REPORT ON NRSS POTENTIAL TO REPLACE MINERAL N AND P FERTILISERS IN THE EU

Deliverable 1.3 – D7 – WP1

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AUTHORS: AURELIEN D'ORIA (AII-RG), NOEMI ARMAL (AII-RG), MUSTAPHA ARKOUN (AII-RG), JUDITH SCHICK (JKI)

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OPTIMISING BIO-BASED FERTILISERS IN AGRICULTURE – PROVIDING A KNOWLEDGE BASIS FOR NEW POLICIES

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Deliverable 1.3 – D7

Work-package n°1

Nature of the deliverable		
R	Report	X
Dec	Websites, patents, filling etc.	
Dem	Demonstrator	
O	Other	

Dissemination Level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

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LEX4BIO aims to reduce the dependence upon mineral/fossil fertilisers, benefiting the environment and the EU's economy. The project will focus on collecting and processing regional nutrient stock, flow, surplus and deficiency data, and reviewing and assessing the required technological solutions. Furthermore, socioeconomic benefits and limitations to increase substitution of mineral fertiliser for BBFs will be analysed. A key result of LEX4BIO will be a universal, science-based toolkit for optimising the use of BBFs in agriculture and to assess their environmental impact in terms of non-renewable energy use, greenhouse gas emissions and other LCA impact categories. LEX4BIO provides for the first-time connection between production technologies of BBFs and regional requirements for the safe use of BBFs.

The project runs from June 2019 to May 2024. It involves 20 partners and is coordinated by Luke (Luonnonvarakeskus - Natural Resources Institute Finland).

More information on the project can be found at: http://www.lex4bio.eu

TABLE OF CONTENTS

List of Figures

List of Tables

D 1.3: REPORT ON NRSS POTENTIAL TO REPLACE MINERAL N AND P FERTILISERS IN THE EU

1. INTRODUCTION

Mineral fertilization is a crucial aspect of modern agriculture, providing essential nutrients to crops and improving yields. However, overuse of fertilisers can have negative environmental impacts, such as polluting water sources and contributing to greenhouse gas emissions. The European Union (EU) has implemented regulations to limit the use of fertilisers in order to mitigate these negative effects.

Indeed, according to the latest information from the European Commission, the consumption of nitrogen (N) and phosphorus (P) mineral fertilisers in the European Union has been steadily increased in recent years (Eurostat). In 2020, the estimated total consumption of N and P fertilisers in the EU was approximately 11.2 million tons, corresponding to 10 and 1.2 million tons for N and P, respectively. This was an overall year-on-year increase of 2.9% compared with 2019 and an increase of 6.9% and 21.9% from 2010 for N and P, respectively. In terms of individual countries, Germany, France, and Spain were the top consumers of N and P fertilisers in the EU, with consumption levels of approximately 2.3, 1.5, and 1.3 million tons respectively.

The consumption of N and P fertilisers is projected to continue to increase in the coming years, driven by growing population and increasing demand for food. Thus, the EU will continue to monitor and regulate the use of fertilisers to ensure sustainable agriculture practices.

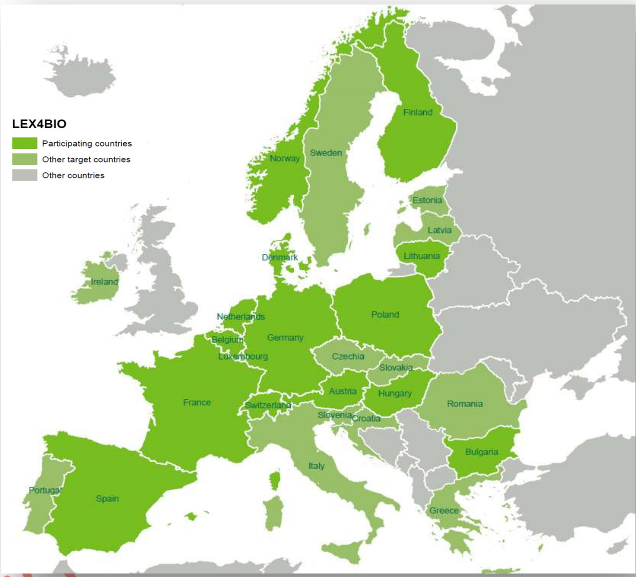
One possible alternative to reduce the need for mineral fertilisers is the use of nutrient-rich side-streams (NRSS) such as agricultural waste or co-products, manure, sewage sludges and biowaste. However, there are also some challenges associated with the use of NRSS as a fertiliser. Most of the NRSS have low nutrient contents even if more efficient bio-based fertilisers (BBFs) from NRSS have been developed. Indeed, the nutrient content of NRSS can vary significantly depending on the source and the treatment methods used. Additionally, there are also concerns about the potential for pathogens and heavy metals to be present in NRSS, which can pose a risk to human health and the environment.

This deliverable provides an overview of the consumption of mineral fertilisers in the EU, including trends over time and usage by individual countries, based on official national or European statistics. The objective of the current report is to evaluate the theoretical potential of NRSS for replacing mineral N and P fertilisers on a national scale for LEX4BIO participating countries, with respect to data from the Natural Resources Institute Finland (Luke) database in relation to availability of NRSS as determined in Task 1.1.

2. METHODOLOGY

2.1. Data collection

The first step was to collect the main figures of mineral fertiliser from European official statistics as EUROSTAT, FAO and National Statistics web sites (**Table 1**) for collecting information about:



- Utilized agricultural area (UAA ; hectares); for all EU countries, 2007-2016
- Estimated mineral fertiliser consumption by agriculture (tonnes); EU-27, 2010-2018
- Estimated mineral N fertiliser consumption by agriculture (tonnes); for all EU countries, 2010-2019
- Estimated mineral P fertiliser consumption by agriculture (tonnes); for all EU countries, 2010-2019
- Nutrient (N and P) inputs per hectare UAA (kg of nutrient per ha); for all EU countries, 2008-2017
- The most common (major) crops (in terms of UAA); for LEX4BIO participating countries, 2019
- The share of each crop in total UAA (%); for LEX4BIO participating countries, 2019
- The common N and P fertilisers used in each LEX4BIO participating country; Most recent data possible (between 2011 and 2019)
- The fertiliser recommendations per hectare per year: the amount of N and P/ha/Y applied for each crop; no complete data

Table 1: The main online data sources used related to fertilisation statistics on a national scale.

Participating Countries	url links of data sources relative to NP fertilisation (statistics, national report, website)
Finland	http://statdb.luke.fi/PXWeb/pxweb/en/LUKE/LUKE__02%20Maatalous__04%20Tuotanto__22%20Kaytossa%20oleva%20maatalousmaa/01_Kaytossa_oleva_maatalousmaa_ELY.px/table/tableViewLayout2/?rxid=001bc7da-70f4-47c4-a6c2-c9100d8b50db
Germany	https://www.bmel-statistik.de/landwirtschaft/tabellen-zur-landwirtschaft https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Industrie-Verarbeitendes-Gewerbe/Publikationen/Downloads-Fachstatistiken/duengemittelversorgung-jahr-2040820197004.pdf?__blob=publicationFile
Denmark	https://www.statbank.dk/statbank5a/default.asp?w=1920
The Netherlands	https://opendata.cbs.nl/statline/#/CBS/en/dataset/80783eng/table?ts=1633436791881
Switzerland	https://www.agrarbericht.ch/de
Spain	https://www.mapa.gob.es/es/estadistica/temas/estadisticas-agrarias/agricultura/superficies-producciones-anuales-cultivos/

Hungary	https://www.ksh.hu/stadat_files/mez/en/mez0008.html
Belgium	https://statbel.fgov.be/fr/themes/agriculture-peche/exploitations-agricoles-et-horticoles#figures
Norway	https://www.ssb.no/en/jord-skog-jakt-og-fiskeri/jordbruk/statistikk/gardsbruk-jordbruksareal-og-husdyr
France	Agreste - Eurostat – UNIFA
Lithuania	https://osp.stat.gov.lt/statistiniu-rodikliu-analize?hash=81cb3743-0dfc-4ae4-b24d-f2bd18ca534a#/

Since obtaining data to evaluate the fertiliser recommendations (*i.e.*, the amount of N or P/ha/Y applied for each crop according to local practices) has proven to be highly challenging, a survey was also dispatched to the whole LEX4BIO consortium. Unfortunately, the low number of responses did not allow to enhance the data and evaluate this aspect of the analysis.

2.2. Estimation of NRSS potential to substitute mineral N and P fertilisers

To estimate the potential of NRSS to substitute mineral N and P fertilisers, the data previously mentioned have been associated with data from the Luke database regarding amount of NRSS available (https://px.luke.fi/PxWeb/pxweb/en/maatalous/). First, all data from the "biomass" tab was extracted for each LEX4BIO participating country and comprising:

- Agricultural plant biomass (including only cereal straw)
- Biowaste from food industry (comprising grape and olive pomace as well as bovine, poultry, and pig slaughterwastes)
- Manure (cattle, pig, sheep, and poultry)
- Municipal biowaste and sewage sludge

These data were compiled and the sum of N or P in tonnes available from cited above NRSS was then calculated for each country. On the other hand, to determine the N and P theoretical needs by country, the average N or P input per hectare by country between 2008 and 2014 (without considering whether the inputs are aligned with best practices or not) was multiplied by the used agricultural area (UAA) 2020 of each country (Eurostat). Finally, the balance between the potential N and P supply from NRRS and the theoretical needs per country was evaluated following the steps below:

1. Data collected used
   i. The N and P levels of inputs per hectare UAA between 2008-2014 (after 2014 data is not complete) i.e., the average N or P apply in kg/ha in each country, whatever the sources of N or P (mineral fertiliser or NRSS)
   (Eurostat online data code: AEI_PR_GNB)
   ii. The utilized agricultural area (UAA) for each country in hectares in 2020
   (Eurostat online data code: APRO_CPSH1)
   iii. The N and P quantity available per year from NRSS (kg/year) as determined in task 1.1 and available at https://px.luke.fi/PxWeb/pxweb/en/maatalous/
2. Calculation
   i. Calculation of the mean between 2008-2014 of N or P inputs in kg/ha by country (from 1.i.)
   ii. For each country, the mean obtain in 2.i was multiplied by the respective UAA of each country (from 1.ii)

→ the result of this calculation is considered as the *“theoretical N and P requirements”* in tonnes of N or P

iii. From 1.iii, calculation of the sum of N or P available in kg/year by country from all sources of NRSS referenced in Luke’ database
→ the result of this calculation is considered as the “*total stock of N and P available from the NRRS*” in tonnes of N or P per year

iv. From 2.ii and 2.iii, the balance was calculated as follows:
“total stock of N or P available from the NRRS” − *"theoretical N or P requirements”*

3. RESULTS

3.1. Mineral NP fertiliser statistics

From 2010 to 2018, the total consumption of mineral nitrogen (N) and phosphorus (P) fertiliser has increased and amounts to 10.3 and 1.2 million tonnes for N and P, respectively, in 2018, corresponding to nearly 11.5 tons cumulated (**Figure 1**).
According to Eurostat, the countries with the largest agricultural areas (**see figure 5A**) are those that tend to use the most mineral fertilisers, such as France, Germany, Poland, or Spain, which consumed 2.2, 1.5, 1.2 and 1 million tons of mineral nitrogen fertilisers and 0.2, 0.09, 0.15 and 0.19 million tons of mineral phosphorus fertilisers in 2020 respectively. Nevertheless, between 2010 and 2020, higher growth in fertiliser use was recorded in countries such as Bulgaria (+83% and +102% for N and P, respectively) and Hungary (+57% and +142% for N and P, respectively) (**Figure 2**). These increases could be due to an increase in the amount of fertiliser applied per hectare for these countries in recent years (Eurostat), as the levels were historically lower than the average in Europe before 2014 (see **Figure 3)**, but tends now to get closer to it.

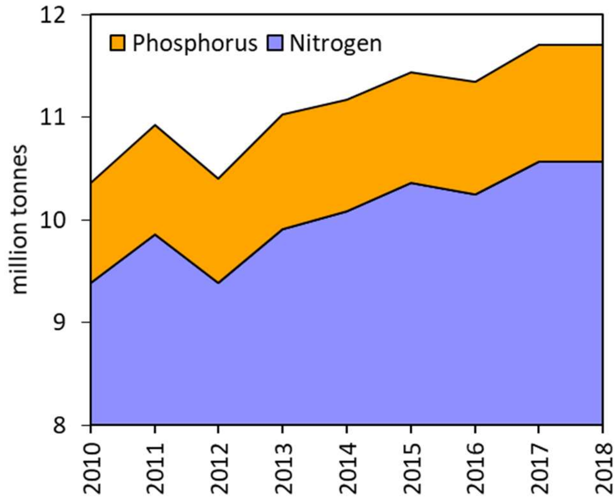


Figure 1: Estimated cumulated mineral fertilizer consumption by agriculture, EU-27, 2010-2018 in million tonnes (Eurostat - online data code: aei_fm_usefert).

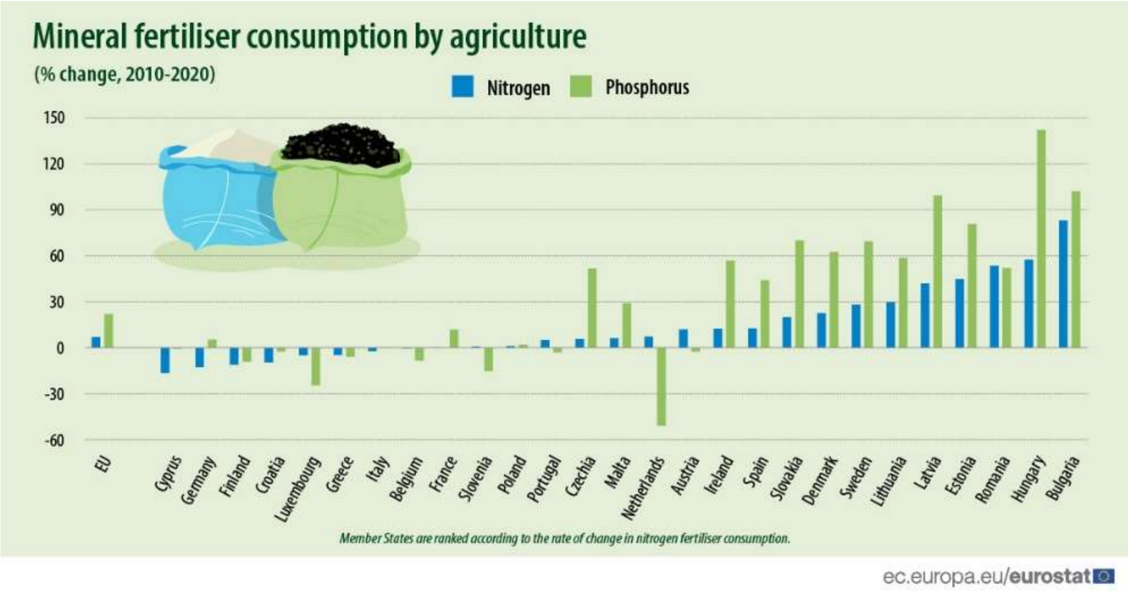


Figure 2: The change of N and P mineral fertiliser consumption in EU between 2010 and 2020 (Eurostat).

Indeed, the data relating to the level of N or P input per hectare UAA (kg of nutrient from both mineral and NRSS sources; Figure 3) showed great disparity between the LEX4BIO participating countries between 2008 and 2014 (Eurostat online data code: AEI_PR_GNB). In 2014, The Netherlands and Belgium had the highest level of N input with 369 and 309 kg/ha respectively, while Spain, Lithuania, Bulgaria or Hungary had input levels lower than 100 kg/ha. Overall, this ranking is similar for P input and the top 3 consumers were The Netherlands, Belgium, and Denmark with 35, 33 and 31 kg/ha respectively. However, these data must be weighed against the fact that, as mentioned above, the estimated fertilization levels of countries such as Bulgaria and Hungary have been increasing significantly in recent years, and are now close to the European average. On the other hand, these figures are also influenced by the type of agricultural system, especially those with high nutrient use on limited surfaces such as greenhouses as well as the fertilization demands of the main cultivated crops under the influence of soil types and their nutrient status.

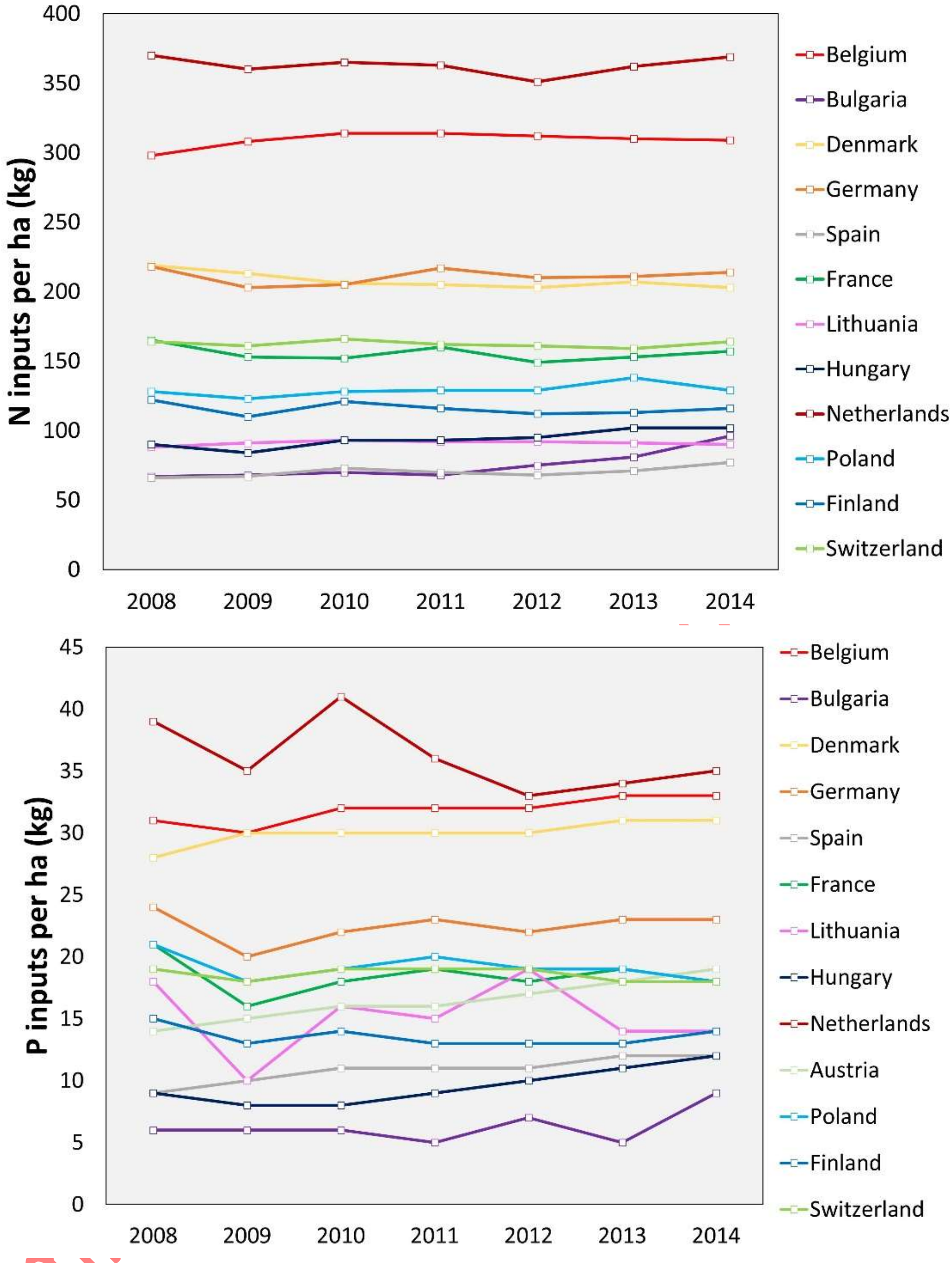


Figure 3: N and P level of inputs per hectare UAA (kg of nutrient from both mineral and NRSS sources) for LEX4BIO participating countries (Eurostat online data code: AEI_PR_GNB and national statistics).

Based on FAO data available between 2011 and 2019, there is a great heterogeneity in the form of N and P used within the countries participating in the LEX4BIO project (Figure 4A). For nitrogen, it seems that the predominant common forms are calcium ammonium nitrate (CAN), urea and NPK compounds. Poland, Norway, France and Lithuania are also using ammonium nitrate (AN). For phosphorus, no predominant form seems to be used in these countries, P being mostly provided in the form of NPK as described previously (Figure 4B). Assuming that BBFs from NRRS could substitute mineral N and P fertilisers, it would be necessary to substitute a broad range of N and P forms currently used and not a few predominant ones.

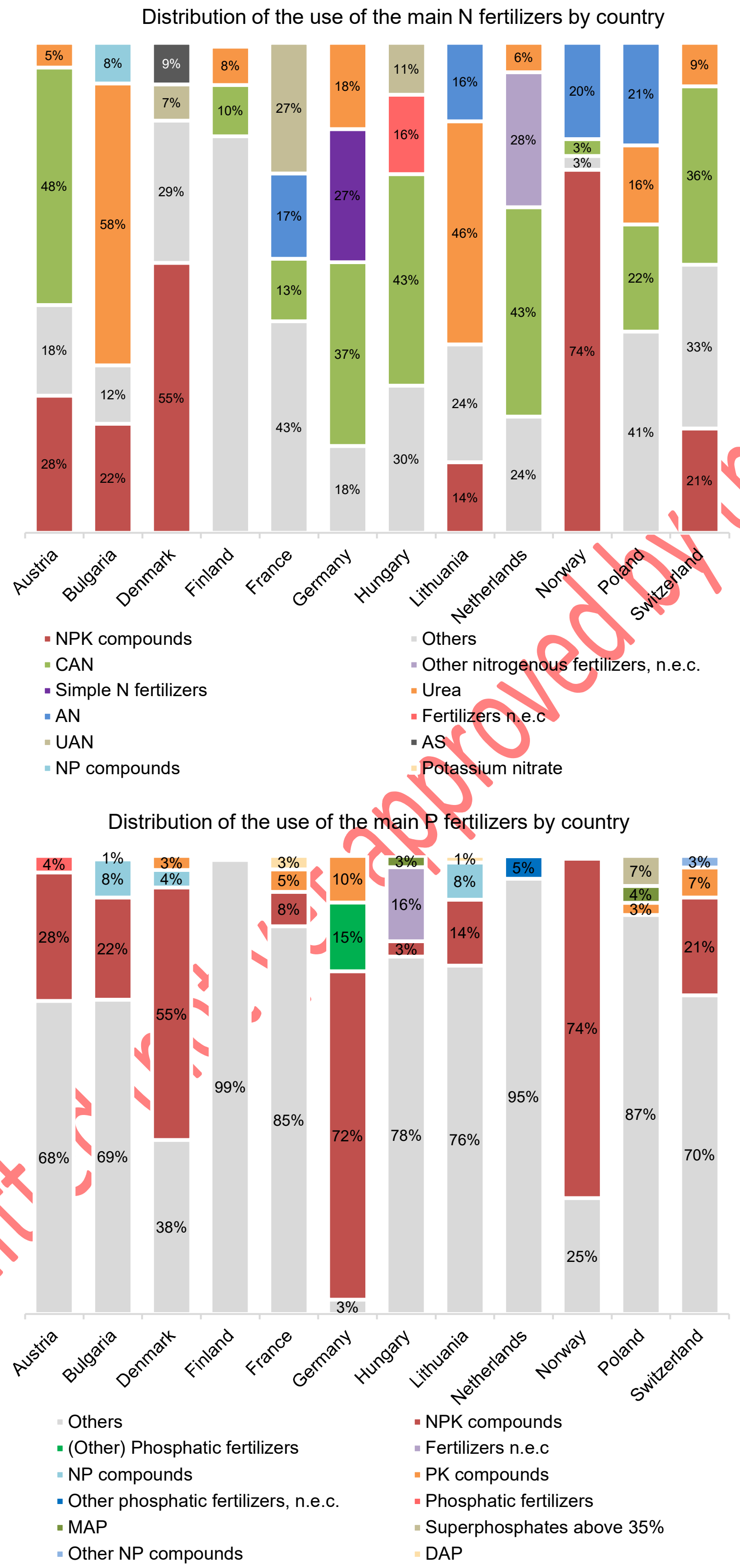


Figure 3: Distribution of the different forms of nitrogen (top) and phosphorus (down) used by country (FAO, 2011-2019). AN: ammonium nitrate; AS: ammonium sulfate; CAN: calcium ammonium nitrate, UAN: urea and ammonium nitrate solutions; MAP: Monoammonium phosphate; DAP: diammonium phoosphate.

3.2. Main crops and utilized agricultural area (UAA) in the EU

Wheat, barley and maize, the main crops studied in the LEX4BIO project are almost always part of the top 3 crops covering the most surface in each country. They occupy the largest number of hectares (**Figure 4A**) but also represent a high percentage of the UAA of each country (**Figure 4B**). For example, around 16.9, 8.8 and 6.1 million hectares are dedicated to wheat, barley, and maize respectively, among the fourteen partners countries (**Figure 4A**). Thus, these crops studied in the LEX4BIO project represented nearly one third of the total UAA at the EU level in 2018, accounting for 14%, 7% and 9% of the cultivated land, respectively (**Figure 4C**).

Figure 4: The surface areas occupied by the main crops (A) and percentage of their utilized agricultural area (UAA) (B) in the LEX4BIO participating countries. Percentage of the UAA of the LEX4BIO studied crops in the EU in 2018 (C) (Eurostat (online data code: APRO_CPSH1); national statistics).

3.3. NRSS potential to replace mineral N and P fertilisers in the EU

The data collected from task 1.1 and retrieved from the Luke database was used in order to quantify the total amount of N or P available from the relevant NRSS from each of the participating country. The results obtained show that a major part of the N stock, but also of P, would come from manure (**Figure 6A & 6B**). Indeed, manure represents at least 70% of the available N and P in all countries. Within this category, cattle manure represents, alone, more than 50% of the available N in each country, except for Spain, Hungary, and Denmark (**Figure 6A**). For almost all the countries concerned, the total amount of slaughterwastes could represent 5% to 6% of the recoverable N and P. On the other hand, if sewage sludge represents on average only 4% of the available N stock, it represents for most countries (except Denmark) more than 10% of the available P from NRSS, being able to represent up to 23%, 19%, 18%, 18% and 17% in Finland, Hungary, Germany, Switzerland, and Austria respectively (**Figure 6B**). However, municipal biowaste, olive or grape pomace as well as cereal straw represent, with rare exception, only very low percentages (1% to 3%) of recoverable N or P.

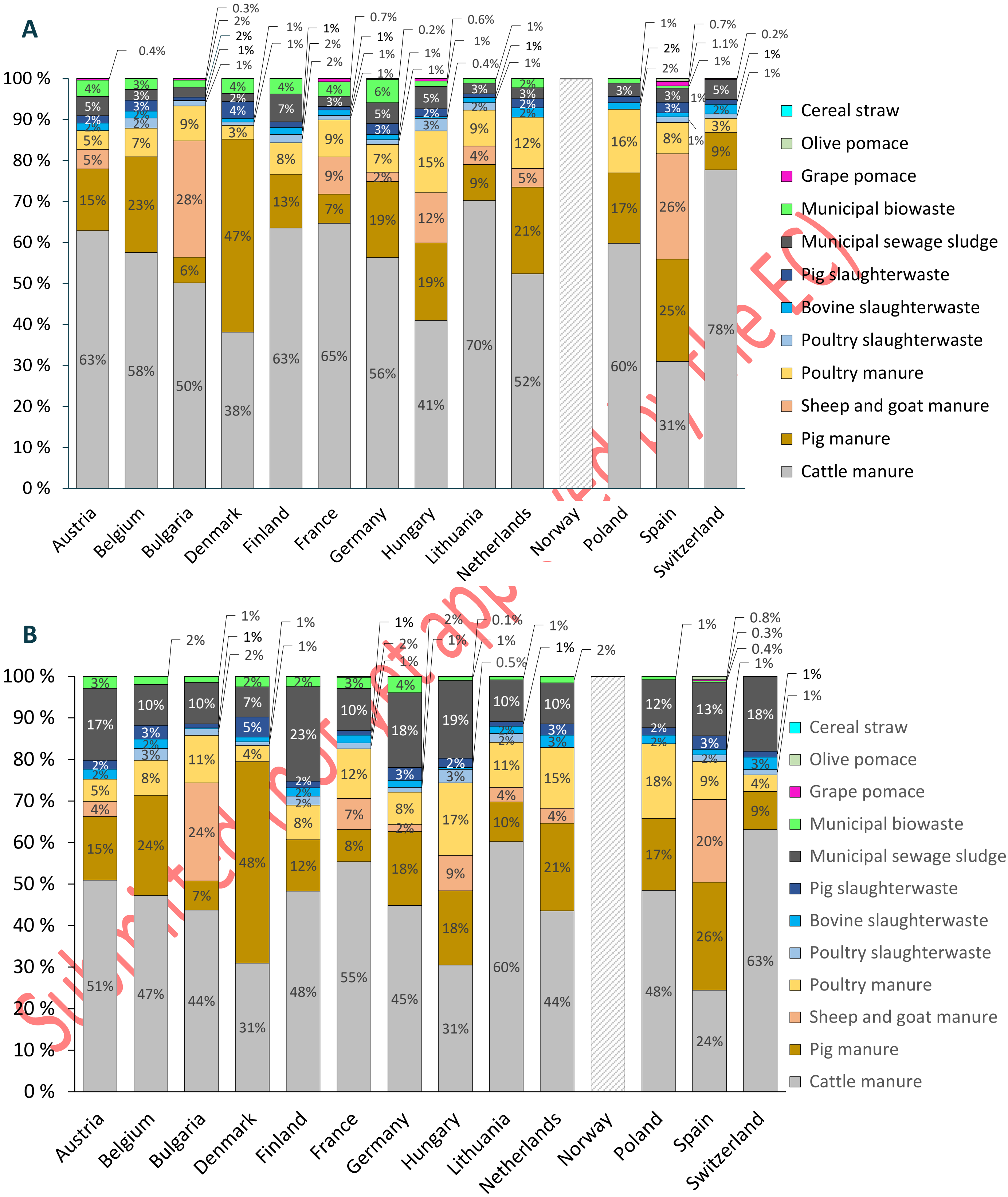


*Figure 5: Distribution of N (**A**) and P (**B**) sources from NRSS based on data from the Luke database. Data for Norway is incomplete.*

A balance was calculated between the theoretical N and P requirements based on the average supply of these nutrients per hectare in each country and the total stock of N and P available from the NRRS previously described. The **figure 7A** depicts, in million tons, the result of this balance for nitrogen. It appears that all countries have a negative balance between 0.1 and 2.7 million tons of N. For almost all countries such as Switzerland, Belgium, Austria, Finland, Norway, Netherlands, Lithuania, Denmark, Bulgaria, Hungary, and Spain, this deficit is lower than 0.5 million tons. In contrast, Poland, Germany, and France have a shortfall of 1.2, 2.1 and 2.7 million tons, respectively, which is not covered by N stocks from NRSS. The results observed for phosphorus (**Figure 7B**) are similar and the top 3 deficit countries are also composed of Poland, Germany, and France with a balance of -108, -146 and -226 thousand tons of P, respectively. However, The Netherlands and Belgium could theoretically cover their needs with P from NRSS, with a positive balance of 25 and 3 thousand tons, respectively. It should be noted that Switzerland has a low deficit of 2 thousand tons of P and is thus very close from balance. For all other countries, the deficit of P is comprised between 9 and 33 thousand tons. Finally, since manure represent a large amount of N and P available from NRSS studied here (**Figures 6A & 6B**) and that the latter is already partly recycled, it was appropriate to do the same approach to have an overview omitting this type of NRSS (**Figure 7C**). Obviously, without manure, the N and P deficits increase substantially for all countries. This is particularly the case for Spain and The Netherlands, whose N deficit is respectively multiplied by 3.8 and 3.3. In the same vein, without manure, the P deficit is multiplied 10, 7 and 4 times for Switzerland, Spain, and Austria, respectively.

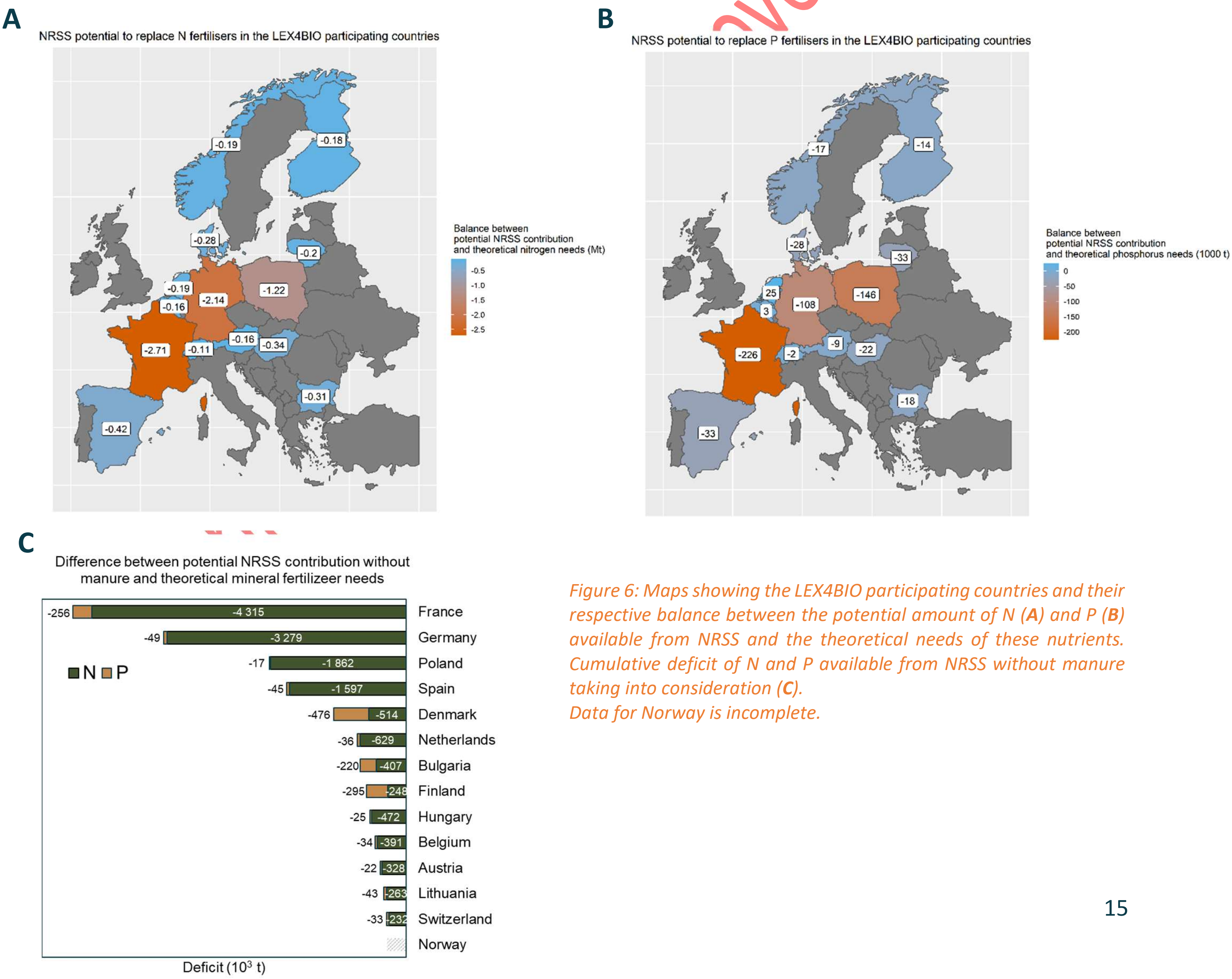


*Figure 6: Maps showing the LEX4BIO participating countries and their respective balance between the potential amount of N (**A**) and P (**B**) available from NRSS and the theoretical needs of these nutrients. Cumulative deficit of N and P available from NRSS without manure taking into consideration (**C**).*
Data for Norway is incomplete.

4. DISCUSSION

This report presents statistical data from official national and European statistics about the consumption of nitrogen (N) and phosphorus (P) fertilisers in LEX4BIO participating countries from 2010 to 2020 according to the available data. Figures on the level of N and P input per hectare, the forms of N and P used, main crops and utilized agricultural area in the EU including trends and country-specific data were provided. This data states that the total consumption of N and P fertilisers has been steadily increasing globally, with the highest consumption in countries with large agricultural areas such as France, Germany, Poland, and Spain. However, a higher growth in use in countries such as Bulgaria and Hungary in the last few years, possibly due to an increase in the amount of fertiliser applied per hectare, is also involved in this growing. This data also reveals a great heterogeneity in the form of N and P used within the countries participating in the LEX4BIO project, and assuming that nutrient-rich side-streams (NRSS) could substitute mineral N and P fertilisers, it would be necessary to substitute a broad range of N and P forms currently used.

On the other hand, the aim of the report was to assess the NRSS potential to replace mineral N and P fertiliser in the EU. To answer this question, a focus has been made on the countries participating in the LEX4BIO project. Since the data about the recommendations or the actual level of N or P input/ha/year for each crop was highly challenging to collect, a questionnaire was published for the project partners. Unfortunately, the amount of data collected did not allow to expand the data and make these calculations on a solid basis. For this reason, a N or P theoretical needs has been calculated based on the product of the average fertilization level per hectare of each country over the period 2008-2014 and their respective UAA in 2020.

If this calculation remains theoretical, it has nevertheless allowed to establish a balance between a quantity of N and P needed on a national scale and a potential stock available from the NRSS data collected in Task 1.1. The results show, *a priori*, that the N requirements are far from being covered by the N reserves available with the NRSS sources quantified in Task 1.1. Indeed, all countries have a N negative balance, with Poland, Germany, and France having the highest shortfall. A similar trend was observed for P, except for Belgium and the Netherlands which are the only countries with a positive P balance, covering their needs with P available from NRSS. Furthermore, manure was found to be an overwhelming source of N and P within the NRSS studied here. To evaluate the potential of substitution of mineral fertiliser by NRSS without manure, assuming that it is partly already recycled, the same approach was therefore used to calculate the theoretical balance omitting this type of NRSS. In that case, the deficits in N and P thus increased substantially for all countries and for example, N deficit in Spain and the Netherlands and P deficit in Switzerland, Spain, and Austria increased more than 3 times, respectively.

Nevertheless, as previously indicated, this calculation remains theoretical. On the one hand, it is founded on factual figures about mineral fertiliser usage, without considering whether such use is justified and/or or aligned with adapted practices. On the other hand, this theoretical construct would require a 100% recycling rate of N or P from NRSS, and for the recycled nutrients to be 100% as efficient as mineral fertiliser currently used. These factors must be taken into consideration when evaluating the feasibility of substituting mineral fertilisers with NRSS, and this topic about the actual agronomic efficiency of BBFs is considered in WP3 and WP4.

The substitution of mineral fertilisers with organic materials is a complex issue that depends on a variety of factors, including the availability and quality of NRSS, the type of crops being grown, and the specific environmental and economic conditions of the region. While there is potential for NRSS to be used as a fertiliser, further research and development is needed to optimize the use of these materials and ensure their safe and sustainable use, to which the LEX4BIO project will try to respond.