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NATURAL FERTILIZATION IN THE STRUCTURE OF FERTILIZATION IN SUSTAINABLE AGRICULTURE - ON THE EXAMPLE OF POLAND

The aim of this paper was to describe the state (as of 2010), structure by type (natural and mineral fertilisation, taking into account doses of nitrogen, potassium and phosphorus) and spatial diversification of fertilisation in the Polish agriculture (16 voivodships and 314 poviats). The studies of these issues concentrated on examining the impact of the external features of agriculture – natural and man-made ones. What has been demonstrated is the presence of a strong spatial diversification of fertilising procedures, mostly due to the impact of man-made conditions: historical and urban. It has transpired that the territorial patterns of fertilisation are bi-polar in nature: on the one hand, there are areas dominated by natural fertilisation (mostly north-eastern Poland); on the other hand, there are places where mineral fertilisation is prevalent (mostly northern and western Poland). Taking into consideration the planned Agricultural Census (2020) as well as the importance of pro-enviormental actions within The Common Agriculture Policy, the used metod of the comprehensive analysis of the feritilization for 2010 year constitutes a good starting point to the evaluation of the occurent changes.

Key words: natural fertilisation, mineral fertilisation, sustainable development of agriculture, Poland

I. INTRODUCTION

Essentially, the issue of sustainable development of agriculture includes the problem of crops fertilisation. Fertilisers enrich the soil with mineral constituents inevitable for plants to grow; at the same time, they improve the soil structure or change soil acidity. From the perspective of eco-development, agricultural holdings should ensure long-lasting soil fertility and a balance between natural matter and nutrients in soil [Jezierska-Thole et al. 2016, Kleijn and Sutherland 2003]. Highly important is the care taken to ensure the abundance of nutrients in soil, which is also at the basis of sustainable agricultural production [Jangid et al. 2008]. Whether soil provides good ground for growth of micro-organisms or not depends on its physical and chemical properties, fertilisation, climate, and agri-technical factors – but first and foremost – on the content of natural matter in soil, as it is the source of energy and nutrients for micro-organisms [Enwall et al. 2007].

The results of the studies conducted in Poland [Grzebisz 2008, Zalewski 2010, Kagan 2011] and in the world [Mäder et al. 2002, Malero et al. 2007] on the use of fertilisers and their impact

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on chemical and biochemical properties of soil suggest unambiguously that an improved fertility of soil and crops can be achieved through balanced natural and mineral fertilisation, on the one hand, and that the understanding of micro-biological processes in soil is important for the management of cropping systems, on the other hand.

Fertilisation falls into the category of the most significant determinants of agricultural production intensification. That fact is due to the yield-producing properties of fertilisation, which is connected to an improved content of nutrients in soil, the analysis of which is mainly – in agricultural statistics – restricted to three basic nutrients that are mostly used by crops, i.e.: nitrogen (N), phosphorus (P) and potassium (K) [Fierer and Jackson 2006]. Therefore, the amount of fertilisers in dry component N, P and K (in total and per 1 ha of agricultural land) has been taken as the basic indicator in this study.

As far as the natural environment is concerned, one should differentiate between agri-technical procedures involving natural fertilisers (use of waste from animal breeding: dung, liquid manure, and slurry) and those making use of mineral fertilisers (purchase of artificial fertilisers: basic current assets in an agricultural holding). That is why the analysis has included also the structure of fertilisation, which was defined by the consumption of the elements mentioned-above with the break-down into natural and mineral fertilisation.

Fertilisation of soil and crops may turn both beneficial and detrimental to the natural environment. To a far greater extent, mineral fertilisers are more likely to have a negative impact, when compared with natural ones. An excessive use of artificial fertilisers may turn deleterious for the natural environment. They (nitrogen fertilisers, in particular) are washed out during precipitation (up to 50%) and drain into surface and subterranean water, thus, contaminating drinking water for people and animals [Shaviv 2001].

This paper constitutes an attempt at a comprehensive presentation of fertilisation in the Polish agriculture, the issue which has been rarely undertaken in spatial studies. The studies of these issues concentrated on examining the impact of the external features of agriculture – natural and man-made ones.

II. MATERIAL AND METHODS

On the basis of the data gathered in the National Agricultural Census 2010 (NAC 2010) [Means of production...2010][2], which was the first nation-wide agricultural census in Poland conducted in compliance with the Eurostat requirements, a spatial study of fertilisation has been carried out, whereby spatial patterns were defined at the level of regions (16 voivodships) and 314 *poviat* units (following the territorial deployment of branch offices of the Agency for Restructuring and Modernisation of Agriculture – the payer of the CAP funds in Poland, *cf.* Rudnicki 2016, pp. 10-11).

The consumption of natural fertilisers in pure form (NPK)[3] in Poland in 2010 amounted to 1.311 thousand tonnes (including: N - 444 thousand t; P - 232 thousand t; K - 635 thousand t), which was calculated on the basis of the used amounts of a particular fertiliser (in tonnes) and the estimated doses of a particular elements per 10 tonnes or 10 m^3 [Gąsowski 2011], i.e.;

- dung 69.4 mln t – with: N x 50 kg, P x 30 kg, K x 70 kg per 10 tonnes;
- liquid manure 14.0 mln m^3 – with: N x 45 kg, P x 5 kg, K x 70 kg per 10 m^3;

[2] It was only in NAC 2010 that the authors were able to find more comprehensive data on mineral and lime fertilisers (NAC 2002 provided information only on the number of agricultural holdings using agri-chemical products), as well as on organic fertilisers; the data included the number of agricultural holdings using a particular type of fertiliser (dung, liquid manure, slurry) and the consumption of fertilisers (in tonnes)

[3] It should be noted that the agricultural statistics refer to NPK only – they do not account for other elements, even these micro-elements which are also significant for agricultural production

- slurry 8.5 mln m^3– with: N x 40 kg, P x 20 kg, K x 60 kg per 10 m^3.

According to NAC 2010, the consumption of mineral fertilisers in dry component in the Polish agriculture in a one-year period ending on the day prior to the census equalled 1.777 thousand t, with: N – 1.028 thousand t, P - 353 thousand t, and K - 397 thousand t.

The calculation of doses of natural and mineral fertilisers rendered it possible to establish the total level of fertilisation, which was at 3.088 thousand tonnes, and the ratios of the three basic elements[4]. The study involved also the external features of agriculture – a group of phenomena and processes occurring independently of agricultural holdings but affecting their spatial patterns. Referring to the approach suggested by Kostrowicki [1973] these features were divided into natural and man-made ones.

Within the natural conditions (NAT), by means of the agricultural production area quality index [APAQI] [Waloryzacja…2000, Witek and Górski 1997] and by referring to the application criteria of the RDP measure 'Aid to farmers in Less Favoured Areas (LFA)', the following categories were differentiated: areas with unfavourable natural and agricultural conditions – 1 (APAQI < 52 points); areas with moderately favourable natural and agricultural conditions – 2 (52 points < APAQI < 72 points); and areas with favourable natural and agricultural conditions – 3 (APAQI > 72 points; excluding LFA payments).

Another qualification within the set of natural determinants was based on ecological factors (ECO), where the delimitation was defined by the share of legally-protected areas in the total area of a *poviat*: 1 – small (< 20%); 2 – average (20 – 40%); and 3 – large (>40%; the average result for Poland = 32,4%).

The examination of man-made conditions covered the determinants specified below:

- historical (HIS) – *poviats* located within: land of the historical Austrian Partition and belonging to Poland in the inter-war period (AP/P); land of the historical Prussian Partition and belonging to Poland in the inter-war period (PP/P); land of the historical Russian Partition and belonging to Poland in the inter-war period (RP/P); land of the historical Prussian Partition and belonging to Germany in the inter-war period (PP/G; *cf.* Brückner 1992);
- urban (URB) – *poviats* categorised as: country districts – CD (poorly-urbanised) and townships – T (highly-urbanised).

III. RESULTS

Natural fertilisation

What is considered the essence of sustainable fertilisation is maintenance of the positive or at least neutral balance of natural matter in soil. Natural fertilisation changes the chemical and bio-chemical properties of soil; it also affects the variety and structure of micro-organic communities in soil [Buckley and Schmidt 2001]. Organic matter in soil is responsible for, e.g.: carbon capture and storage; water retention and management; mineral accumulation and mineral content regulation in soil [Triberti et al. 2008, Baath et al. 1995]. Soil deficient in organic matter cannot retain water well, which leads to bigger surface runoffs and erosion [Benton et al. 2003]. According to NAC 2010, there were 91.1 mln tonnes of natural fertilisers consumed in Poland:

- 69.4 mln t of dung – basic natural fertiliser consisting of farm animal excrement (fermented faeces and urine) and bedding (straw, chaff, etc.); including all nutrients necessary for crops growth and improvement of physical soil properties (mostly used for fertilisation of root crops);
- 14.0 mln t of liquid manure[5] – fermented urine of farm animals collected in receptacles (used for fertilisation of crop plantations, but also for meadows and feeding grounds);

[4] The statistical data used in the study did not include lime fertilisers (CaO), which are particularly important in the cultivation of acid soils

[5] Figures for liquid manure and slurry were given in m^3; for the sake of calculation 1 m^3=1 tonne

- 8.5 mln t of slurry – liquid, fermented mixture of farm animal excrement (faeces and urine) and water, usually coming from intensive animal farming (used for fertilisation of crop plantations, but also for meadows and feeding grounds).

The average level of natural fertilisation equalled about 85 kg of dry component NPK per 1 ha agricultural land and the nation-wide results varied across the voivodships: starting with regions in the west of Poland – the Dolnośląskie and Zachodniopomorskie Voivodships - (below 20 kg) and finishing with the region of Wielkopolska (208 kg) (tab. 1).

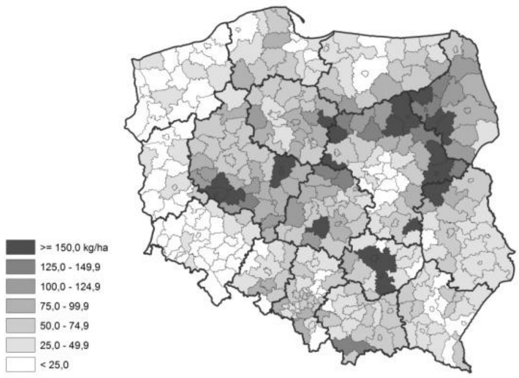
Table 1 – Tabela 1

Fertilisation in Polish agriculture – consumption level and structure – by voivodships in 2010
Nawożenie w rolnictwie polskim – poziom i struktura zużycia – wg województw w 2010 r.

Specification *Wyszczególnienie*		Consumption of natural fertilisers calculated for dry component NPK *Zużycie nawozów naturalnych w przeliczeniu na czysty składnik NPK*		Consumption of mineral fertilisers calculated for dry component NPK *Zużycie nawozów mineralnych w przeliczeniu na czysty składnik NPK*		Consumption of fertilisers in total calculated for dry component NPK *Zużycie nawozów ogółem w przeliczeniu na czysty składnik NPK*		
		thousand tonnes *w tys. ton*	kg/ha agricultural land *w kg/ ha UR*	thousand tonnes *w tys. ton*	kg/ha agricultural land *w kg/ ha UR*	thousand tonnes *w tys. ton*	kg/ha agricultural land *w kg/ ha UR*	ratio *relacja**
Polska		1310.9	84.6	1776.9	114,6	3087.8	199.2	0.74
By voivodships / *W tym województwa*								
Dolnośląskie		18.9	19.3	138.4	141.4	157.3	160.6	0.13
Kujawsko-pomorskie		83.8	77.9	165.6	153.9	249.4	231.8	0.51
Lubelskie		83.8	58.8	148.1	103.8	231.9	162.6	0.57
Lubuskie		11.3	24.3	43.7	94.1	55.0	118.4	0.26
Łódzkie		88.9	88.3	120.8	120.0	209.7	208.3	0.73
Małopolskie		41.1	62.3	36.8	55.8	77.9	118.2	1.11
Mazowieckie		266.1	136.8	190.8	98.1	456.9	234.9	1.40
Opolskie		24.6	47.2	94.5	181.9	119.1	229.1	0.26
Podkarpackie		26.3	37.6	40.6	58.0	66.9	95.6	0.66
Podlaskie		121.3	113.8	111.7	104.8	233.0	218.5	1.09
Pomorskie		36.2	44.7	99.2	122.5	135.4	167.2	0.37
Śląskie		23.9	55.0	43.9	101.0	67.8	156.0	0.54
Świętokrzyskie		47.2	84.1	45.1	80.5	92.3	164.6	1.04
Warmińsko-mazurskie		54.1	48.6	113.7	102.2	167.8	150.8	0.48
Wielkopolskie		366.5	208.4	264.8	150.6	631.3	359.0	1.38
Zachodniopomorskie		16.9	17.2	119.0	121.1	135.9	138.3	0.14
By conditions / *W tym uwarunkowania*								
Natural - agricultural	1	128.2	108.3	94.0	79.4	222.2	187.8	1.37
Przyrodniczo-rolnicze	2	992.3	97.4	1100.9	108.0	2093.2	205.4	0.90
(NAT)**	3	190.4	46.1	581.9	140.9	772.3	187.0	0.33
Natural - ecological	1	410.3	74.4	739.3	134.0	1149.6	208.4	0.56
Przyrodniczo-ekologiczne	2	372.2	68.7	602.3	111.1	974.5	179.8	0.62
(EKO)**	3	528.4	115.7	435.3	95.3	963.7	211.0	1.22
Historical	AP/P	65.8	49.7	69.1	52.3	134.9	102.0	0.96
Historyczne	PP/P	414.3	159.2	394.4	151.5	808.7	310.7	1.05
(HIS)***	RP/P	688.9	98.8	731.2	104.9	1420.1	203.8	0.94
	PP/G	141.9	30.8	582.1	126.3	724.0	157.1	0.24
Urban (URB)****	CD	1306.7	86.3	1755.8	116.0	3062.5	202.3	0.74
Urbanizacyjne	T	4.2	11.6	21.0	58.2	25.2	69.8	0.20

* natural fertilisation per 1 kg of mineral fertilisation
** level: 1 – low, 2 –average, 3 – high
*** historical units: AP/P - land of the historical Austrian Partition and belonging to Poland in the inter-war period, PP/P - land of the historical Prussian Partition and belonging to Poland in the inter-war period, RP/P - land of the historical Russian Partition and belonging to Poland in the inter-war period, PP/G - land of the historical Prussian Partition and belonging to Germany in the inter-war period
**** DC – country districts; T – townships
Source: own study based on NAC 2010

Taking *poviats* into consideration, a high consumption of natural fertilisers – over 150 kg in dry component NPK per 1 ha of agricultural land – was characteristic of 19 units located in the following voivodships: Mazowieckie (7 *poviats*), Wielkopolskie (4 *poviats*), Podlaskie (3 *poviats*), Świętokrzyskie (2 *poviats*), Kujawsko-Pomorskie, Łódzkie and Lubelskie (1 *poviat* in each; *cf*. fig. 1). These *poviats* feature intensive animal farming concentrated on factory farms, animal production, which usually leads to overproduction of natural fertilisers and concomitant problems in the natural environment.



Source: own study based on NAC 2010

Fig. 1. / ***Ryc. 1.*** Level of natural fertilisation in kg of dry component NPK per 1 ha agricultural land
Poziom nawożenia naturalnego w kg czystego składnika NPK na 1 ha użytków rolnych

The outcomes were juxtaposed with the external features of agriculture specified above. Upon examination, disparities were discovered in the dose of natural fertilisers in NPK per 1 ha of agricultural land, which was the most conspicuous in the case of:

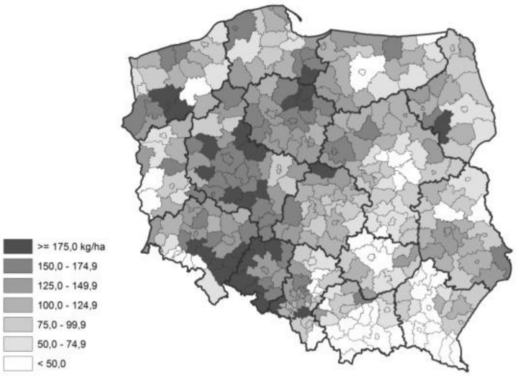
- natural-agricultural conditions – the dosage oscillated between 46 kg (NAT 3) and 108 kg (NAT 1); the authors of this paper consider this phenomenon positive, because reducing natural fertilisation in areas with poor (sandy) soils is tantamount to their productive degradation; in fact, natural fertilisation is prerequisite for continuation of agricultural activity (what poses risk is the fact that some agricultural holdings are departing from farm animal breeding);
- natural-ecological conditions – the positive phenomenon was observed here, namely: large doses of natural fertilisers in *poviats* with a significant share of protected areas (ECO 3 – 115.7 kg), in comparison to units with a small and average share of these areas (ECO 1, ECO 2 – about 70 kg);
- historical conditions – there were big differences in doses: from 31 kg in northern and western Poland (PP/G; outcome of state farm closures and their lessees' departure from animal production) to 159 kg in PP/P (outcome of traditional intensive animal farming).

Mineral fertilisation

Mineral fertilisation can considerably contribute to improved crops. Long-lasting studies of and achievements in agri-technical practices indicate unambiguously that mineral fertilisation has a remarkable impact on the number of micro-organisms and the quality of entire colonies of soil micro-organisms [Melero et al. 2007]. At the same time, fertilisation can prove detrimental, for instance: it can cause a decrease in soil productivity through excessive erosion, wash-out of nutrients, and deteriorated chemical soil properties. Used for several years, mineral fertilisers can significantly affect, for example: soil pH; quality and quantity of organic matter in soil; and the circulation of nutrients in the soil profile [Lalfakzuala et al. 2008]. In compliance with the principles of sustainable development, fertilisers should be applied only in such amounts which can be used by particular plantation or which can be retained by the soil.

According to NAC 2010, the consumption of mineral fertilisers in Poland amounted to 1.777 thousand tonnes of dry component NPK, which gave 115 kg per 1 ha agricultural land (from 56 – 58 kg in the Małopolskie and Podkarpackie Voivodships – south-eastern Poland; to approx. 150 kg in the Kujawsko-Pomorskie and Wielkopolskie Voivodships and over 180 kg in the Opolskie Voivodship; tab. 1).

The spatial patterns illustrating this index are depicted in Fig. 2. The largest, territorially-compact group of *poviats* (12 units) exhibiting a very high level of mineral fertilisation (175 kg <) was found in the Dolnośląskie (6 *poviats*) and Opolskie (6 *poviats*) Voivodships.



Source: own study based on NAC 2010

Fig. 2. / ***Ryc. 2.*** Level of mineral fertilisation in kg of dry component NPK per 1 ha of agricultural land / *Poziom nawożenia mineralnego w kg czystego składnika NPK na 1 ha użytków rolnych*

With regard to the external features of agriculture differentiated in this paper, the analysis of the mineral fertilisation level evinced a strong impact of the historical determinant (from 52 kg – HIS AP/P to 152 kg – HIS PP/P) and natural-agricultural conditions (from 79 kg – NAT 1 to 141 kg – NAT 3). Moreover, a positive trend was noted: the more ecologically valued an area is, the smaller a dose of fertiliser is becoming (from 134 kg – ECO 1 to 95 kg – ECO 3).

Fertilisation in total

In order to establish the importance of fertilisation to the agricultural productiveness in Poland, by referring to the outputs of the NAC 2010, a total dose of natural and mineral fertilisers in dry component NPK was defined (3.088 thousand t; tab. 1 & 2), which was the basis for creation of two indices presenting: the total dose of these fertilisers per 1 ha of agricultural land, and the internal relation (ratio) between natural and mineral fertilisers.

The average dose of fertiliser per 1 ha of agricultural land amounted to 199 kg NPK and was characterised by remarkable spatial diversification: at the level of voivodship (from 96 kg in the Podkarpackie Voivodship to 359 kg in the Wielkopolskie Voivodship – tab. 1) and even more so at the level of *poviat* (fig. 3).

The differences in the level of fertilisation in agricultural holdings in Poland were due to several factors. An average farmer in the area of the historical Prussian Partition which belonged to Poland in the inter-war period used over three times more fertilisers (HIS PP/P - 311 kg) than a farmer in the area of the historical Austrian Partition (HIS AP/P - 102 kg).

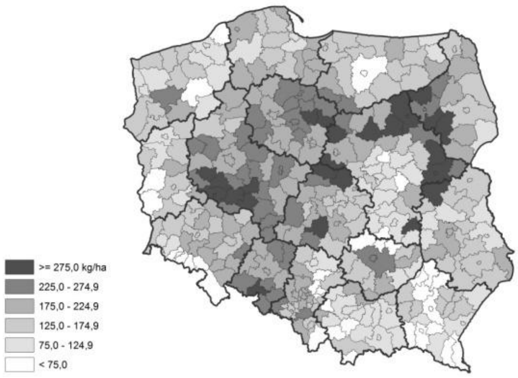
Table 2 – Tabela 2

Fertilisation in Polish agriculture – level and structure (as of 2010) / *Nawożenie w polskim rolnictwie – poziom i struktura (w 2010 r.)*

Specification *Wyszczególnienie*	Consumption of fertilisers calculated for dry component NPK *Zużycie nawozów w przeliczeniu na czysty składnik NPK*		Including *W tym*					
			nitrogen *azotowe (N)*		phosphorus *fosforowe (P)*		potassium *potasowe (K)*	
	thousand tonnes *w tys. ton*	kg/ha agricultural land *w kg/ha UR*	% NPK	kg/ha agricultural land *w kg/ha UR*	% NPK	kg/ha agricultural land *w kg/ha UR*	% NPK	kg/ha agricultural land *w kg/ha UR*
Natural fertilisers *Nawozy naturalne*	1310.9	84.6	33.8	28.6	17.7	15.0	48.4	40.9
Mineral fertilisers *Nawozy mineralne*	1776.9	114.6	57.8	66.3	19.8	22.7	22.3	25.6
Fertilisers in total *Nawożenie - razem*	3087.7	199.2	47.7	94.9	18.9	37.7	33.4	66.5

Source: own study based on NAP 2010

The analysis also showed a considerably lower level of fertilisation in townships (URB T - 70 kg; URB CD - 202 kg). No co-relation was discovered between the total dose of fertilisers and the agricultural production area quality index – APAQI (NAT 1 - 188 kg, NAT 3 - 187 kg) and the share of protected areas (ECO 1 - 208 kg, ECO 3 - 211 kg).



Source: own study based on NAC 2010

Fig. 3. Level of natural and mineral fertilisation in total in kg of dry component NPK per 1 ha of agricultural land / *Poziom nawożenia naturalnego i mineralnego w kg czystego składnika NPK na 1 ha użytków rolnych*

IV. CONCLUSIONS

Modern agriculture is facing several challenges. Among them there is one stressing the need for continuous improvement in efficiency so as to guarantee food security for the increasing number of people. What comes as the fundamental solution to this issue, besides bio-technology, is fertilisation; however, it – when incompetently used – may pave the way to major environmental losses. Rational soil fertilisation, which is compliant with the principles of sustainable development, should reconcile nutritional requirements of crops with the storage of only the necessary amounts of nutrients in soil. Consequently, application of fertilisers by agricultural producers ought to make sense from both economic and ecological points of view.

The study has demonstrated that there were 3.088 thousand tonnes (199 kg per 1 ha of agricultural land) of fertilisers in dry component NPK used in the Polish agriculture in 2010. The figures were highly diversified across regions (from below 100 kg in the Podkarpackie Voivodship to over 350 kg in the Wielkopolskie Voivodship) and *poviats.*

The calculations show that mineral fertilisers represented about 60% of the total dose of fertilisers. What was also established was the ratio of the three basic components: nitrogen (34% of the total dose of NPK in natural fertilisers, 58% of the total dose of NPK in mineral fertilisers), phosphorus (18%, 20%) and potassium (48%, 22%). The research evinced bi-polarity of the structure of fertilisation. While there are areas dominated by natural fertilisation in agriculture – particularly north-eastern Poland (agrarian fragmentation in the areas of high natural value) and eastern Poland (large share of animal farms), there are also areas where mineral fertilisation is prevalent – northern and western Poland (significant share of privatised state farms; lessees rarely continue animal production).

The study has presented that the state, structure and spatial diversification of fertilisation are affected by several external features of agriculture. It transpired that the strongest impact should be ascribed to the historical determinants and urban conditions. Moreover, among the findings there are some positive phenomena related to the decreasing dose of mineral fertilisers (with the increasing dose of natural fertilisers) and the simultaneous growth in the share of protected areas as well as a bigger dose of natural fertilisers in areas with less favourable natural conditions.

The results of the study justify the conclusion that fertilisation in agricultural holdings is a multi-faceted problem which presents itself differently depending on location; it is conditioned by a number of factors. Taking into consideration its environmental impact and the current objectives of the CAP – emphasising the need for sustainable development – fertilisation becomes a vital, present-day-oriented and many-sided subject in agricultural studies.

BIBLIOGRAPHY

1. Baath E., Frostegard A., Pennanen T., Fritze H. 1995. Microbial community structure and pH response in relation to soil organic matter quality in wood-ash fertilized, clear-cut or burned coniferous forest soils. Soil Biology and Biochemistry. 27(2). 229-240.
2. Benton T.G., Vickery J.A., Wilson J.D. 2003. Farmland biodiversity: is habitat heterogeneity the key. Trends in Ecology and Evolution. 18. 182-188.
3. Brückner T. 1992. LPG – was nun? Agrarkonzentration im Osten Deutschlands. Die Neugestaltung des ländlichen Raumes. Internationalismus-Verlag. Hannover, Germany.
4. Buckley, D.H., Schmidt T.M. 2001. The structure of microbial communities in soil and the lasting impact of cultivation. Microbial Ecology. 42. 11-21.
5. Enwall K., Nyberg K., Bertilsson S., Cederlund H., Stenström J., Hallin S. 2007. Long-term impact of fertilization on activity and composition of bacterial communities and metabolic guilds in agricultural soil. Soil Biology & Biochemistry. 39. 106-115.
6. Fierer N., Jackson R.B. 2006. The diversity and biogeography of soil bacterial communities. Proceedings of the National Academy of Science of United States of America. 103. 626-631.

7. Gąsowski M. 2011. Nawożenie łąk i pastwisk nawozami naturalnymi. *http://www.odr.pl/produkcja-roslinna/uzytki zielone/538/ (13.07.2011).*
8. Grzebisz W. 2008. Nawożenie roślin uprawnych. Podstawy nawożenia. Powszechne Wydawnictwo Rolnicze i Leśne. Poznań. 146.
9. Jangid K., Williams M. A., Franzluebbers A. J., Sanderlin J. S., Reeves J. H., Jenkins M. B., Endale D. M., Colemann D. C., Whitman W. B. 2008. Relative impacts of land-use, management intensity and fertilization upon soil microbial community structure in agricultural systems. Soil Biology and Biochemistry. 40(11). 2843-2853.
10. Jezierska-Thöle A., Rudnicki R., Kluba M. 2016. Development of energy crops cultivation for biomass production in Poland. Renewable and Sustainable Energy Reviews. 62. 534-545.
11. Kagan A. 2011. Oddziaływanie rolnictwa na środowisko naturalne. Zagadnienia Ekonomiki Rolnej. 328 (3). 99-115.
12. Kleijn D., Sutherland W.J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? Journal of Applied Ecology. 40. 947-969.
13. Kostrowicki J. 1973. Zarys geografii rolnictwa. PWN. Warszawa.
14. Lalfakzuala R., Kayang H., Dkhar M.S. 2008. The effects of fertilizers on soil microbial components and chemical properties under leguminous cultivation. Am-Euras. Journal Agriculture Environ. Sci. 3. 314-324.
15. Mäder P., Fliessbach A., Dubois D., Gunst L., Fried P., Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science. 296(5573). 1694-1697.
16. Melero S., Madejón E., Ruiz J. C., Herencia J. F. 2007. Chemical and biochemical properties of a clay soil under dryland agriculture system as affected by organic fertilization. European Journal of Agronomy. 26 (3). 327-334.
17. Rudnicki R. 2016. The spatial structure of Polish agriculture – conditioned by Common Agricultural Policy instruments. Wydawnictwo Naukowe UMK. Toruń.
18. Shaviv A. 2001. Advances in controlled-release fertilizers. Advances in agronomy. 71. 1-49.
19. Strategy Means of Agricultural Production. National Agricultural Census 2011. 2011. Central Statistical Office. Warsaw.
20. Triberti, L., Nastri, A., Giordani, G., Comellini, F., Baldoni, G., Toderi, G. 2008. Can mineral and organic fertilization help sequestrate carbon dioxide in cropland? European Journal of Agronomy. 29(1). 13-20.
21. Waloryzacja rolniczej przestrzeni produkcyjnej Polski. 2000. The Institute of Soil Science and Plant Cultivation. Puławy.
22. Witek T., Górski T. 1997. Przyrodnicza bonitacja rolniczej przestrzeni produkcyjnej w Polsce. The Institute of Soil Science and Plant Cultivation. Puławy.
23. Zalewski A. 2010. Rynek nawozów mineralnych w Polsce. Opinie i Ekspertyzy OE-133. Bureau of Analyses and Documentation by the Senate Chancellery. Warszawa.

NAWOŻENIE NATURALNE W STRUKTURZE NAWOŻENIA W ZRÓWNOWAŻONYM ROLNICTWIE - NA PRZYKŁADZIE POLSKI

Streszczenie

Celem pracy było rozpoznanie stanu (2010 r.), struktury rodzajowej (nawożenie naturalne i mineralne, z wydzieleniem dawek azotu, potasu i fosforu) i zróżnicowania przestrzennego nawożenia w polskim rolnictwie (16 województw i 314 jednostek powiatowych). Podjęto problem kształtowania się wymienionych cech pod wpływem zewnętrznych uwarunkowań rolnictwa – przyrodniczych i pozaprzyrodniczych.

Przeprowadzone badania udowodniły silne zróżnicowanie przestrzenne nawożenia, określone przede wszystkim przez oddziaływanie czynnika historycznego i urbanizacyjnego. Wykazano, że układy terytorialne nawożenia mają charakter dwubiegunowy – od obszarów o przewadze nawożenia naturalnego (głównie Polska północno-wschodnia) do dominacji nawożenia mineralnego (głównie Polska północna i zachodnia). Biorąc pod uwagę planowany Powszechny Spis Rolny (2020) oraz rosnącą wagę działań prośrodowiskowych w ramach Wspólnej Polityki Rolnej, wypracowana metoda kompleksowej analizy nawożenia przeprowadzona dla roku 2010, stanowi dobry punkt wyjścia do oceny zachodzących przemian.

Słowa kluczowe: nawożenie naturalne, nawożenie mineralne, zrównoważone rolnictwo