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## **RESOURCES OF MAIN MACRONUTRIENTS IN NATURAL FERTILIZERS IN POLAND<sup>1</sup>**

Key words: natural fertilizers, animal stock, dose, fertilization level, nitrogen, phosphorus, potassium

**ABSTRACT.** Results of analysis of the consumption of particular macronutrients in natural fertilizers in Poland are discussed in this paper. Analysis included the consumption of nitrogen, phosphorus and potassium in particular types of natural fertilizers, both in relation to the fertilized area and agricultural land. The study period covered the years 2018-2019. The amount of macronutrient resources of natural fertilizers was determined at a voivodeship level. As a result of data analysis, it was shown that more than 80% of NPK macronutrients were applied to the soil in the form of manure. In Poland, total NPK consumption in manure was estimated at about 80 kg/ha UAA, including 27.4 kg of N, 17.3 kg of P<sub>2</sub>O<sub>5</sub> and 33.5 kg of K<sub>2</sub>O. The highest doses of NPK components in natural fertilizers, on a fertilized area, were applied in the Lubuskie, Podlaskie, Lubelskie and Warmińsko-Mazurskie voivodeships, as well as the Wielkopolskie Voivodeship. In none of the voivodeships the average dose of nitrogen used in manure did not exceed the permissible level of 170 kg of N/ha. In terms of intensity of macronutrient fertilization from natural fertilizers, the Podlaskie Voivodeship take a lead, which confirms its importance in terms of animal production and its significance for the development of bioeconomy in Poland.

### **INTRODUCTION**

Natural fertilizers are recyclables for the benefit of bioeconomy [Chyłek 2017], although they are often treated as a by-product of livestock production. The fertilizers's components contained in them are important elements in conducting correct, rational fertilizer management, as they should be the first to be taken into account in meeting the nutritional needs of plants. A significant reduction in the use of natural fertilizers leads to a violation

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of the ionic balance in the soil environment, and consequently to a decrease in soil fertility and productivity, due to an insufficient reproduction of soil organic matter [Kopiński, Kuś 2011, Kopiński 2017]. The main advantage of natural fertilizers, justifying their widespread use, is that, in contrast to mineral fertilizers, they contain all the nutrients necessary for proper plant growth and development, despite not always appropriate from the point of view of plant nutrition proportions of these components. In contrast to mineral fertilizers, the effects of their use are visible in subsequent years after their application [Gonet 2006].

Natural fertilizers are: manure, including bird manure, liquid manure and slurry. Considering production as well as economic and environmental effects, the correct inclusion of individual types of natural fertilizers in the fertilization system requires knowledge of their chemical composition [Walczak et al. 2012, Skowron et al. 2019, Wrzaszcz, Kopiński 2019], which has a significant environmental aspect. The amount of available macronutrients in natural fertilizers depends on the size and structure of the livestock population. At a farm level, their quality is determined by the direction of animal use, the way they are fed and maintained, as well as the conditions of storage and application of natural fertilizers.

Despite a significant reduction in the number of livestock and a decrease in both the number of farms applying natural fertilizers and the fertilized area in the last dozen or so years, animal production still remains a dominant section in the structure of commodity agricultural production in Poland [Kopiński, Wrzaszcz 2020]. Regarding the aforementioned aspects, there are very large regional differences [Kopiński 2020].

The aim of this study was to determine, quantitatively and spatially, the size of resources of main macronutrients in natural fertilizers in Poland.

## MATERIAL AND METHODS OF THE STUDY

Research and analysis were carried out on a small-scale. The main sources of information were statistical data of the Central Statistical Office [GUS 2019-2020a,b,c] and the results of own research [Wrzaszcz, Kopiński 2019, Kopiński, Wrzaszcz 2020]. Determining the amount of macronutrient resources of natural fertilizers concerned the period between 2018 and 2019.

The amount of consumption of NPK fertilizer macronutrients was calculated based on their average content in individual types of natural fertilizers on the basis of papers by Czesław Maćkowiak [1997], Czesław Maćkowiak and Jacek Żebrowski [2000], Jacek Walczak et al. [2012] (Table 1). The calculations took into account the structure of livestock in large animal units (LU<sup>2</sup>).

<sup>2</sup> LU – the livestock unit according to the Ministry of Agriculture and Rural Development, used on the basis of the Annex to the Regulation of the Council of Ministers of 9 November 2004 [Journal of Laws 2004, No. 257, item 2573].

Table 1. Average content of nitrogen, potassium and phosphorous in different type of natural fertilizers

Type of natural fertilizer	Average content [kg/t of fresh matter]		
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Manure			
Cattle	4.7	2.8	6.5
Pigs	5.1	4.4	6.8
Sheep and goats	7.5	3.8	11.9
Poultry	22.0	15.0	21.0
Horses	5.4	2.9	9.0
Liquid manure			
Cattle	3.2	0.3	8.0
Pigs	2.8	0.4	4.1
Slurry			
Cattle	3.4	2.0	3.7
Pigs	4.3	3.3	2.3

Source: own study based on [Maćkowiak 1997, Maćkowiak, Żebrowski 2000, Walczak et al. 2012]

A comparative analysis in the spatial system was conducted at a province level (NUTS-2), where the reference point was average values for Poland. The analysis included the amount and level of consumption of nitrogen, phosphorus and potassium in particular kinds of natural fertilizers and with reference to fertilized area and agricultural land maintained in good condition (UAA).

## RESEARCH RESULTS AND DISCUSSION

According to SP data [GUS 2019-2020a], the average consumption of manure in Poland between years 2018 and 2019 was 44.3 million tons, 6.7 million m<sup>3</sup> constituted liquid manure and 14.1 million m<sup>3</sup> constituted slurry (Table 2). The relations of consumption of individual types of natural fertilizers in Poland were as follows: manure 68%, liquid manure 10.3%, slurry 21.7%. The consumption of natural fertilizers is regionally strongly diversified. These discrepancies result directly from differences in the size of the livestock population and indirectly from differences in the area size of provinces and systems of keeping individual animal species in livestock buildings. In Poland, the greatest use of natural fertilizers was characteristic for the Podlaskie (20.1%) and Wielkopolskie (16.4%) voivodeships.

Table 2. Natural fertilizer consumption and livestock structure expressed in livestock units by species in the voivodeships of Poland in years 2018-2019

Voivodeships	Consumption of natural fertilizers		Structure of animals number [% LU]					Load of livestock [LU/ha UAA]	
	manure [thous.t]	liquid manure [thous. m <sup>3</sup> ]	slurry [thous.m <sup>3</sup> ]	cattle	pigs	sheep and goats	poultry		horses
Dolnośląskie	852	72	241	53.4	15.2	0.7	24.4	6.3	17.9
Kujawsko-pomorskie	2,992	460	1,072	65.8	22.8	0.2	9.8	1.5	53.5
Lubelskie	4,357	308	580	66.5	12.1	0.4	15.3	5.8	30.4
Lubuskie	644	38	188	44.4	10.2	0.4	40.6	4.3	39.5
Łódzkie	3,957	298	1,118	63.4	23.8	0.2	10.8	1.7	57.6
Małopolskie	1,245	494	174	67.6	8.9	3.7	11.1	8.6	35.1
Mazowieckie	6,176	951	1,879	70.2	10.6	0.1	16.5	2.6	63.6
Opolskie	720	217	376	59.3	25.7	0.2	13.0	1.8	31.7
Podkarpackie	928	167	102	53.1	14.4	1.9	20.1	10.6	20.6
Podlaskie	8,211	1,607	3,772	86.5	4.1	0.2	6.7	2.4	85.6
Pomorskie	1,340	286	367	57.4	28.9	0.4	9.6	3.8	38.2
Śląskie	890	146	232	57.9	14.8	0.6	21.6	5.1	46.0
Świętokrzyskie	1,075	104	146	65.5	13.2	0.4	14.7	6.3	38.3
Warmińsko-mazurskie	2,766	472	1,294	64.4	11.1	0.2	21.8	2.5	62.5
Wielkopolskie	7,548	946	2,291	51.7	31.3	0.2	15.2	1.6	83.0
Zachodnio-pomorskie	607	118	254	50.6	16.7	0.4	28.5	3.7	21.2
Poland	44,308	6,683	14,085	64.3	17.3	0.3	15.0	3.0	50.9

Source: own study based on [GUS 2019-2020a,c]

In these voivodeships the indicator of animal stocking exceeds 80 LU/ha UAA. Regional differentiation is also visible in the structure of livestock structure. Analysis of Table 2 shows that, in 11 voivodeships, the share of poultry stock, expressed in livestock units (LU), was larger than the share of swine stock, which confirms significant structural changes that have taken place in Polish agriculture [Kopiński 2020]. Obviously, it also influences the structure of consumption of particular kinds of natural fertilizers and, in consequence, the consumption of particular macronutrients (NPK; Table 3).

The calculations show that, in Poland, in 2018-2019, average annual nitrogen consumption was: 327.8 thousand tons in manure, 20.8 thousand tons in liquid manure and 50.6 thousand tons in slurry (Table 3). A significant proportion (82%) of nitrogen was applied as manure. The amount of nitrogen delivered in manure was 2.5 times higher than in the applied slurry. The highest amount of nitrogen (in all kinds of natural fertilizers) was introduced in the Podlaskie and Wielkopolskie voivodeships (68-69 thousand tons) and the lowest in the Opolskie and Zachodniopomorskie voivodeships (6-7 thousand tons).

In all voivodeships, a definitely higher level of phosphorus and potassium application in the form of farmyard manure was recorded than in the applied liquid manure and slurry. Relatively, the consumption of phosphorus ( $P_2O_5$ ) in liquid manure was very small, i.e. ca. 1% of the total amount of phosphorus in manure. On the other hand, potassium consumption in Poland, both in liquid manure and slurry, was at a similar level, about 48 thousand tons of  $K_2O$ .

Analysis of data presented in Table 3 shows that the amount of potassium brought in natural fertilizers (486.9 thousand tons of  $K_2O$ ) was higher than the amount of nitrogen applied in these fertilizers (399.2 thousand tons of N). On the other hand, the amounts of phosphorus that was used were much smaller and amounted to 252 thousand tons of  $P_2O_5$  (Table 3).

In Poland, in 2018-2019, the average level of consumption of macronutrients in natural fertilizers, with respect to the area of UAA maintained in good cultivation, was: 27.4 kg of N, 17.3 kg of  $P_2O_5$  and 33.5 kg of  $K_2O$  (Figure 1). For phosphorus and potassium, the estimated amounts were at similar levels of consumption on individual farms as shown in the work of Wioletta Wrzaszcz and Jerzy Kopiński [2019]. On the other hand, the calculated, both total and unit consumption of nitrogen in mineral fertilizers (Table 3, Figure 1), was much lower than that shown in the work of Jerzy Kopiński [2017]. This is due to methodological differences, as in the 2017 paper these were “gross” amounts of nitrogen, calculated from livestock numbers, while the current results were converted to “net” nitrogen content in manure. In Poland, the total NPK consumption in natural fertilizers was estimated at a level of about 80 kg/ha UAA. The lowest level of macronutrient NPK consumption was in the Zachodniopomorskie Voivodeship, constituting only 24 kg NPK/ha UAA in dkr.

Table 3. Consumption of nitrogen, phosphorous and potassium in different types of natural fertilizers in Polish voivodeships in 2018-2019

Voivodeship	Nitrogen [thousand t N]			Phosphorus [thousand t P <sub>2</sub> O <sub>5</sub> ]			Potassium [thousand t K <sub>2</sub> O]		
	manure	liquid manure	slurry	manure	liquid manure	slurry	manure	liquid manure	slurry
Dolnośląskie	7.7	0.2	0.9	5.1	0.02	0.6	8.8	0.5	0.8
Kujawsko-pomorskie	19.4	1.4	3.9	13.0	0.15	2.5	24.0	3.2	3.6
Lubelskie	32.4	1.0	2.1	21.2	0.10	1.3	38.9	2.3	2.0
Lubuskie	7.6	0.1	0.7	5.1	0.01	0.4	8.1	0.3	0.6
Łódzkie	26.4	0.9	4.1	17.8	0.10	2.6	32.4	2.1	3.7
Małopolskie	8.5	1.6	0.6	5.4	0.15	0.4	10.6	3.7	0.6
Mazowieckie	47.1	3.0	6.6	30.8	0.30	4.1	55.6	7.1	6.6
Opolskie	5.1	0.7	1.4	3.5	0.07	0.9	6.1	1.5	1.2
Podkarpackie	7.8	0.5	0.4	5.1	0.05	0.2	9.1	1.2	0.3
Podlaskie	48.5	5.1	13.0	30.3	0.49	7.8	62.1	12.6	13.7
Pomorskie	8.7	0.9	1.4	5.9	0.10	0.9	10.8	1.9	1.2
Śląskie	7.6	0.5	0.8	5.1	0.05	0.5	8.8	1.1	0.8
Świętokrzyskie	7.9	0.3	0.5	5.2	0.03	0.3	9.5	0.8	0.5
Warmińsko-mazurskie	23.6	1.5	4.6	15.6	0.15	2.8	27.0	3.5	4.5
Wielkopolskie	56.4	2.9	8.6	39.0	0.32	5.7	66.8	6.2	7.3
Zachodniopomorskie	5.9	0.4	0.9	4.0	0.04	0.6	6.5	0.8	0.9
Poland	327.8	20.8	50.6	217.8	2.1	32.1	391.0	48.0	47.9
Share [%]	82.1	5.2	12.7	86.4	0.9	12.7	80.3	9.9	9.8

Source: own study and calculations based on [Maćkowiak 1997, Maćkowiak, Żebrowski 2000, Walczak et al. 2012, GUS 2019-2020a,c]

Macronutrient consumption in natural fertilizers per unit area is one of the indicator for assessing management intensity in quantitative terms. In Poland, total NPK consumption in manure was estimated at a level of ca. 80 kg per ha UAA. The lowest level of macronutrient NPK consumption was found in the Zachodniopomorskie Voivodeship with only 24 kg of NPK/ha UAA. In the Wielkopolskie Voivodeship over 100 kg of NPK/ha UAA was used in manure. The highest level of macronutrient consumption in natural fertilizers was shown in the Podlaskie Voivodeship (179 kg NPK/ha UAA) (Figure 1). It should be noted

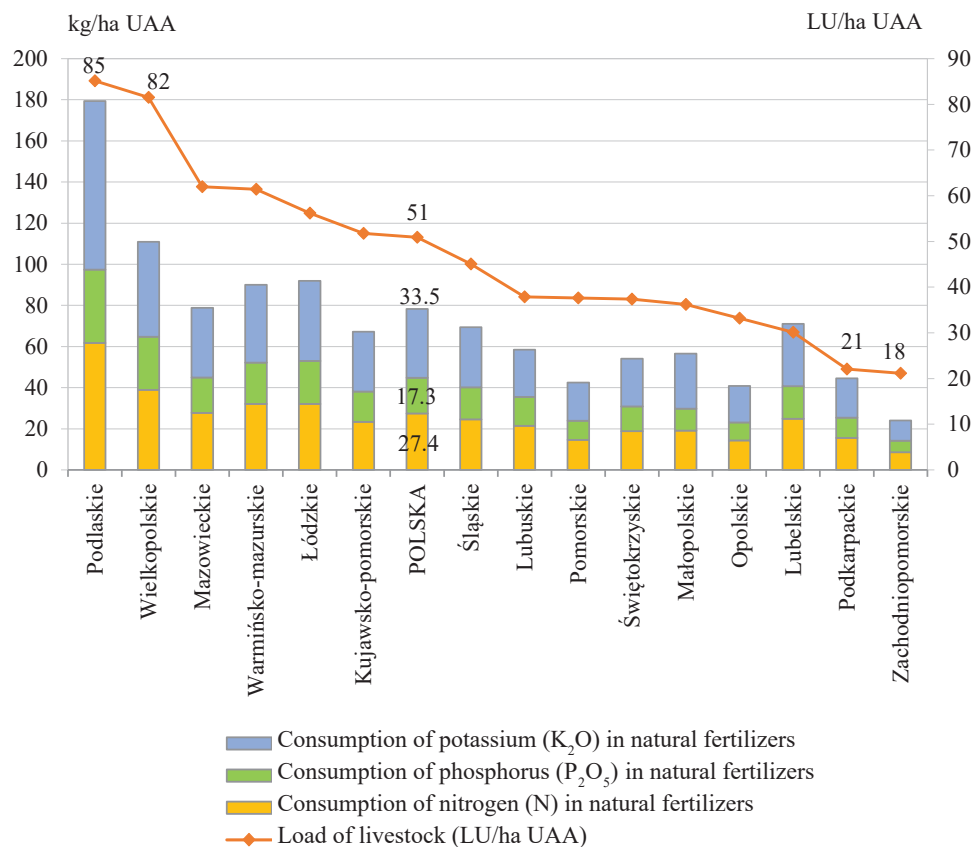


Figure 1. Territorial differentiation of natural fertilizer intensity and loads of livestock in Polish voivodeships in years 2018-2019

Source: own study and calculations based on SP data [GUS 2019-2020a,b,c]

that a relatively high level of NPK fertilizer components in relation to livestock density was consumed in the agriculture of the Lubelskie Voivodeship.

A measure of comparison of the intensity of manure management is the level of applied doses of particular macronutrients on the area fertilized with them. The level of applied doses also indicates the strength of pressure exerted on the environment. In this respect, in Poland, in 2018-2019, the highest doses of NPK components in natural fertilizers were applied in the Lubuskie, Podlaskie, Lubelskie, Warmińsko-Mazurskie and Wielkopolskie voivodeships (Figure 2). In none of the voivodeships the average dose of nitrogen applied in manure did not exceed the permissible level of 170 kg N/ha specified by the Nitrate Directive No. 91/676/EEC [2003]. In those voivodeships, the average doses of applied nitrogen, phosphorus and potassium were higher than the average

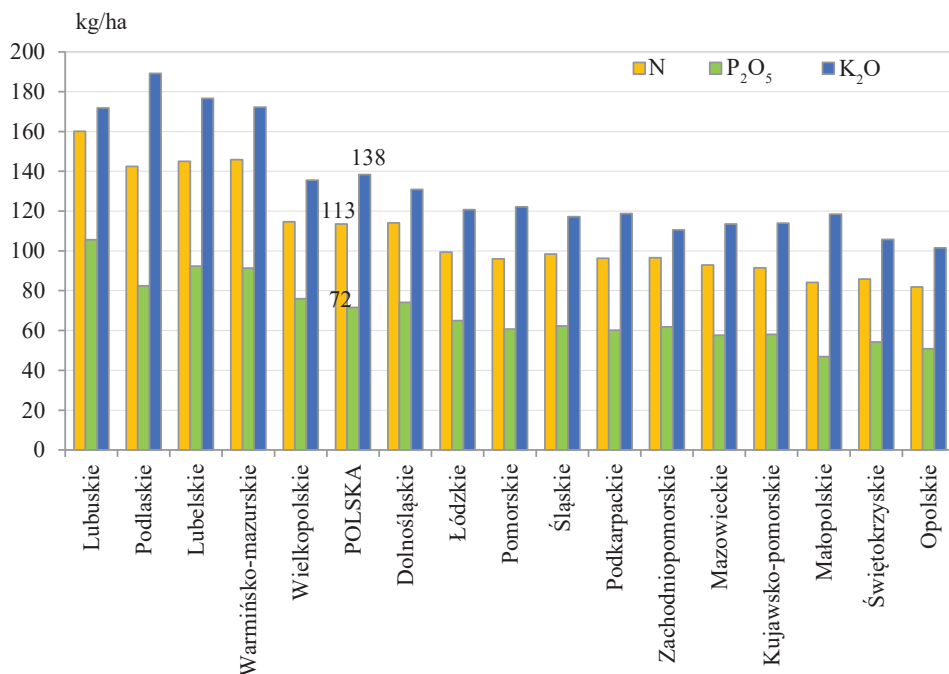


Figure 2. Level of doses of nitrogen, potassium and phosphorous in natural fertilizers (per fertilized area) in Polish voivodeships in years 2018-2019

Source: own study and calculations based on SP data [GUS 2019-2020a]

for the country, constituting 113 kg of N/ha, 72 kg of P<sub>2</sub>O<sub>5</sub>/ha and 138 kg of K<sub>2</sub>O/ha, respectively. However, the lowest doses of macronutrients from natural fertilizers, not exceeding a total of 250 kg of NPK/ha, were applied in the Małopolskie, Świętokrzyskie and Opolskie voivodeships (Figure 2).

When relating this indicator with the range of influence (the scale of applied manure in individual voivodeships) [Kopiński, Wrzaszcz 2020], the leading voivodeship in Poland, in terms of organization and intensity of macronutrient fertilization with natural fertilizers, was the Podlaskie Voivodeship.

## SUMMARY

The analysis of the average consumption of individual macronutrients in natural fertilizers and the comparison of the livestock stocking rate in a spatial arrangement facilitates, allows for evaluation of the scale of regional differences in Poland, also in terms of the strength of its potential environmental impact. In Poland, in 2018-2019, the



average consumption of manure was 44.3 million tons, 6.7 million m<sup>3</sup> constituted liquid manure and 14.1 million m<sup>3</sup> constituted slurry. In Poland, the highest consumption of natural fertilizers was distinguished by the Podlaskie (20.1%) and Wielkopolskie (16.4%) voivodeships, where the livestock density rate exceeded 80 LU/ha UAA.

The conducted analysis shows that, in most voivodeships, the share of poultry in stock structure expressed in livestock units (LU) was larger than the share of swine, which is confirmation of significant structural changes that have taken place in Polish agriculture. The specific structure of the livestock population has an impact on the structure type of natural fertilizers and individual macronutrients (NPK).

In Poland, between 2018 and 2019, 82% of nitrogen was applied in the form of manure. The amount of nitrogen delivered in the form of manure was 2.5 times higher than in the applied manure. The highest amounts of nitrogen in all kinds of natural fertilizers were used in the Podlaskie and Wielkopolskie voivodeships (68-69 thousand tons). Similar trends were also observed in the consumption of two other analyzed macronutrients, that mean phosphorus and potassium. Relatively, the consumption of phosphorus (P<sub>2</sub>O<sub>5</sub>) in liquid manure was very small, i.e. ca. 1% of the total amount of phosphorus in manure. On the other hand, the consumption of potassium was at a similar level, both in liquid manure and slurry, amounting to about 48 thousand tons of K<sub>2</sub>O. The amounts of applied potassium in total were higher than the amounts of applied nitrogen in these fertilizers.

Total NPK consumption in manure in Poland was estimated at a level of ca. 80 kg/ha UAA. The lowest level of macronutrient NPK consumption was recorded in the Zachodniopomorskie Voivodeship (a total of only 24 kg NPK/ha UAA), and the highest – in the Podlaskie Voivodeship (179 kg NPK/ha UAA). Relatively large amounts of fertilizer components from natural fertilizers, in relation to the number of animals, were used in agriculture in the Lubelskie Voivodeship.

The level of applied doses on fertilised area indicates the strength of pressure exerted on the environment. In Poland, the highest doses of NPK components in natural fertilizers were applied in the Lubuskie, Podlaskie, Lubelskie, Warmińsko-Mazurskie and Wielkopolskie voivodeships. In none of the voivodeships the average dose of nitrogen applied in manure did exceed the permissible level of 170 kg N/ha specified by the Nitrate Directive No. 91/676/EEC [2003].

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## ZASOBY GŁÓWNYCH MAKROSKŁADNIKÓW NAWÓZÓW NATURALNYCH W POLSCE

Słowa kluczowe: nawozy naturalne, pogłowie zwierząt, dawka, poziom nawożenia, azot, fosfor, potas

### ABSTRAKT

Przedstawiono wyniki analizy wielkości zużycia poszczególnych makroskładników w nawozach naturalnych w Polsce. Analizą objęto zużycie azotu, fosforu i potasu w poszczególnych rodzajach nawozów naturalnych, zarówno w odniesieniu do powierzchni nawożonej, jak i użytków rolnych. Okres badań obejmował dane za lata 2018-2019. Wielkość zasobów makroskładników nawozów naturalnych określono na poziomie województw. W wyniku analizy danych wykazano, że ponad 80% makroskładników NPK zaaplikowano do gleby w postaci obornika. Łączne zużycie NPK w nawozach naturalnych w Polsce oszacowano na poziomie ok. 80 kg/ha UR w dkr, w tym 27,4 kg N, 17,3 kg P<sub>2</sub>O<sub>5</sub> i 33,5 kg K<sub>2</sub>O. Największe dawki składników NPK w nawozach naturalnych na powierzchni nawożonej stosowane były w województwach lubuskim, podlaskim, lubelskim, warmińsko-mazurskim i wielkopolskim. W żadnym z województw średnia dawka stosowanego azotu w nawozach naturalnych nie przekraczała dopuszczalnego poziomu 170 kg N/ha. Pod względem intensywności nawożenia makroskładnikami z nawozów naturalnych wiodącym było województwo podlaskie, co potwierdza jego znaczenie w aspekcie produkcji zwierzęcej oraz istotność dla rozwoju biogospodarki w Polsce.

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