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GROSS NITROGEN AND PHOSPHORUS BALANCE IN THE POLISH AGRICULTURE AGAINST THE BACKGROUND OF SELECTED EUROPEAN UNION MEMBER STATES AND THE HELCOM GROUP

Key words: mineral fertilizers, gross nitrogen balance, gross phosphorus balance, crop productivity, EU, HELCOM

ABSTRACT. The aim of the study is the comparative analysis of the of gross nitrogen (N) and phosphorus (P) balances in Poland and selected EU countries and those belonging to the HELCOM group. The scope of the analysis covered the years 2011-2019. The main source of information was Central Statistical Office of Poland and EUROSTAT statistical data. A comparative analysis of the gross nitrogen and phosphorus balances for the surveyed EU Member States and regions (HELCOM) indicates the diversity of results, trends of changes and approaches in their management over the years. The study showed that the gross nitrogen balance was positive in all analysed years, in the HELCOM Group countries. The average gross nitrogen balance surplus for Poland in 2011-2019 was slightly below 50 kg N/ha UAA and this was below the average level observed for all EU-27 Member States, but higher than the average for the HELCOM Group. In most of the analysed countries, there was a positive phosphorus balance over 9 years. Phosphorus deficits (on average for the entire period) were recorded only in Germany and Romania. Poland does not stand out significantly in terms of the average balance of gross phosphorus in agriculture, which on average in 2011-2019 amounted to an average of 2.7 kg P/ha UAA. Both in Poland and for the compared groups of countries, the highest balance of phosphorus balance was recorded in the first period of the analysis, i.e. in 2011-2013, this reducing trend should be considered a positive phenomenon as it is a sign of reduced agricultural pressure on the environment.

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INTRODUCTION

The functioning of Poland within the EU constantly creates new challenges for agriculture, related to environmental protection in rural areas, regarding the proper conduct of production activities [MI 2024, p. 66]. Nutrients like nitrogen and phosphorus if applied in excessive quantities that are not absorbed by plants can be lost from agricultural cycle into the environment, where they contribute to water pollution. Elevated nitrate (NO_3) levels in groundwater are a particular concern, posing risks to both the environment and human health [WHO 2003]. Addressing this issue has been a priority for EU policy since the implementation of the Nitrates Directive [Council Directive 91/676/EEC, Oenema et al. 2009].

The primary contributors to nitrate pollution in EU groundwater are mineral fertilizers and manure with agriculture [EEA 2022] accounting for approximately 80% of nitrogen runoff into aquatic ecosystems. As a result, roughly 30% of surface waters and 80% of marine areas in the EU experience eutrophication [EC 2021]. As more than 80% of surface water bodies in Poland are below good status or potential due to their excessive content of nitrogen and/or phosphorus [MI 2024, p. 22] the Common Agricultural Policy is increasingly taking into account the objectives of reducing environmental risks caused by agriculture. Currently, the challenge for the Polish agriculture are the goals included in the assumptions of the European Green Deal (including "the Farm to Fork Strategy" (F2F) and the EU Biodiversity Strategy for 2030 "Bringing nature back into our lives") [Kopiński 2024]. They result from the fact that agricultural activity causes a significant interference in the natural circulation of nutrients, mainly through the intensification of production, often measured by the level of consumption NPK kg/ha UAA from mineral fertilisers or the level of livestock density in the LU/ha UAA.

The environmental effects of intensive agricultural production are measurably revealed in the change of soil fertility indicators and in the composition of surface and groundwater or air quality. Different methods and models are used to assess and simulate the environmental impact of agriculture, depending on the level of application and the needs of consumers. Nutrient use efficiency approach measures nutrient inputs versus crop uptake, identifying waste, pollution risks, and opportunities to optimize fertilizer use at different scales [Oenema et al. 2009]. Assessing the environmental impact of agriculture at the farm level is a top priority of many models that include: the RISE model (ang. Response-Inducing Sustainability Evaluation) [Häni et al. 2003, Boller et al. 2004], CalcGosPuck calculator [Dzierzbicka-Głowacka et al. 2019] or RIS (ang. Rapid Identification System) [Kupiec 2023]. The RISE model is a farm-level assessment tool that evaluates the sustainability of agricultural practices by analyzing 10 key indicators across environmental, economic, and social dimensions, providing a holistic framework for improving sustainability performance [Häni et al. 2003]. The CalcGosPuck calculator is an agricultural tool designed to estimate nutrient balances at the farm level using the "at the farm gate" method. It assesses inputs like fertilizers and animal feed against outputs such as plant and animal products to calculate nutrient surpluses or deficits for nitrogen (N), phosphorus (P), and potassium (K) [Dzierzbicka-Głowacka et al. 2019]. Rapid Identification System (RIS) is a tool designed to assess the pressure that farms exert on the natural environment. RIS is particularly useful in analysing the impact of agricultural production on surface waters, soils, the atmosphere and biodiversity. The system uses parameters related to production practices and technologies used on farms [Kupiec 2023].

One of the common model used at the broader scale is the sectoral partial equilibrium model CAPRI (Common Agricultural Policy Regionalised Impact) which is a global agro-economic model, operational since 1999, designed for assessing economic and environmental impacts on agriculture[Britz and Witzke 2014]. One of these methods is nutrient balance [Kopiński 2006, 2017] that allows the assessment of the potential threat as a result of a specific intensity of farming in agriculture and proves the correct management of nutrients [Kopiński 2010]. Oene Oenema and team highlights the critical role of nutrient balances and nitrogen use efficiency (NUE) as essential tools for implementing the Nitrates Directive [Oenema et al. 2009].

The gross nitrogen balance (GNB) and gross phosphorus balance (GPB) are used by international institutions i.e. European Environment Agency [EEA 2018], according to the method proposed by the Organisation for Economic Cooperation and Development (OECD) and then adopted by the EUROSTAT [OECD 2004, Kremer 2013]. Issues related to balancing and reducing nitrogen emissions from agriculture are also raised by international conventions, such as Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention, 1992) [HELCOM 2014], Convention for the Protection of the Marine Environment of the North-East Atlantic [OSPAR Convention 1992, Kopiński 2006]. The aim of the study was a comparative analysis of the gross phosphorus and nitrogen balances in Poland and selected EU countries, as well as countries belonging to the HELCOM Group.

MATERIAL AND METHODOLOGY OF RESEARCH

Table 1 presents the main elements of GNB and GPB – input and output side [OECD 2004, Kremer 2013]. The balance (gross) of nitrogen and phosphorus given in element form (N and P) for comparisons was related to the unit of area – hectares of agricultural land used for agricultural purposes, maintained in good agricultural and environmental conditions (UAA in GAEC).

The basic source of data in terms of balances for countries other than Poland was statistical data of EUROSTAT [2024]. The subject of the comparative analysis were the outcomes of GNB and GPB for the following selected the EU Member States: Denmark,

Table 1. Elements of the gross balance of nitrogen and phosphorus

Symbol	Components of the nitrogen and phosphorus balance
S_{min}	Mineral fertilizers (simple and multi-component mineral fertilizers)
S_{nat}	Natural fertilizers (based on livestock numbers of different categories of cattle, pigs, sheep, goat, poultry and other livestock i.e. horses, rabbits)
S_{org}	Only sewage sludge used in agriculture
N_{sym}	Symbiotic nitrogen
N_{atm}	Nitrogen in deposition from the atmosphere
S_{seed}	Seed and crops material
S_{out}	Output with crop yields
GNB	Gross balance of nitrogen (N) GNB = $S_{min} + S_{nat} + S_{org} + N_{sym} + N_{atm} + S_{seed} - S_{out}$
GPB	Gross balance of phosphorus (P) GPB = $S_{min} + S_{nat} + S_{org} + S_{seed} - S_{out}$

Source: own study

Germany, France, Italy, Hungary, Netherlands, Poland, Romania, Finland, Sweden and the EU average (27) and the average for HELCOM Group countries, namely: Denmark, Estonia, Finland, Lithuania, Latvia, Germany, Poland, Sweden, excluding Russia and EU. The average GNB and GPB for the EU Member States, in the years 2011-2019, does not take into account the actual results for Denmark, Italy and Hungary. These countries did not report results in 2016-2019 (Denmark) and 2018-2019 (Hungary and Italy), therefore, in order to perform a comprehensive analysis, the missing data were replaced by the calculated average GNB and GPB from the available years in the analysed period. Calculations of GNB and GPB for Poland was performed using the desk study approach. The methodology of the calculating balance prepared for Poland is described in details in the monograph [Kopiński 2017]. Input data (Tabel 1) originated from geostatistical reports of the Central Statistical Office database [GUS 2024] which collects data based on surveys conducted in all agricultural holdings of legal persons and organizational units plus a sample of private farms. The analysis in the dynamic system included a comparison of changes in the N and P balances in the years 2011-2019 and in the periods of 2011-2013, 2014-2016 and 2017-2019.

RESEARCH RESULTS

An analysis of the data in Table 2 shows that the gross nitrogen balance was positive in all years of the period under review in most of the analysed EU Member States, with the exception of Romania, for which the average GNB was -5.5 kg N/ha UAA. The balance results in individual years of the analysed countries show very large differentiation. They ranged from –27.4 kg N/ha UAA in Romania (in 2018) to 196 kg N/ha UAA

Table 2. Gross nitrogen balances for selected EU Member States, HELCOM Group countries in the years 2011-2019

Country	Gross nitrogen balance [kg N/ha UAA]									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	average 2011-2019
Denmark	88.0	83.4	87.1	79.8	80.0	–	–	–	–	83.7*
Finland	50.2	47.5	46.5	47.5	49.5	47.4	51.5	58.0	43.7	49.1
France	49.1	23.5	29.7	29.6	37.3	47.5	33.7	40.8	38.0	36.6
Netherlands	172.8	170	171.4	162.6	192.4	194.5	182.0	196.0	165.8	178.6
Germany	88.6	75.1	78.9	65.9	81.8	69.1	61.5	77.9	53.4	72.5
Poland	53.0	48.1	54.8	39.8	47.8	44.1	48.4	61.8	47.4	49.5
Romania	-11.2	16.3	4.2	-0.7	8.6	-1.4	-12.6	-27.4	-24.9	-5.5
Sweden	42.2	31.2	34.5	30.7	31.7	36.7	35.3	60.6	26.1	36.6
Hungary	30.8	42.7	37	24.6	36.2	28.5	33.3	–	–	33.3**
Italy	62.5	79.6	70.1	65.7	66.0	64.6	68.0	–	–	68.1**
HELCOM	52.8	45.8	45.1	39.5	43.0	27.8	27.4	41.0	28.0	38.9
EU (27)	62.6	61.7	61.4	54.6	63.1	61.5	58.5	65.3	53.5	60.2

* Average for the years 2011-2015, ** average for the years 2011-2017, – no data reported to EUROSTAT
Source: own study based on EUROSTAT data [2024]

in the Nederlands (also in 2018). The average GNB surplus for the EU-27 Member States was 60.2 N/ha UAA and was higher than the average gross nitrogen balance observed in the HELCOM countries (38.9 N/ha UAA).

Assessment and inference based on the obtained data require a thorough understanding of the complexity of the indicator used. Nutrient budgets and among them, GNB is commonly used to measure the difference between nitrogen inputs (like fertilizers, animal manure, biological fixation, and atmospheric deposition) and outputs (such as nitrogen removed in crops or forage) within agricultural systems. It was developed by the Organization for Economic Co-operation and Development (OECD) to compare the evolving conditions in member states but are also used by the US Department of Agriculture Natural Resource Conservation Service [NRCS 2011] to calculate nutrient plans. Gretchen Sassenrath et al. [2013] found that gross annual N balance could be a useful tool in assessing the sustainability of agricultural practices. A surplus often suggests inefficient nitrogen use and a higher risk of environmental issues, such as nitrate leaching into groundwater or nitrous oxide emissions [HELCOM 2023].

The average GNB surplus for the EU-27 Member States was significantly (by 55%) higher than observed in the HELCOM Group countries. As GNB is intended to be an indicator of the amount of excess nutrient applied to the system that is not captured in harvested product, and hence is a potential pollutant from the system [Parris 2011], the fact that GNB between EU-27 countries has a significantly higher value than of HELCOM countries may indicate significantly better nitrogen management in these countries. A significantly higher gross nitrogen balance suggests differences in nitrogen inputs and outputs in agriculture, reflecting variations in farming practices, policies, and environmental factors as countries with intensive farming systems often have higher fertilizer and manure use, leading to higher nitrogen surpluses Annika Svanbäck et al. [2019]. On contrary, it is known that stricter environmental policies (as introduced in HELCOM countries) or better enforcement, can lead to more efficient nitrogen management and lower surpluses. Conversely, less regulated regions may exhibit greater nitrogen imbalances. The average GNB surplus for Poland in 2011-2019 was slightly below 50 kg N/ha UAA and this was below the average level observed for all EU-27 Member States, but at the same time it was higher, by approx. 10 kg N/ha UAA, from the average GNB observed for the HELCOM Group countries. Compared to other countries, the gross nitrogen balance surplus in Poland showed relatively low volatility and ranged from 44.1 kg N/ha UAA in 2016 to 61.8 kg N/ha UAA (in 2018).

Figure 1 shows that over the last 9 years, in the three separate 3-year periods, in the analysed EU Member States, there has been no visible change in the environmental protection dimension, i.e. the nitrogen balance surplus has not been significantly reduced. Only a minimal downward trend is observed. The average GNB for the EU-27 Member States remained relatively stable over the period under review, fluctuating with some fluctuations around 60 kg N/ha UAA. This was the case for most of the countries analysed (Denmark, France, Italy, Finland and Sweden), for which small fluctuations suggest some stability in nitrogen management. Similarly, Poland showed little change in the size of the nitrogen balances, which oscillated around the average for EU Member States. On the other hand, a significant decrease in the average gross nitrogen surplus can be observed in Romania, Germany and the HELCOM Group countries.

The decreasing nitrogen balance trends in HELCOM Group countries likely stem from a combination of targeted environmental policies, improved agricultural practices, and the adoption of precision farming technologies. These countries have implemented stricter nutrient management measures under HELCOM's Baltic Sea Action Plan [HELCOM 2021], focusing on reducing nitrogen runoff to combat eutrophication. Actions include optimized fertilizer application, manure management, and the promotion of sustainable

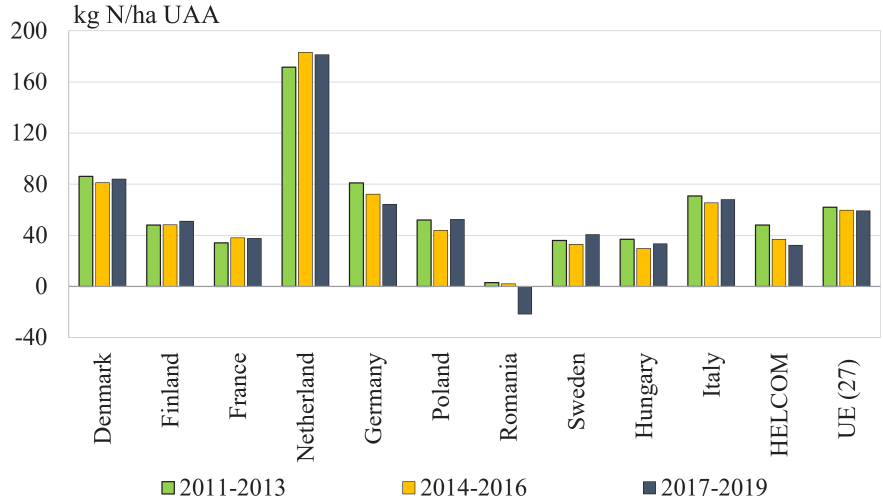

Figure 1. Gross nitrogen balances for selected EU Member States and HELCOM Group countries in the three-year periods 2011-2013, 2014-2016 and 2017-2019 (Denmark – average for 2011-2015, Hungary, Italy – average for the years 2011-2017)

Source: own study based on EUROSTAT data [2024]

farming techniques. Precision agriculture technologies may have also played a significant role, allowing for more efficient nutrient use and reducing excess nitrogen inputs. For example, tools for soil analysis and tailored fertilization plans ensure that only the required amounts of nutrients are applied, minimizing losses. It should be assumed that economic reasons (relatively high fertilizer prices) could also have had an impact on observed decreasing nitrogen balance trends in HELCOM Group countries. While this process should be assessed positively, as the balance in these countries is still positive, the observed deficit of nitrogen balance in Romania may lead to the depletion of nitrogen from the soil, which in the long term may be a factor degrading soil fertility although, the negative GNB in Romania may be to some extent due to a slightly different methodological approach (nutrient of coefficients). According to Alena Schmidt et al. [2017] the nitrogen soil surface balance in Romania reveals a minimal N surplus (0.17 kg/ha), indicating an efficient use of nitrogen in the agricultural sector, with an N use efficiency (NUE) of 99%. While the GNB approach offers accessibility due to data availability, its accuracy is limited because it does not consider internal farm nutrient fluxes. This limitation can lead to underestimations or overestimations of actual nitrogen losses, particularly in animal production systems. Authors conclude that implementing a farm-gate balance calculations could provide a more comprehensive view of nutrient dynamics by incorporating losses in manure management and other farm-specific factors [Schmidt et al. 2017].

On the other hand, as in previous years, the highest nitrogen balances among the countries surveyed are recorded in the Netherlands [Kopiński and Fotyma 2001, Kopiński 2006] this should be explained by very intensive agricultural production and the use of high doses of nitrogen fertilizers, despite modern and innovative production techniques [Wrzaszcz and Sobierajewska 2023].

The existing significant differences in nitrogen surpluses between the compared countries may result from differences in agricultural practices, the level of economic development and environmental protection policies [Oenema et al. 2009].

Table 3 presents the results of gross phosphorus balances (kg P/ha UAA) for selected EU Member States and HELCOM Group countries, including Poland. Among the analysed countries and groups (EU-27, HELCOM), various trends in changes in the GPB can be observed. In most of the analysed countries, a positive balance was recorded over 9 years.

Table 3. Gross phosphorus balances for selected EU Member States, HELCOM Group countries in the years 2011-2019

Country	Gross phosphorus balance [kg P/ha UAA]									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	averege 2011-2019
Denmark	7.0	7.0	8.0	7.0	7,0	–	–	–	–	7.2*
Finland	3.7	3.7	3.9	3.8	4,0	3.6	5.6	5.8	3.3	4.2
France	2.5	0.2	1.6	0.5	0,9	2.9	0.4	2.1	1.1	1.4
Netherlands	6.6	3.2	4.5	1.2	3,9	4.7	2.2	6.9	4.0	4.1
Germany	-0.4	-2.6	-1.0	-3.7	-2,0	-2.9	-5.2	-1.9	-4.8	-2.7
Poland	5.7	3.0	3.2	0.3	2,1	0.8	1.3	4.0	3.6	2.7
Romania	-3.0	1.0	-2.0	-2.0	-0,7	-3.1	-5.6	-7.5	-6.1	-3.2
Sweden	-0.1	-0.4	0.1	-1.3	-1,6	-0.2	-0.7	4.1	-1.5	-0.2
Hungary	-3.2	0.0	-0.5	-2.7	-0,9	-2.8	0.0	–	–	-0.8**
Italy	-3.0	-2.0	-2.0	-1.0	-1,0	-1.8	-1.8	–	–	-1.8**
HELCOM	2.3	1.6	2.4	1.1	1,6	0.3	0.3	2.0	0.0	1.3
UE (27)	1.4	1.6	1.5	0.8	–	–	–	–	–	–

* Average for the years 2011-2015, ** average for the years 2011-2017, – no data reported to EUROSTAT

Source: own study based on EUROSTAT data [2024]

The largest phosphorus balance surplus among the analysed countries was recorded by Denmark (on average 7.2 kg P/ha UAA), Finland and the Netherlands (on average 4.2-4.1 kg P/ha UAA), while countries such as Germany, Italy, Hungary, Romania, Sweden have a negative balance, which may suggest on a global scale their use of soil reserves and needs detailed analysis. Prominent phosphorus deficits in national agricultural systems are observed in Germany and Romania (-2.7 and -3.2 kg P/ha UAA).

In Poland, in the years 2011-2019, the balance of phosphorus balance, expressed in kg P/ha UAA, varied in the range of 0.3 in 2014 to 5.7 in 2011 and on average during the 9 analysed years it amounted to 2.7 kg P/ha UAA. In relation to Poland, this balance surplus is at least partly justified by a significant share of soils with low and very low abundance in this component (about 1/3 of soils) and the resulting needs of its supplementation, taking into account, the nutritional needs of crops [Kopiński and Jurga 2016, Wrzaszcz and Kopiński 2019, Kopiński and Wrzaszcz 2020].

When comparing the Polish phosphorus balance with other countries, it can be seen that Poland is in the middle or higher part of this range. This means that Poland does not stand out significantly in terms of either the excess or deficit of phosphorus in agriculture compared to other European countries, including those from the HELCOM group. Despite this, it can be pointed out that there is still some possibilities to improve the management of this nutrient such as: broader adopting precision agriculture technologies, mandatory soil P testing or targeted anti-erosion treatments. It can be assumed that these interventions, informed by data and tailored to regional conditions, will enhance sustainability and reduce phosphorus-related environmental pressures.

Changes in GPB in the analysed countries in the analysed period are caused by various factors, and the resulting differences in agricultural practices, environmental policy or availability of natural resources [HELCOM 2023]. GPB for the HELCOM countries appear to be relatively stable, hovering around positive values and showing a decreasing trend, which may indicate the effectiveness of the efforts made to optimize phosphorus fertilization in this region. The analysis of the gross phosphorus balance, for selected EU countries and the HELCOM Group, shows uneven trends and different needs for the management of this nutrient, what was found also by others [HELCOM 2023]. At the same time, this suggests the need for a tailored approach to phosphorus management, taking into account in-depth analysis of the phosphorus input streams, specific soil conditions, agricultural practices and needs [Tóth et al. 2014]. Countries with lack of crop available P as a factor limiting agricultural productivity [Tóth et al. 2014] will have to focus on mobilizing soil P reserves and not reducing significantly doses of new fertilisers when countries with high P surplus should consider efforts to optimize phosphorous supply [Withers et al. 2015].

Figure 2 presents the gross phosphorus balance balances in three 3-year periods: 2011-2013, 2014-2016 and 2017-2019 in Poland and selected EU Member States and HELCOM Group countries. The balances of the phosphorus, over the analysed years, Denmark, France, the Netherlands, Finland and the HELCOM Group of countries show relative stability. Their average values remain at a similar level in the studied periods. On the other hand, the gross phosphorus balances in Germany and Romania show a decreasing trend in subsequent periods under review. On the other hand, Poland and Sweden show some volatility in the balances of phosphorus balances over the analysed years. In Poland, the highest balance of phosphorus was recorded in the first period of the analysis, i.e. in 2011-2013. On average, in this period, it was at the level of about 4 kg P/ha UAA. After a relatively high level of the average result of balance in the first period, in the second period there was a decrease and another increase in the third period to the level of 3 kg P/ha UAA. In Sweden, on the other hand, phosphorus balances fluctuate around zero, but what is worth highlighting is the fact the surplus of P at the national level in Sweden has been reduced by downsizing the use of mineral P fertilizers and using manure, while maintaining or even increasing crop yields [Bergström et al. 2015].

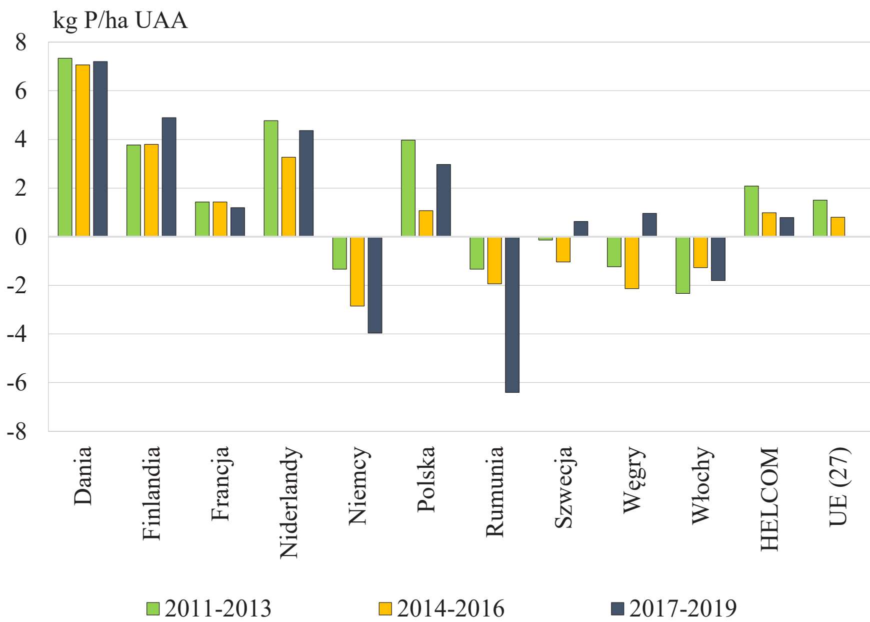

Figure 2. Gross phosphorus balances for selected EU Member States and HELCOM Group countries in the three-year periods 2011-2013, 2014-2016 and 2017-2019 (Denmark – average for 2011-2015. Hungary, Italy – average for the years 2011-2017)

Source: own study based on EUROSTAT data [2024]

The average phosphorus balance for the EU-27 Member States, as well as the averages of the HELCOM Group countries, decreased slightly, ranging from 0.8 to 2.1 kg P/ha UAA. Comparing the average GPB for the average of the EU-27 countries and the HELCOM Group, it should be noted that the countries around the Baltic Sea are slightly better management of nutrients than this is the case on average in all European Union countries (UE-27).

SUMMARY

Different methods are used to assess the environmental impact of agriculture, depending on the specificities of the research being carried out, including its application, the availability of data and the purpose it is intended to serve. The balance of the main macronutrients is one of the most important and popular methods for assessing the potential environmental pressure of agriculture. The gross nitrogen and phosphorus balances, which are also used by international institutions to make comparisons between countries in the indicated scope, is of particular informational importance. Gross nitrogen and phosphorus balances are critical tools for evaluating agriculture's environmental impact. Positive balances signal a surplus of nutrients, which can lead to issues like eutrophication, while negative balances may indicate nutrient depletion, potentially threatening soil fertility.

Research results indicated, that gross nitrogen balance was positive in all years of the study in most of the analysed EU Member States, with the exception of Romania, for which it averaged -5.5 kg N/ha UAA, but this result should be considered with in individual years and compared countries, there is a large variation in nitrogen balances, from -27.4 kg N/ha UAA in Romania (in 2018) to 196 kg N/ha UAA in the Netherlands (also in 2018). The average gross nitrogen balance surplus for Poland in 2011-2019 was slightly below 50 kg N/ha UAA and this was below the average level observed for all EU-27 Member States, but at the same time higher, by approx. 10 kg N/ha UAA, than the average balance of the HELCOM Group countries.

In most of the analysed countries and regional group (EU-27, HELCOM), there were varied trends in changes in the gross phosphorus balances. In most of the analysed countries, over 9 years, it was a positive balance. Phosphorus deficits (on average for the entire period) were recorded only in Germany and Romania. Poland, compared to other European countries, including the HELCOM Group, does not stand out significantly in terms of the average balance of gross phosphorus in agriculture, which in 2011-2019 averaged 2.7 kg P/ha UAA. It should be emphasized that both in Poland and for the compared groups of countries, the highest balance of phosphorus balance occurred in the first period of analysis, i.e. in 2011-2013. The decline in phosphorus surpluses over time is a positive trend, suggesting improved efficiency in phosphorus use and possible

impacts of regulations or mitigation measures. The analysis of gross nitrogen (N) and phosphorus (P) balances highlights key environmental and management insights in selected EU Member States and regions like HELCOM countries. These findings provide a nuanced understanding of nutrient management in agriculture. The substantial variation in nitrogen balances, from negative values in Romania to high surpluses in the Netherlands, underscores diverse agricultural practices, environmental conditions, and nutrient management strategies across countries. The large surplus in countries like the Netherlands (196 kg N/ha UAA in 2018) reflects intensive agriculture, necessitating stricter nutrient management to reduce environmental pressure. For countries with negative balances, strategies should aim at enhancing nutrient inputs sustainably to maintain soil fertility. This underscores the necessity for cooperation, local innovations and tailored, country-specific strategies that address unique agricultural and environmental challenges while moving toward sustainable nutrient management.

In conclusion, the comparative analysis of the gross nitrogen and phosphorus balances for the EU Member States and regions surveyed (HELCOM) shows the diversity of results, trends of changes and approaches in their management over the years. Decreasing trends in some countries may indicate the effectiveness of measures taken to reduce excess nitrogen or phosphorus, while volatility in other countries may indicate the need to stabilize further actions in the field of optimization of the management of these nutrients. Having in mind that Europe is strongly dependent on imports of phosphorus and that losses of nutrient causes economic and environmental costs the only correct conclusion and recommendation seems to be optimization of nutrient management in EU and HELCOM countries for maximum resource and environmental benefits.

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BILANS AZOTU I FOSFORU BRUTTO W POLSKIM ROLNICTWIE NA TLE WYBRANYCH KRAJÓW CZŁONKOWSKICH UNII EUROPEJSKIEJ I GRUPY HELCOM

Słowa kluczowe: nawozy mineralne, saldo bilansu azotu brutto, saldo bilansu fosforu brutto, produkcyjność roślin, UE, HELCOM

ABSTRAKT. Celem badań była analiza porównawcza wielkości sald bilansu azotu (N) brutto i fosforu (P) brutto w Polsce i w wybranych krajach UE oraz państw należących do grupy HELCOM. Zakres analizy obejmował lata 2011-2019. Podstawowe źródło informacji stanowiły dane statystyczne GUS i EUROSTAT. Analiza porównawcza sald bilansu azotu i fosforu brutto dla badanych państw członkowskich UE i regionów (HELCOM), wskazuje na różnorodność wyników, trendów zmian i podejść w ich gospodarowaniu w analizowanym okresie. Badania wykazały, że saldo bilansu azotu brutto było dodatnie we wszystkich latach badań w krajach grupy HELCOM i w analizowanych państw członkowskich UE, z wyjątkiem Rumunii. Średnia nadwyżka bilansowa azotu brutto dla Polski w latach 2011-2019 wynosiła nieco poniżej 50 kg N/ha UR w dobrej kulturze rolnej (dkr) i była to wielkość poniżej średniego poziomu obserwowanego dla wszystkich państw członkowskich UE-27, ale wyższa od średniej dla grupy HELCOM. W większości analizowanych krajów w ciągu 9 lat występował dodatni bilans fosforu. Deficyty fosforu (średnio dla całego okresu) odnotowano tylko w Niemczech i Rumunii. Polska nie wyróżniała się znacząco pod względem wysokości przeciętnego salda fosforu brutto w rolnictwie, które średnio w latach 2011-2019 wynosiło średnio 2,7 kg P/ha UR. Zarówno w Polsce, jak i w porównywanych grupach krajów, najwyższe saldo bilansu fosforu występowało w I okresie analiz, tj. w latach 2011-2013 i tę tendencję spadkową należy uznać za zjawisko pozytywne, gdyż to świadczy o zmniejszeniu presji rolnictwa na środowisko.

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