Fragm. Agron. 33(4) 2016, 73–86

# ANALYSIS OF PHOSPHORUS BALANCE IN AGRICULTURAL PRODUCTION AS AN ENVIRONMENTAL INDICATOR IN THE GEOGRAPHICAL AND HISTORICAL LAND OF WIELKOPOLSKA IN 1843–2012

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**Abstract.** The aim of the study was to assess the intensity of agricultural phosphorus management on the basis of field surface balance in Wielkopolska region, with its capital in Poznań. The study selected 14 periods at the turn of three centuries: XIX, XX and XXI. Wielkopolska is a region strongly associated with the onset of Poland. Agriculture in the region represented a very high level for centuries. Development in Wielkopolska has for the last 200 years been subject to considerable pressure as a result of political, constitutional, and economic factors. The level of agricultural production fluctuated and underwent to progress very easily. Crop and livestock production underwent a kind of metamorphosis. Species of plants and animals that were popular in the nineteenth century, early twentieth century, and after World Wars I and II have practically ceased to have meaning. The calculated phosphorus balance results ranged from -3.61 to 25.17 kg P·ha$^{-1}$ per agricultural land. By 1912, the balance of phosphorus was in the negative, since when only positive balances have been recorded.

**Key words:** phosphorus balance, non-point pollution, Wielkopolska's agriculture, agri-environmental indicators

## INTRODUCTION

Wielkopolska is a region that has featured strongly in Polish history and is strongly associated with the onset of the Polish state. The strongest national movements and the struggle for national identity during the partitions are also focused here. The first people appeared in Wielkopolska in the late Paleolithic era, approx. 10,000 BC. In the Bronze Age (1700−650 BC) there was marked development of settlements in Wielkopolska. At the peak period of the Sorbian culture and the early Iron Age many castles were built in the region. At the beginning of the modern age there was intense agricultural development and farming [Pietruszczyński 1936, Rocznik… 2006, Wojtasiewicz 1991]. The wooden plough also began to be used in field work. In the VI and VII centuries tribal organisations formed and spread agriculture. In the mid-ninth century an intertribal state called "state of Gniezno" was created [Topolski 1969]. The nineteenth century is a special century in Polish history because it had lost its identity as a result of the three partitions put in place by Austria, Prussia and Russia in 1769, 1793 and 1795. During the second partition Prussia took over, among others, the provinces of Gniezno, Poznań, Kalisz and Wieluń. All of them belonged to Wielkopolska in the past or currently [Baranowski and Topolski 1964]. The loss of Polish own state led to the destruction of the achievements of the Enlightenment and the

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inhibition of the formation of the capitalist system. Poznan during this period was not a leading area in terms of agriculture. However, good economic conditions, the activity of pioneers of agriculture (including Dezydery Chłapowski and Vladimir Wolniewicz) and good examples from other Prussian provinces gradually raised the level of farming there [Baranowski and Topolski 1964]. In the second half of the nineteenth century, agricultural progress under Prussian rule was greatest. At the turn of 1918/1919 the victorious Wielkopolska Uprising broke out, which enabled the Poznan Province to join the Republic of Poland. After World Wars I and II, both of which had a big impact on the geo-political situation in Poland, Wielkopolska region excelled in technology and agricultural productivity, despite the enormous social, economic and political problems [Kostrowicka et al. 1984].

The aim of the study was to assess the intensity of phosphorus management in agriculture in terms of diffuse pollution monitoring based on the field surface balance in the changing boundaries of the Wielkopolska region, with its capital in Poznań.

## MATERIAL AND METHODS

**Agricultural statistics**. Information about the structure of animal species and their abundance, structure of land use and crops, crop yield and fertiliser use are obtained with the statistical studies and practical guidelines developed by agricultural activists and scribes [Ziemianin 1850, Grabski 1914 and 1915, Strasburger 1916, Historia… 1994, Kuklo et al. 2014, Rocznik… 1949, Rocznik… 1950, Mały Rocznik… 1931, Mały Rocznik… 1935, Mały Rocznik… 1939, Romer and Weinfeld 1917, Rocznik … 1923, Rocznik … 1956, Rocznik … 1948, Tablice… 1923, Tablice… 1956, Tablice… 1927, Rocznik… 1964, Rocznik… 1973, Rocznik… 1983, Rocznik… 1993, Rocznik… 2003, Rocznik… 2013]. Analyses were made for years, resulting in the most complete and accurate data.

**Phosphorus balance**. The correctness of the phosphorus management is calculated based on the field surface balance [Kupiec and Zbierska 2012]. Some of the elements of the balance structure were significant only at certain times. Later, due to changes in agricultural techniques and legislative acts, share of balance elements decreased or completely lost its importance. The phosphorus balance formula is as follows:

$$P_{budget} = \Sigma P_F + \Sigma P_M + \Sigma P_S + \Sigma P_W + \Sigma P_L + \Sigma P_A - \Sigma P_C - \Sigma P_G$$

...where:

F – *fertilisers*, M – *solid manure*, S – *slurry*, W – *fecal/domestic waste water*, L – *forest litter*, A – woody *ash*, C – *crops*, G – *yield of grassland*.

In the phosphorus balance sheet formula historical conditions and cultivated agricultural practices in a given period were taken into account. Nutrient content was based on the results of chemical analyses and the researchers' experiments during the period.

**Mineral fertilisers**. Due to the low interest in fertilisers in the nineteenth century and their marginal usage rate, this part of the balance sheet is omitted for the years 1843 and 1873. In other periods, the amount of phosphorus from fertilisers was calculated on the basis of their consumption in the region. Because of the lack of data for the years 1912−1947 the average consumption of phosphorus mineral fertilisers for the Polish territory was assumed from that period and increased by the average higher consumption in the region (19% more).

**Manures**. In the nineteenth century and the first half of the twentieth century, the handling of liquid manures was irrational and their usage was marginal. Therefore, up to 1938, was calculated phosphorus from produced solid manure only. The quantity of manure produced by

livestock was calculated according to Górski [by Niklewski 1949]. The amount of phosphorus in the manure produced in this period was calculated by Mayer [by Niklewski 1949].

The amount of resulting manure in the period 1843−1955 was calculated based on Haselhoff [by Niklewski 1949] and Górski [1947]. The amount of manure produced in the period 1961−2012 was calculated according to the guidelines of the Council of Ministers of 18 May 2005 [Rozporządzenie... 2005]. Phosphorus content in manure produced in this period was calculated by Mazur and Górski [by Wrześniowski at al. 1997].

**Straw and forest litter**. In the twentieth century forest litter was often used as bedding for animals when straw was not available. The first regulations restricting this type of practice that adversely affected the functioning of forest ecosystems were introduced at the beginning of the twentieth century. In this paper, the amount of forest litter used is counted on the basis of the difference between the amount of straw harvested from the fields and the needs of the animals in this area [Stutzer 1902].

The amount of straw produced in the fields was calculated based on the proportion of main crop to by-product. The proportions were calculated on the basis of the average yield of grain and straw given by Stutzer [1902]. It amounted to rye 1:4, wheat 1:2, barley 1:1.3, oats 1:1.8. Straw harvested from the fields is calculated on the basis of information from Kostrowicka et al. [1984]. Farmers living in the nineteenth century in the region of the Grand Duchy of Poznań cut the ears of crops by hand, with sickles. The rule was to cut the straw as high as possible, so the vast majority of the straw remained on the field. In the first half of the twentieth century agriculture in the region modernised significantly. The introduction of new machinery and equipment used for the harvesting of cereals resulted in a greater yield of straw which was useful in the intensification of animal production. Therefore, the paper assumes that farmers harvested approx. 25% of straw in 1843 and 1873 and 50% in 1912. The demand for bedding for livestock were calculated based on the individual needs of each species [Stutzer 1902]. The contents of the nutrient in the forest litter was calculated by Niklewski [1949].

**Fecal**. In the nineteenth century not much attention was paid to the storage of domestic sewage and it was mostly collected in bare earthen pits, leading to liquid manures penetrating the soil. However, this was an important element of fertilisation in some farms. For the period 1943−1912 only the amount of hard excrement was calculated according to the information given in Ziemianin [1850]. The sum of the faeces was calculated for a rural population living in this region in particular periods. The phosphorus content in solid faecal matter was calculated by Stutzer [1902].

The amount of human faeces used as fertiliser in the years 1921−1946 and the content of phosphorus were calculated by Stutzer [1902]. Other authors also reported that human faeces are also an excellent phosphorus fertiliser [F.R. Rolnik Nadwiślański 1900]. However, in subsequent periods faeces ceased to be used as fertiliser, therefore they are not included in the balance sheet components.

**Woody ash**. Ash was used frequently as a fertiliser in the nineteenth and early twentieth century. The ingredients brought this way were counted for the 1843−1931 period. In subsequent years, they ceased to be relevant as a fertiliser and were instead treated as waste. The amount of wood consumed as fuel in farms in the analysed periods was calculated based on the average consumption of firewood [Zużycie… 2012]. The content of PK ingredients in ash was calculated by Gaerdt-Lobner [following Niklewski 1949].

## RESULTS AND DISCUSSION

**The characteristics of Wielkopolska region**. The research area is the historical and geographical region of Wielkopolska, with its capital in Poznan. Administrative borders of the region changed several times in the analysed period (Fig. 1−4). Wielkopolska is a region that has featured strongly in the history of Poland and is strongly associated with the onset of Polish statehood [Topolski 1969, Włodarczyk 2012]. The nineteenth century is a special century in the history of Poland because it had lost its identity as a result of the three partitions put in place by Austria, Prussia and Russia in 1769, 1793 and 1795. During the second partition Prussia took over, inter alia, Province Gniezno, Poznań, Kalisz and land of Wieluń associated with the Wielkopolska region [Baranowski and Topolski 1964]. The result of the partition was the acquisition by Prussia of 20% of Poland territory, 18% by Austria, and 62% by Russia. The Prussian sector, including Wielkopolska region, was inhabited mostly by the Polish population and the land was incomparably better economically developed. Austria, Prussia and Russia, occupying Poland, retained the feudal system and the supremacy of nobility over the villagers. In Prussia and Austria, however, there were partial attempts to reform these feudal relations.

Several periods affecting Wielkopolska region and developing agriculture there can be distinguished in the analysed period [Baranowski and Topolski 1964, Kostrowicka et al. 1984, Kraciński 2011] (Fig. 5−6). Wielkopolska region was a leader in terms of technology and agricultural productivity throughout the period considered.

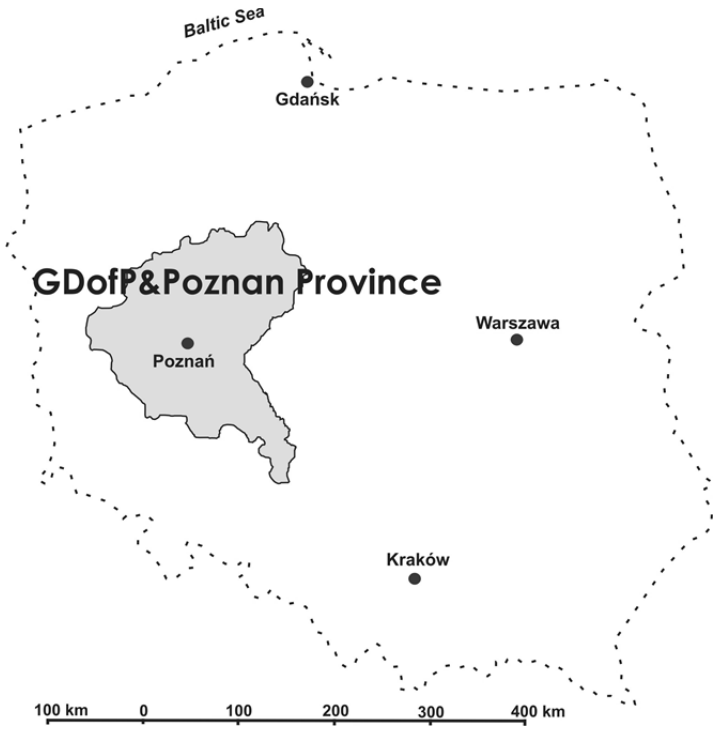


Fig. 1. Border of Grand Duchy of Poznań (1815−1848) and Poznań Province (1848−1919) in the background of the current Polish border


Fig. 2. Border of Poznańskie voivodeship in 1919−1939

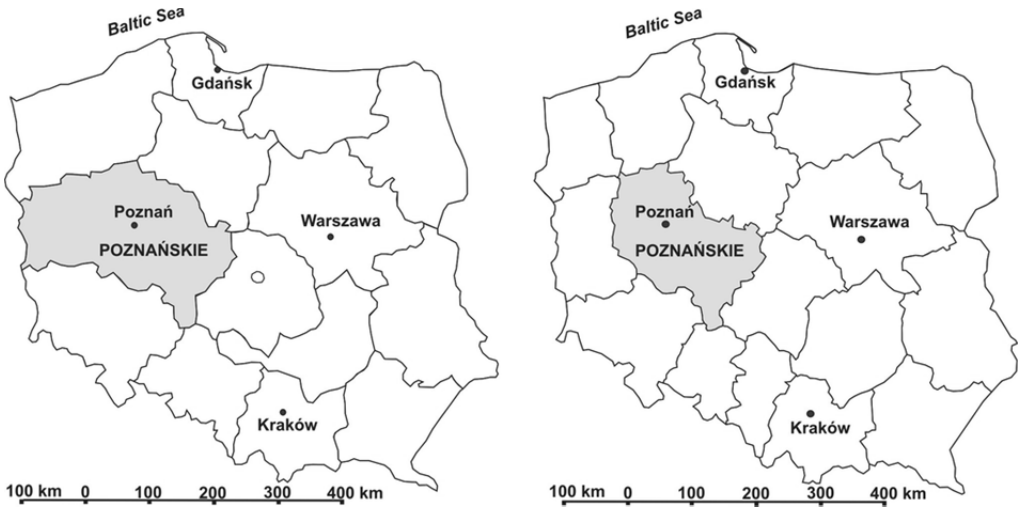


Fig. 3. Border of Poznańskie voivodeship in 1946−1950 and 1950−1975

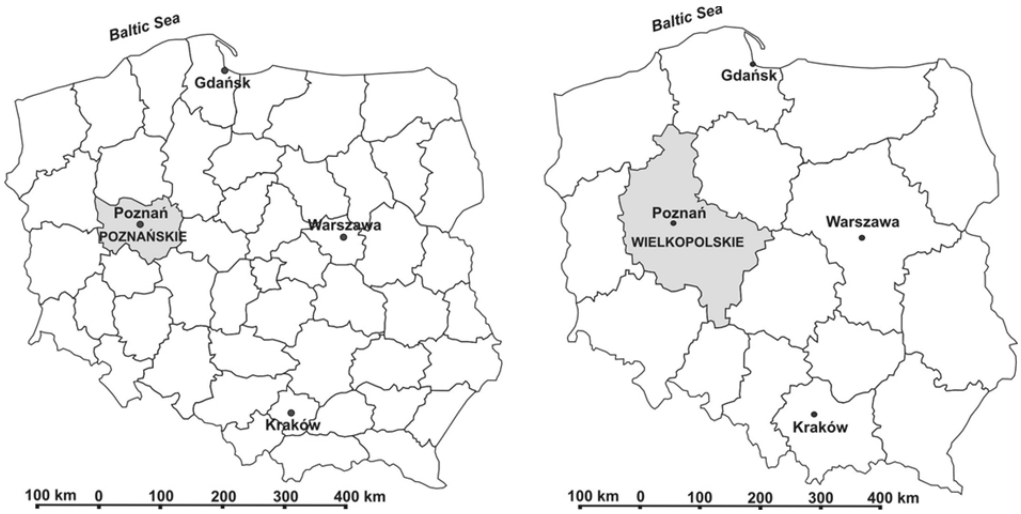


Fig. 4. Border of Poznańskie voivodeship in 1975−1998 and Wielkopolskie voivodeship in 1998−2016

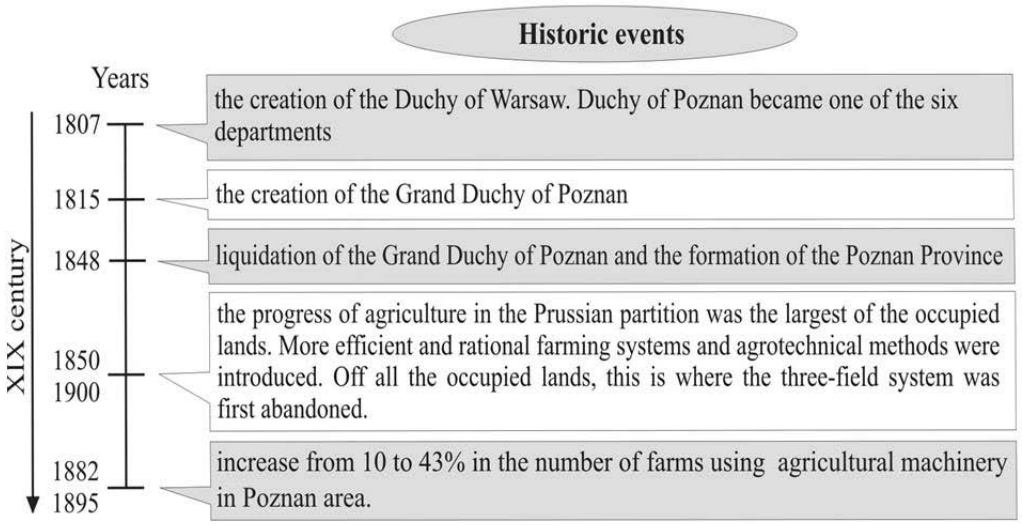


Fig. 5. Historical and morphogenetic factors affecting the development of agriculture in the analysed region in XIX century


Fig. 6. Historical and morphogenetic factors affecting the development of agriculture in the analysed region in XX and XXI centuries

The area of the region examined increased from 815,097 in 1992 to 3,950,300 ha in 1947 (Table 1). The land structure was clearly dominated by agricultural land, including arable land. In the period 1843−2014, the area was reduced by approx. 16%. Major changes took place mainly in areas of permanent grassland, which decreased from 34.2 in 1843 to 8.4% in 2012.

Table 1. Land use structure in particular periods

| Year | Region area | Agricultural land | Arable land with orchards and gardens | Meadows | Pastures | Woods, forests and woodlots | Other land and wasteland |
|---|---|---|---|---|---|---|---|
| | [ha] | (%) | | | | | |
| 1843 | 2987010 | 74.8 | 40.6 | 14.1 | 20.1 | 20.5 | 4.7 |
| 1873 | 2895239 | 74.9 | 61.6 | 8.1 | 5.2 | 20.2 | 4.9 |
| 1912 | 2899000 | 75.0 | 64.6 | 7.8 | 2.6 | 18.1 | 6.9 |
| 1922 | 2657929 | 76.0 | 65.6 | 7.8 | 2.6 | 18.1 | 5.9 |
| 1931 | 2835000 | 75.1 | 64.6 | 7.1 | 3.4 | 17.4 | 7.5 |
| 1938 | 2835000 | 75.1 | 64.6 | 7.1 | 3.4 | 17.4 | 7.5 |
| 1946 | 3950300 | 67.8 | 57.4 | 7.5 | 2.8 | 24.1 | 8.1 |
| 1955 | 2744300 | 69.9 | 59.0 | 6.9 | 4.0 | 19.8 | 10.3 |
| 1961 | 2 672 269 | 70.5 | 59.7 | 7.0 | 3.9 | 21.7 | 7.8 |
| 1972 | 2 684 885 | 66.7 | 55.7 | 7.8 | 3.2 | 23.6 | 9.7 |
| 1982 | 822 757 | 66.4 | 58.6 | 5.7 | 2.2 | 20.9 | 12.7 |
| 1992 | 815 097 | 66.2 | 58.6 | 5.4 | 2.2 | 21.1 | 12.7 |
| 2002 | 2 982 559 | 59.6 | 51.2 | 6.8 | 1.5 | 25.7 | 14.7 |
| 2012 | 2 982 559 | 58.8 | 50.4 | 7.6 | 0.8 | 25.7 | 15.5 |

Analysing the share of individual plant groups in the crop structure it can be seen that the share of cereals underwent fairly large fluctuations of up to 30% (Table 2). Root crops, including potatoes, had almost no importance in the nineteenth century. In the second half of the nineteenth century there was an increase in the acreage of potatoes and sugar beets crops. Root crops occupy large cultivated areas mainly between the First and Second World War. Currently root crops constitute a small share in the crop structure. The balance after World War II quickly returned to normal.

In analysed period (1843−2012) the population of horses in the region has decreased dramatically (Table 3). This was mainly associated with the increased mechanisation of agriculture and horses losing their significance as draft animals. In the period under review the amount of sheep and goats decreased significantly to a marginal amount. Swine, which in the nineteenth century accounted for only 4% of the inventory, has gained in importance in the twentieth century. In the analysed period the share of swine increased to 51%. In the last two periods (2002−2012), the population of poultry significantly increased.

**Phosphorus balance**. The phosphorus balance sheet structure has also changed over time (Table 4). In the nineteenth century NPK mineral fertilisers were used on a small scale. Much at-

Table 2. Structure of crops in investigated periods

| Year | Cereals | Fabaceae | Industrial and special plants | Forage crops | Root plants | Others |
|---|---|---|---|---|---|---|
| | (%) | | | | | |
| 1843 | 80.3 | 17.0 | 0.8 | 0.0 | 0.6 | 1.3 |
| 1873 | 71.3 | 17.6 | 0.7 | 0.6 | 9.1 | 0.7 |
| 1912 | 63.4 | 4.6 | 0.0 | 7.3 | 20.0 | 4.6 |
| 1922 | 69.7 | 0.0 | 0.0 | 0.0 | 30.3 | 0.0 |
| 1931 | 71.8 | 1.5 | 0.2 | 0.0 | 26.4 | 0.1 |
| 1938 | 73.8 | 1.1 | 0.9 | 0.0 | 24.1 | 0.0 |
| 1946 | 66.0 | 2.4 | 2.6 | n.d. | 17.2 | 11.8 |
| 1955 | 50.9 | n.d. | n.d. | n.d. | 22.6 | 26.5 |
| 1961 | 53.5 | 0.5 | 2.4 | 15.8 | 25.6 | 2.2 |
| 1972 | 60.9 | 5.7 | 3.3 | 0.0 | 28.0 | 2.2 |
| 1982 | 50.3 | 9.1 | 3.5 | 10.6 | 22.1 | 4.4 |
| 1992 | 56.6 | 7.8 | 7.2 | 6.8 | 16.1 | 5.5 |
| 2002 | 79.0 | 2.1 | 5.7 | 0.0 | 10.5 | 2.8 |
| 2012 | 70.0 | 3.8 | 7.4 | 7.9 | 7.3 | 3.5 |

n.d. – no data

Table 3. Structure of animal species in analysed periods

| Year | Horses | Cattle | Swine | Sheep/goats | Poultry/rabbits | Summary LSU = 100% |
|---|---|---|---|---|---|---|
| | (%) | | | | | |
| 1843 | 23 | 54 | 4 | 17.3 | 2.4 | 761720 |
| 1873 | 21 | 45 | 4 | 27.5 | 2.4 | 1027499 |
| 1912 | 25 | 59 | 10 | 2.8 | 2.4 | 1291512 |
| 1922 | 23 | 62 | 9 | 3.5 | 2.4 | 1135712 |
| 1931 | 27 | 58 | 11 | 2.3 | 2.4 | 1222246 |
| 1938 | 26 | 59 | 10 | 2.7 | 2.4 | 1594893 |
| 1946 | 29 | 55 | 10 | 3.0 | 2.0 | 998343 |
| 1955 | 24 | 55 | 16 | 2.2 | 3.1 | 1140980 |
| 1961 | 22 | 55 | 18 | 3.0 | 1.6 | 1241843 |
| 1972 | 16 | 54 | 26 | 2.5 | 0.9 | 1403648 |
| 1982 | 6 | 52 | 37 | 4.4 | 1.3 | 485248 |
| 1992 | 5 | 41 | 51 | 2.4 | 1.0 | 438105 |
| 2002 | 2 | 55 | 29 | 0.6 | 14.0 | 1320250 |
| 2012 | 2 | 50 | 31 | 0.4 | 16.4 | 1200834 |

Table 4. Structure of phosphorus balance in farms of Wielkopolska region in analysed periods

| Year | Input P kg·ha$^{-1}$ AL | | | | | | | Output P kg·ha$^{-1}$ AL | | | Balance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mineral fertilisers | Manures | | Faecal | Woody ash | Forest litter | Summary input | Crops | Sward from grassland | Summary output | |
| | | solid manure | slurry | | | | | | | | |
| 1843 | - | 2.38 | - | 0.57 | 0.15 | 0.11 | 3.23 | 0.92 | 3.12 | 4.04 | -0.81 |
| 1873 | - | 2.97 | - | 0.72 | 0.19 | 0.03 | 3.91 | 6.21 | 1.31 | 7.52 | -3.61 |
| 1912 | 0.48 | 4.62 | - | 0.87 | 0.23 | 0.30 | 6.50 | 5.51 | 1.07 | 6.58 | -0.08 |
| 1922 | 0.61 | 4.25 | - | 0.33 | 0.23 | - | 5.42 | 3.76 | 1.05 | 4.81 | 0.61 |
| 1931 | 1.04 | 4.41 | - | 0.41 | 0.28 | - | 6.14 | 4.74 | 1.04 | 5.79 | 0.36 |
| 1938 | 1.67 | 5.68 | - | 0.41 | - | - | 7.76 | 4.18 | 1.04 | 5.22 | 2.54 |
| 1946 | 1.72 | 2.95 | 4.89 | 0.40 | - | - | 9.96 | 7.19 | 2.66 | 9.86 | 0.11 |
| 1955 | 5.19 | 4.80 | 7.84 | - | - | - | 17.83 | 8.80 | 1.55 | 10.35 | 7.47 |
| 1961 | 6.76 | 8.81 | 0.87 | - | - | - | 16.44 | 9.19 | 1.12 | 10.31 | 6.13 |
| 1972 | 19.75 | 10.66 | 1.25 | - | - | - | 31.66 | 8.77 | 1.44 | 10.22 | 21.44 |
| 1982 | 26.77 | 10.34 | 1.43 | - | - | - | 38.54 | 12.01 | 1.37 | 13.37 | 25.17 |
| 1992 | 6.15 | 10.70 | 1.54 | - | - | - | 18.38 | 12.14 | 0.95 | 13.08 | 5.30 |
| 2002 | 8.46 | 8.63 | 1.29 | - | - | - | 18.38 | 12.05 | 1.63 | 13.68 | 4.70 |
| 2012 | 13.43 | 7.53 | 1.00 | - | - | - | 21.97 | 15.87 | 1.85 | 17.72 | 4.25 |

tention was focused on organic matter [Ziemianin… 1850, Godlewski… 1901], the main source of which was the straw and manure left on the field. Other mineral-organic or organic fertilisers were also used, such as wood ash, roasted or minced bones, blood, powdered faeces, compost, peat, mud containing manure or faeces, forest litter, peat soaked with liquid manure, moss with faeces or river mud, and fermented dung obtained from plants or animal residues. In the first two decades of the last century fertilisers were divided for full and auxiliary. Full fertilisers included manure and compost and provided a full range of essential nutrients for plants [Langie 1920]. These fertilisers were considered to be very important to the farm. Auxiliary fertilisers included mineral fertilisers and green manures, which were used rarely.

In the nineteenth century the dominant crop systems were still different varieties of the three-field system. Inadequate fertilisation and cultivation meant that ear plants forced the annual shut down of approximately 1/3 of arable land in order to regenerate fertility. This system of cultivation was practiced in almost all contemporary Europe. The ability to fertilise during this period was directly related to the level of livestock [Baranowski and Topolski 1964].

Phosphorus balance in the studied region ranged from -0.81 to 25.17 kg P·ha$^{-1}$. In the analysed period the balance did not exceed 7.5 kg, with the exception of periods in 1972 and 1982. The consumption of phosphate fertilisers during this period was high, mainly because farmers used excessive doses “for reserve in ground”, as in Germany [Sapek 2008]. At the beginning of

the 90s fertilisation sharply declined, returning almost to the level of the 50s and 60s. The optimal balance for phosphorus in Wielkopolska region is about -3.5–1.5 kg P·ha$^{-1}$ [Toczyński et al. 2013]. Result of the phosphorus balance may be close to zero in soils with an average content of available to plants form of this nutrient. On soils of low and very low phosphorus content it is recommended to use 50% more fertilisers in relation to the uptake by crops. In turn, soils with very high phosphorus content, dose of the fertilisers it should be reduced by 50% compared to uptake by plants [Kodeks... 2004]. The vast majority of municipalities in the Wielkopolska have soils rich in phosphorus. Central Wielkopolska looks best, with the northern and south-western parts of the region being slightly worse [Agronomiczne… 2005]. The phosphorus balance for Wielkopolska should generally be around zero. It can be seen in the balance sheet structure how in analysed period this nutrient increased, due mainly to the increase in use of mineral fertilisers, but also manures. With growing intensity of agricultural production, the amount of harvested phosphorus from crops also increased. This increase is observed even after a decline in fertiliser consumption from 1992 to 2012 r. This may indicate more rational and accurate fertilisation based on balanced doses implemented primarily as a result of environmental standards, but also for economic reasons.

Consumption of phosphorus from manure from the nineteenth century increased (Table 4). Decrease in the use of this fertiliser was observed after World War II, when agriculture was significantly weakened by the war and the number of animals decreased. The greatest use of phosphorus from manure was observed in 1992, influencing the economic transformation of Poland. The collapse of farms with large-scale cattle breeding meant that farms which provided faster capital turnover, including farms with pigs, were more intensively developed during that period. Intensive breeding of these animals produces increased amounts of manure and slurry. During this period, Poznań voivodeship was a small area and many large farms and large-scale intensive farms were clustered around the capital of the region (Fig. 4). The region was deprived of districts with the extensive agricultural production – czarnkowsko-trzcianecki, złotowski, pilski, chodzieski or wągrowiecki district, as well. The very structure of the herds could also affect on higher balance input. Slurry phosphorus consumption also increased up to 1992 (Table 4). In the nineteenth century and the first half of the twentieth century consumption of liquid manure was minimal. Animals were kept mostly on bare ground, so liquid manure directly penetrated the ground. In practice, up to 50s of the twentieth century did not use slurry as fertiliser [Niklewski 1949]. Flooring of livestock building was often paved or lined with brick, however the loss of liquid manure from this type of surface was still large [Stutzer 1902]. Farmers in the nineteenth century rarely had tanks for liquid manure, and if they did they were often earth structures with limestone or clay walls. So the loss of this type of fertiliser was significant. After World War II new agrarian techniques and scientific advances increased the demand for fertiliser, which became more widely used than previously.

In terms of the phosphorus balance in the studied region from 1843 to 1912, negative balances of up to -3,61 kg P·ha$^{-1}$ AL can be observed (Table 4). After this period, only a positive balance was recorded. This was influenced mainly by land reforms after World War II and the introduction of the so-called agrominimum. From an environmental point of view, a negative balance does not constitute a threat to the environment because farms did not generate a surplus of phosphorus. However, long-term growing of plants in such a system could lead to a unilateral depletion of nutrients in the soil and decrease the quantity and quality of the crop. Therefore, in the nineteenth century and at the beginning of the twentieth century the main system of cultivation was the three-field system, which allowed the soil to regenerate. After World War II finished in 1946, the component amount collected from the field was even higher than before the war. Already in 1945, the sowing area in Poland was 90% of the state before World War II. Agriculture

received a strong boost of assistance from the government. Exceptionally favourable weather conditions also contributed during this period.

In 1961, the effects of intensification of agricultural production could already be seen. This was a priority after the end of World War II. Results of the phosphorus balance increased up to 1982. They exceeded the requirements of the Code of Good Agricultural Practice [2004] and recommendations proposed by Toczyński et al. [2013) (Table 4]. In the twenty-first century balances have fallen due to adverse socio-economic conditions and the more sustainable agricultural economy implemented since Polish accession to the European Union. After Polish accession to the EU results of phosphorus balance still were exceeding recommended standards.

## CONCLUSIONS

Phosphorus management in farms in Wielkopolska region has varied. In most of the analysed periods the balance was not high, which is directly related to lower consumption of phosphorus fertiliser. However, phosphorus balance in some years was economically and environmentally unbalanced. Due to various historical events that had an impact on the development of the region, the level of intensity of agricultural production fluctuated quite strongly. Feudal relations prevailing in the nineteenth and early twentieth century were not conducive to economic changes in agriculture and did not contribute to improving the level of production. Extensive agriculture in this period did not generate a phosphorus surplus. The interwar period created a difficult geo-political and economic situation in the country and the crisis in 1929−1933 also contributed to the lack of nutrient surpluses. Also, the socialist economy favoured phosphorus surpluses due to the availability and low cost of fertilisers, the intensification of livestock production, and the lack of environmental standards. The situation changed drastically after the fall of communism and Polish accession to the European Union.

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## ANALIZA BILANSU FOSFORU W PRODUKCJI ROLNICZEJ JAKO WSKAŹNIKA ŚRODOWISKOWEGO W GEOGRAFICZNO-HISTORYCZNEJ KRAINIE WIELKOPOLSKI W 1843–2012

**Synopsis**. Celem niniejszych badań była ocena intensywności gospodarowania fosforem na podstawie bilansu na powierzchni pola w krainie Wielkopolski. Analizy obejmowały 14 okresów na przestrzeni trzech wieków – XIX, XX i XXI. Badania nad historią rolnictwa, mające długie i dobre tradycje w polskim piśmiennictwie historycznym, nie obejmowały do tej pory spraw związanych ze skalą produkcji w gospodarstwach rolnych oraz stopniem zagrożenia dla środowiska na przestrzeni wieków. Mimo, iż niejednokrotnie interesowano się dawnym rolnictwem, to zupełnie wyjątkowo można mówić o środowiskowych aspektach tych rozważań. Rolnictwo Wielkopolski reprezentowało od wieków bardzo wysoki poziom. Rozwój regionu w ostatnich 200 latach podlegał znacznej presji, wynikającej z sytuacji polityczno-ustrojowej, ale także gospodarczej. Poziom produkcji rolnej ulegał więc wahaniom jak również poddawał się bardzo łatwo postępowi. Produkcja roślinna jak i zwierzęca przeszły swoistą metamorfozę. Gatunki roślin i zwierząt, które były popularne w XIX i na początku XX w. po I i II wojnie światowej praktycznie przestały mieć znaczenie. Obliczone bilanse fosforu wahały się w granicach od -3,61 do 25,17 kg $P \cdot ha^{-1}$ UR. Do 1912 roku notowano ujemne wyniki bilansów. Po tym okresie obserwowano już tylko salda dodatnie.

**Słowa kluczowe:** bilans fosforu, zanieczyszczenia obszarowe, rolnictwo Wielkopolski, wskaźniki rolno-środowiskowe

*Accepted for print* – Zaakceptowano do druku: 16.11.2016

*For citation* – Do cytowania:
Kupiec J.M. 2016. Analysis of phosphorus balance in agricultural production as an environmental indicator in the geographical and historical land of Wielkopolska in 1843–2012. Fragm. Agron. 33(4): 73–86.