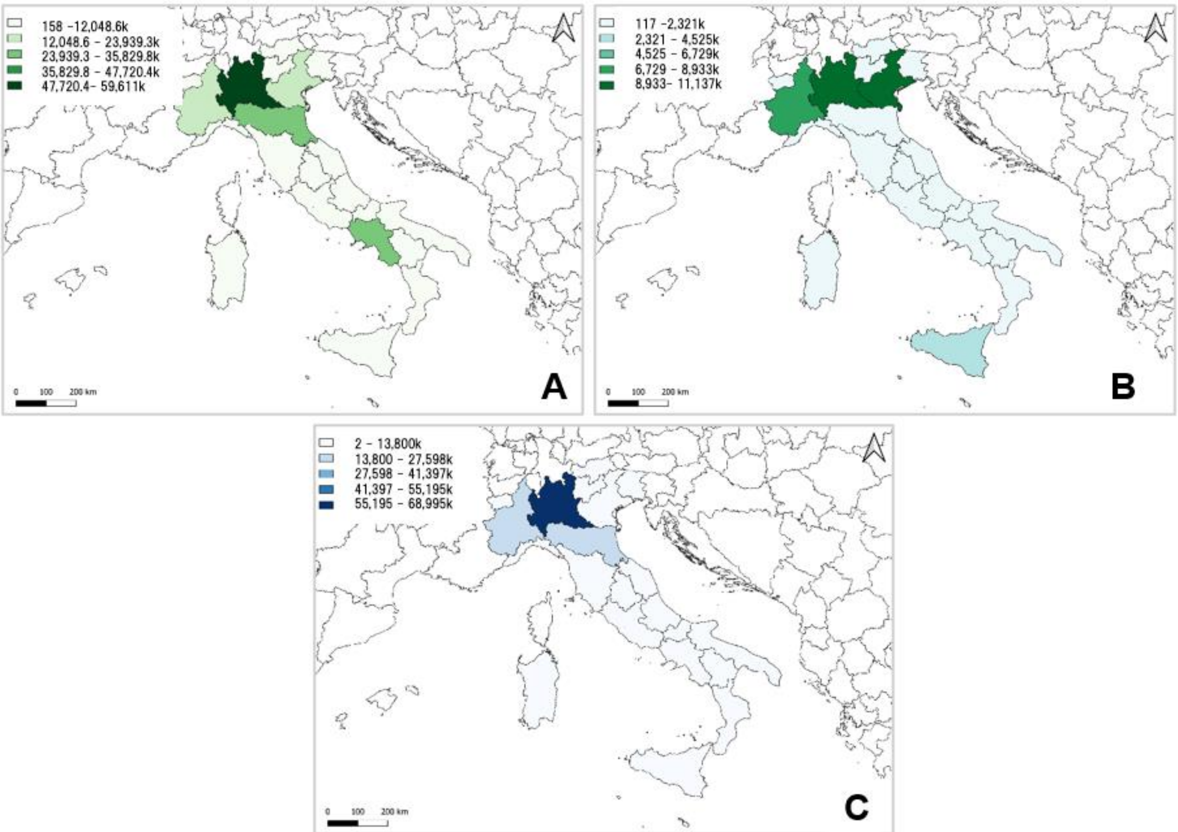

Figure 42. Quantity of nitrogen (thousand kg N/municipality) per animal type. Dairy cows (A) beef cattle (B), pigs (C).

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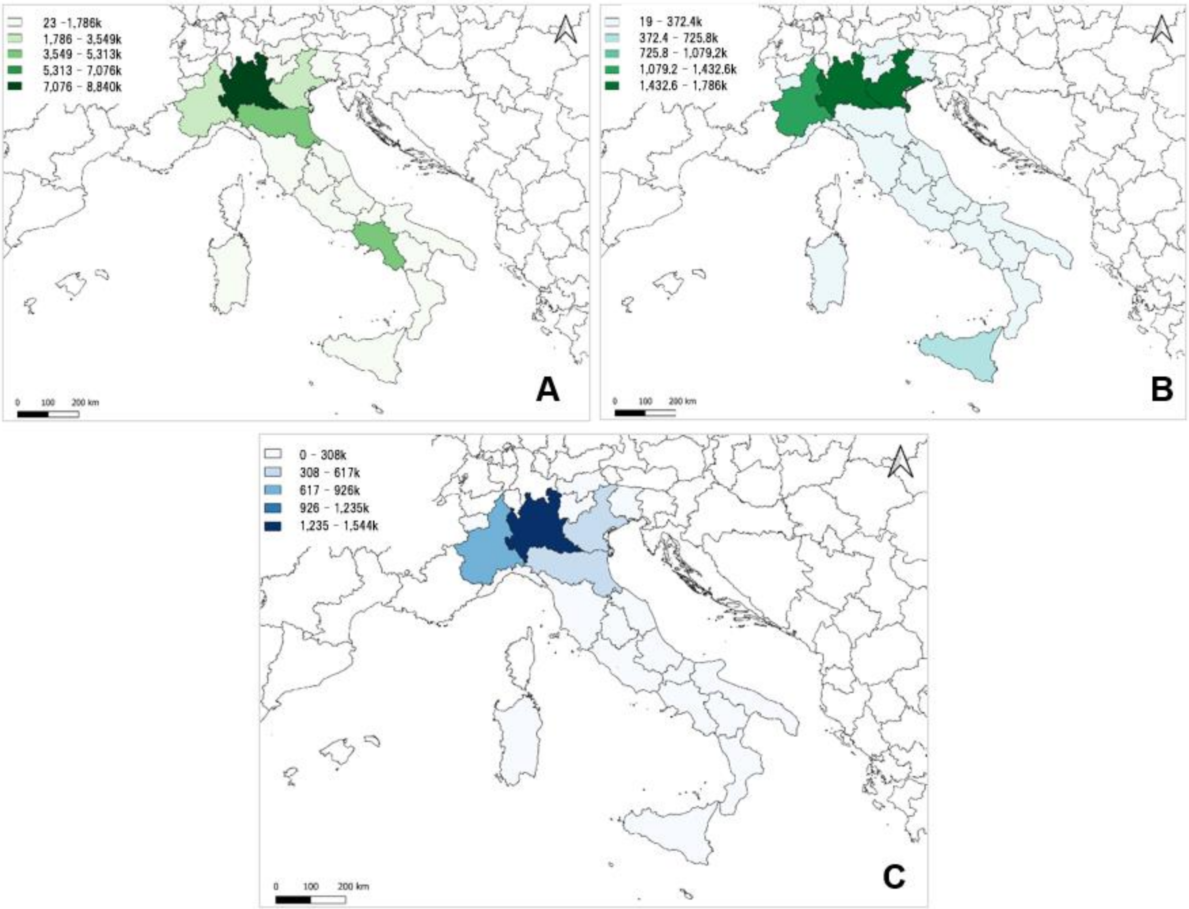

Figure 43. Quantity of phosphorus (thousand kg P/municipality) per animal type. Dairy cows (A) beef cattle (B), pigs (C).

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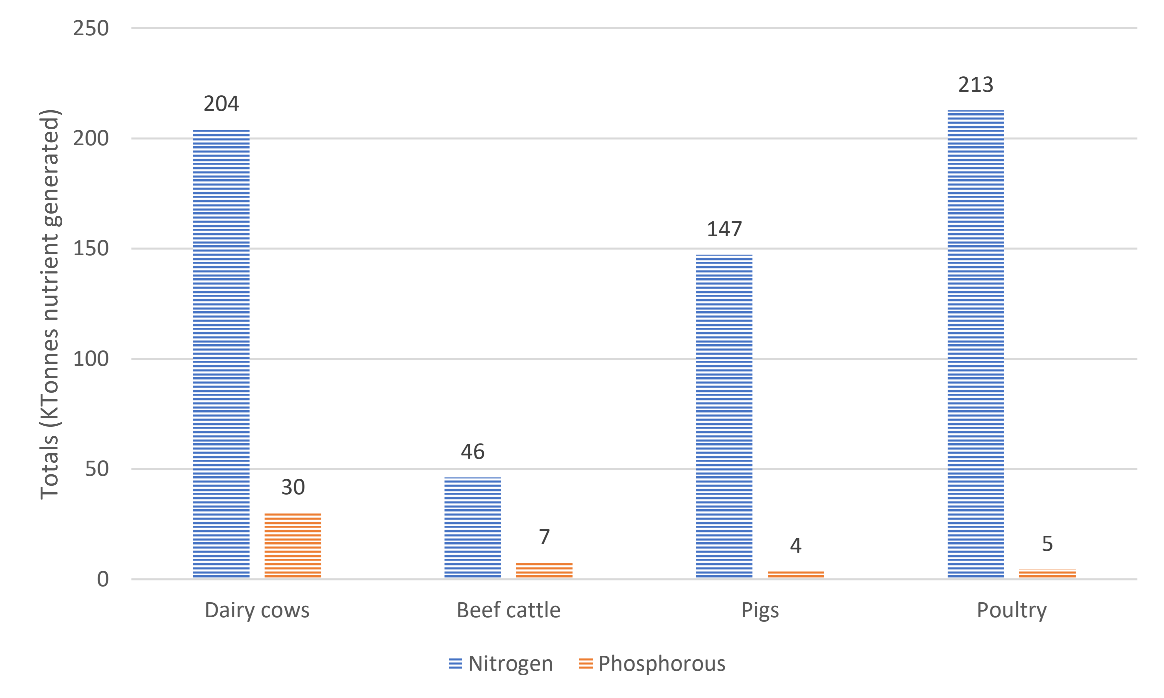

Figure 44. Quantities of nitrogen (N) and phorphorus (P) generated per animal type in Italy.

The northern part of Italy produces primarily grains, grapes and dairy products (orchards), while in the South within arable land, olives and grapes are found to be the main crops (Figure 45).

In Italy, where the agricultural area that is designated as Nitrate Vulnerable Zone, in line with the Nitrate Directive, the maximum application standard for manure is 170 kg N per ha. In the agricultural area that is designated as non-vulnerable zone, the maximum application standard for manure is 340 kg N per ha (see Figure 46).

As regards phosphorus applications, in Italy there is no regulation. The only legal reference is an EU regulation, which also applies Italy, and which states that when you request an exception for the use of nitrogen in vulnerable areas, a phosphorus balance must also be presented.

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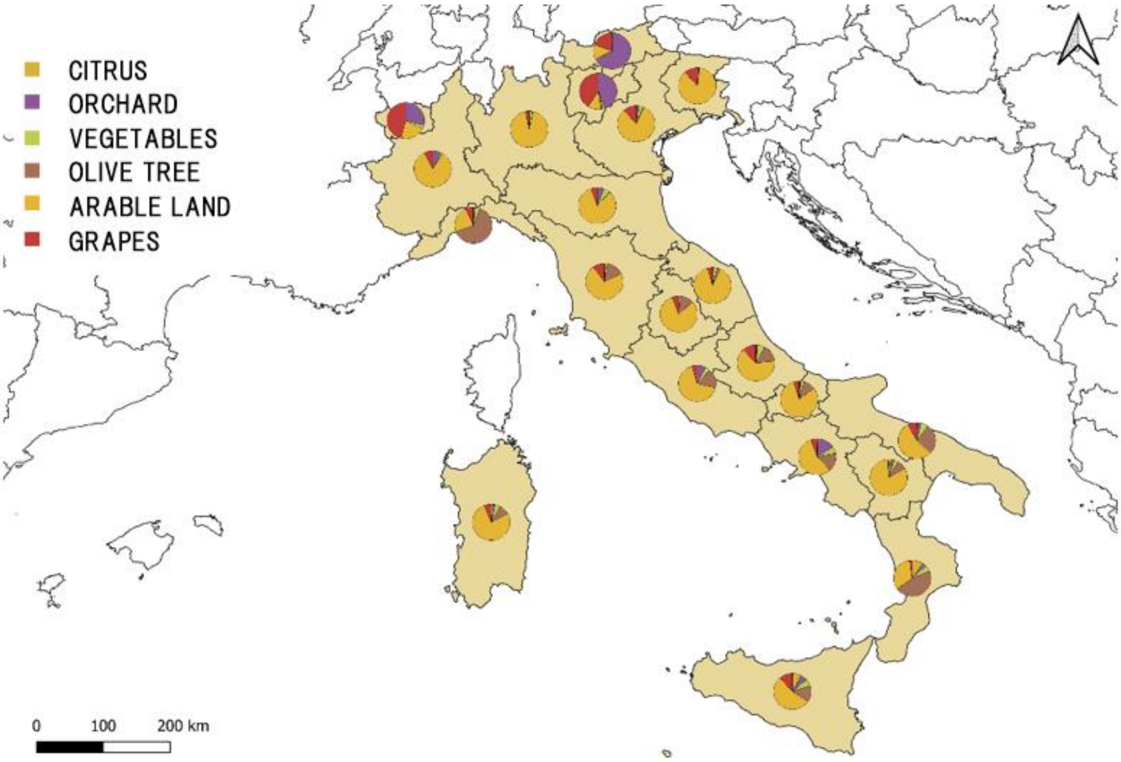

Figure 45. Crop type and systems (ha/regions) average of the years 2016 (Eurostat).

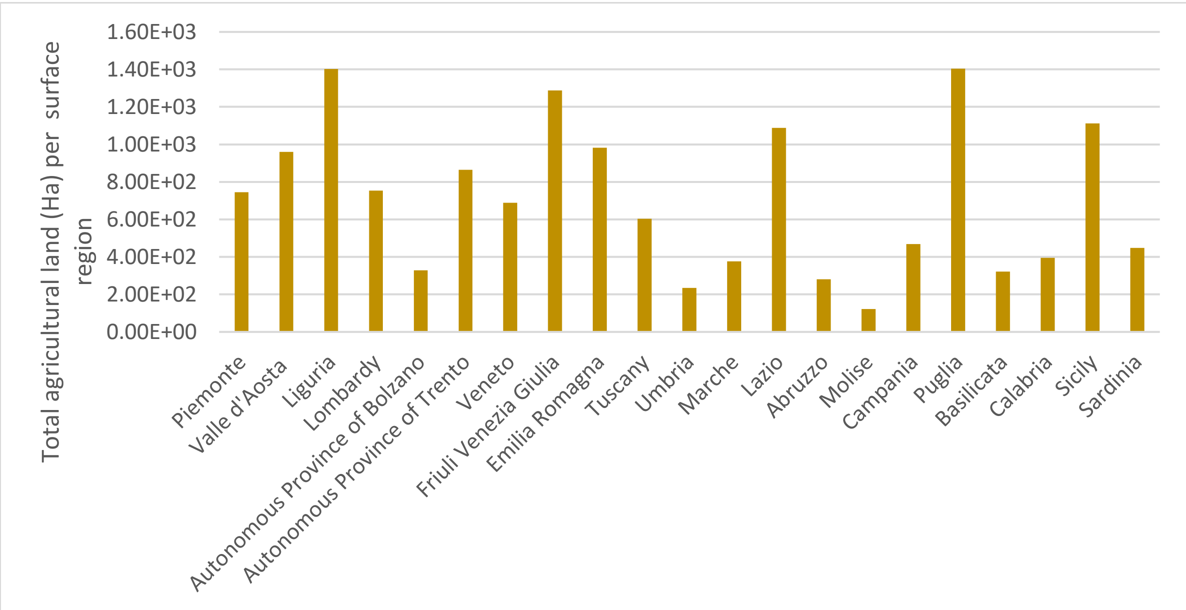

Figure 46. Italy total agricultural land (hectares) per region.

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FERTIMANURE

4. Manure management

Table 10. Current manure management, treatment, and costs from all the regions

Region	Type of treatment	Equipment used	Cost
Spain	Separation	Centrifuge	3 – 4 (€/m3 slurry)
		Ramps	0.35 – 0.75 (€/m3 slurry)
		Screw press	1 – 1.5 (€/m3 slurry)
	Composting		4 – 6.5 (€/ton manure)
	Solar dried		7 – 8 (€/m3 slurry)
	Digestion (only slurry) and electric production (cogeneration)		0.31 (€/m3 slurry)
	nitrification-denitrification		3.6 – 4.5 (€/m3 slurry
Netherlands	Separation (10 000 ton/y)	Drum sieves / screw press	0.75 - 1.5 €
		Sieve belt / centrifuges	2-3 €
	Drying & pelleting	Only solid fraction	8-15€
	Composting	Extensive (outside; months)	6 €
		Intensive (inside; aeration; 1-2 wk)	15 – 25 €
		Incl. pelleting and sanitation	25 €
	Incineration (poultry)	Only poultry	15 -20 €
Germany	Digestion	Biogas plant	Zero cost or recovery of transport cost
	Separation (not widely applied)	Screw press	0.36 to 1.50 €/m3
France	Separation phase[1]	Screw press	20 – 40 k€
		Centrifuge	80 (1.5m3/h) – 150 k€ (5 m3/h
		Drying belt	250k€/year for 1.500 m3 of raw digestate to be dehydrated
			€ 350k for 3,500 m3 / year and € 600k for 10.000 m3 / year.
	Composting		4.6 € /t including:

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		The easiest: Composting at the field (100 T manure)	- Stable emptying, field transport, swath setting 3h30 * 50€ = 175€
			- Composting, turning = 150€ (average hourly time needed)
			- Loading, spreading = 140 €
			460 € / 100 T
	Composting[2]	On farm composting platform (only manure from the farm)	Grinder: 100 – 250 k€
			Turner: 80 k€
			Siever: 100 k€
	Digestion[3]	Too many different equipment and processes	But using averages costs for on farm anaerobic digestion:
			For cogeneration: 30-75 kW= 7 – 13 k€/kW and 80-500 kW = 5.3 – 10 k€/kW
			For injection: 50 – 150 Nm3/h = 30 – 50 k€/Nm3/h
Belgium	Separation	Centrifuge	1.47 - 3.17 €/m³
		Screw press	0.64 - 1.44 €/m³
	Drying	Air dry system + air washer	20.2 €/m³
	Precipitation	CAFR-process	18 .3 €/m³
	Stripping	SMELOX-installation (excl. Separation costs)	4.5 - 5 €/m³
	Composting	Extensive	6.5 €/ton
		Intensive (Aeration)	16.1 - 22.1 €/ton
	Digestion	Biogas installation	8.3 €/m³
	Biological treatment	Only liquid fraction	5.7 - 11.2 €/m³

1Pascal Levasseur (coordinateur). IFIP Institut du porc. Aurore Toudic. Chambre d'agriculture de Bretagne. Stéphanie Bonhomme. Trame Elise Lorinquer. Idèle. 2017. GESTION ET TRAITEMENT DES DIGESTATS ISSUS. DE METHANISATION. Fiches réalisées dans le cadre du projet Casdar « METERRI »
2 CA Occitanie. 2019 december. Guide du compostage à la ferme.
3 ADEME. 2019. RÉALISER UNE UNITÉ DE MÉTHANISATIONÀ LA FERME.

The cost of transportation is a significant factor in manure application. The further the field is from the manure resource, the more expensive it will be to apply it to the field. The nutrient value of the manure will help offset the transportation cost by replacing commercial fertilizer input costs. Unfortunately, soils surrounding livestock facilities often have very high nutrient levels due to excessive manure application. Looking for ways to reduce volume when handling manure, such as composting drying manures, or minimizing dilution of slurries with

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water, all helps make the transport of manures over greater distances more cost-effective and allows nutrients from manures to be more effectively used on fields with lower fertility.

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Table 10. Manure transport costs for each region.

REGION	TRANSPORT TYPE	TYPE OF MATTER	HOURLY COST	COST PER KM?	OTHER ASSOCIATED COTS?
Spain	23-ton truck + spreader	Liquid	65 euros	1.21 €/km (4.26 €/t)	
	16-ton tractor + spreader	Liquid	60 euros	5.50 €/km (2.07 €/t)	
	26-ton truck	Solid Fraction	70 euros	1.13 €/km (3.51 €/t)	
Netherlands	36-ton truck	Liquid	65 euros	0.07	10
Germany	18 m3 truck + spreader	Liquid manure	95 euros	Var. 1.33 €/m^3*km	
				Fix. 1.98 €/m^3	
	13 t truck + spreader	Solid dung	75 euros	Var. 2.50 €/m^3*km	
				Fix. 3.61 €/m^3	
France	18-ton truck[1.2]	Liquid	20 euros	4€ (<30 km)	Spreading: 1.6 €/m3
				3.4€ (40<x<60km)	
				2.2 (80<x<100 km)	
	Spreader 14-16 m3	Solid	20 euros	3 - 6 €	Spreading: 1.2 €/t
Italy	27-ton truck	Liquid	70 euros	2.33	No
	27-ton truck	Liquid	80 euros	2.67	No
Belgium	Transport truck (volume not specified)	Liquid	0.18 euro/km.m^3	10 (disposal costs)	No

1 simulateur de l'IFIP 2 BIEN VALORISER LES EFFLUENTS D'ELEVAGE – guide technique. Décembre 2016. CA Alsace;
2 BIEN VALORISER LES EFFLUENTS D'ELEVAGE – guide technique. Décembre 2016. CA Alsace

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In the Netherlands, manure transport costs per km (Table 10) are based on a transport distance of 80 km with a manure truck of 36 ton, assuming an average speed of 60 km/h, loading/unloading total time of 45 minutes, and no return freight. The other associated costs are related to the intermediate fertilisers activities like storage per ton application. Finally, farmers who receive the manure receive economic compensation, which often varies between 3 – 7 €/ton, but higher values are also paid, depending on the pressure on the manure market. When also taking this payment into account, the overall costs are about 17 - 21 €/ton.

5. Overall conclusions

In this report, information has provided about overall EU nutrient balances and flows to put the manure generation in the proper EU context. Nitrogen and phosphorus excretions as a part of the nutrient fluxes in the European Union have indicated where livestock production has the greatest impact on these nutrient flows.

At the regional scale, livestock density and nutrient loading, along with crop types on agricultural land, are diverse between the regions, all affecting potential advantageous management schemes and business models for manure valorisation. A summary of these differences follows:

- Barcelona is dominated by pig rearing and N and P production is most intensive in the interior part of the region. Osona and Bages are the counties which have the greatest total amount of agricultural land. There are high added-value crops such as vineyard which may serve as markets for improved fertilisers.

- The Achterhoek region has mainly dairy farms and pig farms. The main crop types are permanent grassland and fodder crops.

- Oberpfalz is dominated by poultry and N and P generations are influenced mainly by chicken rearing and most of the agricultural area is used for cultivation of grain and field vegetables.

- In Flanders, pig farming is the most important activity, followed by vegetable production and dairy sector. As expected, gross production nitrogen is influenced by pig raising.

- Livestock breeding in Brittany is the main activity. Due to its high livestock density this region has the highest nitrogen and phosphorus levels in France. Grand Est region livestock breeding is mainly integrated in crop-livestock farming systems and nitrogen and phosphorus surplus are lower than in the Brittany region.

- In Italy, there are significant differences in farming productivities and N and P generation between northern and southern regions, being higher in the northern region and producing primarily grains, grapes and dairy products (orchard).

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Data collected in this deliverable will be used for a number of later tasks, including those which assess different innovative solutions and models on the use, management, treatment, and redistribution of manure and manure sub-products within the pilot regions.

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