Abstract. The aim of the study was the comparative analysis of the results of the phosphorus balance calculated by two methods, in the field scale and the farm scale, and assessment of usefulness of the application of balances in monitoring the agricultural production. Twenty-six large-scale farms were selected for studies with the area from 204.0 to 11391.5 ha. The analyses used data from the years 2002–2006. The spatial scope included the farms located in 33 municipalities, which administratively belonged to three provinces. Twenty-six municipalities were located in 7 areas, particularly nitrate vulnerable zones (NVZ’s). The evaluation of phosphorous load of the selected farms in different regions was performed based on the calculation of the balance with two methods – field surface and farm gate. As research has shown although the balance of the phosphorus calculated with the field surface method was on average higher by 7.2 kg P₂O₅·ha⁻¹·AL, the results obtained based on two different methodical approaches indicate similar trends. The higher balance was mainly affected by manures produced in the own farm. Maximal values of the balance in both methods remained at a similar level, reaching approx. 60 kg P₂O₅·ha⁻¹·AL. In the case of the field surface balance, 7 farms fitted in the standard, and in the case of the farm gate balance 5 met recommendations concerning the acceptable balance for the analysed region.

Keywords: phosphorus, agricultural pollution, field surface balance, farm gate balance, large scale farms

INTRODUCTION

The discussion about the size of the phosphorus emission to the environment from agricultural sources has lasted for many years. As some authors say, in Poland the views are that the level of fertilisation with this nutrient is low (The state..., 2007). Based on these views one can get the impression that agriculture does not have a negative impact on the water quality. Meanwhile, agriculture uses 90% of phosphorus obtained from minerals. They are used mostly for producing mineral fertilisers. However, already small surplus of this nutrient causes its accumulation in the soil, as an added value to the sustainable supply of this nutrient, not entirely defined in Poland (Sapek, 2008). However, the capacity of the soil to retain phosphorus is limited and when the saturation with the nutrient is exceeded, the process of its release into the environment takes place, which can cause the uncontrolled process of eutrophication (Sibbesen and Sharpley, 1997). Another problem is the monitoring of pollution from agricultural sources, which in terms of nutrient dispersing in the environment is often inefficient and unreliable. The main problem is variety of balance methods, which are used to control agricultural production and give incomparable results (Fotyma et al., 2000; Kupiec, 2010; Kupiec and Zbierska, 2012). Using the models for the assessment of size and characteristics of pollution sources cannot be entirely correct and can generate significant mistakes (Ilnicki, 2014). The large problem also involves the belittling possibilities of ways the phosphorus gets to the environment other than fertilising. Poorly stored and kept manures and their inappropriate use is very often a standard in the Polish farms.

The aim of the study was the comparative analysis of the results of the phosphorus balance calculated with methods in the field scale and in the farm scale and the assessment of usefulness of the application of balances in the agricultural production monitoring.

MATERIALS AND METHODS

Twenty-six large scale farms were selected for studies. The analyses used data from the years 2002–2006. The spatial scope included the farms located in 33 municipalities, which administratively belonged to three regions.
Fig. 1. Localization of analysed large area farms.

(19). 26 municipalities partially or entirely were located in 7 special areas – nitrate vulnerable zones (NVZ’s). The average size of the farm was 1680.3 ha, with the diverse surface from 209.0 to 11391.5 ha. Selected elements of the farm characteristics are shown in Table 1.

The assessment of the phosphorus load of the selected farms was performed based on the balance calculation with two methods:  

**field surface balance** (Isermann, 1991; Oenema, 1999; Rozporządzenie..., 2002):  

\[
P_{\text{field surface balance}} = \sum P_{\text{DEP}} + \sum P_{\text{MF}} + \sum P_{\text{M}} + \sum P_{\text{SM}} + \sum P_{\text{CCp}} - \sum P_{\text{Mc}} - \sum P_{\text{CCh}}
\]

where:

- DEP – deposition,
- MF – mineral fertilizers,
- M – manures,
- SM – sowing material,
- CCp – by-product and catch crops plowed,
- MC – main crops,
- CCh – by-product and catch crops harvested from the field.

**farm gate balance** (Barszczewski, 2004; Kaczyńska et al., 2004) – the method takes into account elements only to a large extent dependent on the farmer, meaning those, which were brought in or out from the farm by the farmer:

\[
P_{\text{farm gate balance}} = \sum P_{\text{MF}} + \sum P_{\text{PM}} + \sum P_{\text{PA}} + \sum P_{\text{CF}} + \sum P_{\text{SM}} - \sum P_{\text{C}} - \sum P_{\text{F}} - \sum P_{\text{AP}} - \sum P_{\text{A}} - \sum P_{\text{Ad}}
\]

where:

- MF – mineral fertilisers,
- PM – purchased manures,
- PA – purchased animals for breeding,
- CF – concentrates and feeds,
- SM – purchased sowing material,
- C – sold commodity crop,
- F – sold feed plants,
- AP – sold animal products,
- A – sold animals,
- Ad – animal death.

Both these methods are known and used in many countries around the world under the same name but in different modifications. Calculations of particular elements of both balances were performed according to Kupiec and Zbierska (2010) and Kupiec (2010). Utilisation of nutrient was calculated using the formula:

\[
U = \frac{\text{output}}{\text{input}} \times 100
\]

### RESULTS AND DISCUSSION

#### Characteristics of farms

The arable lands accounted for 86.5% of total farmland. The area occupied by the grassland, was on average 12%. Crops pattern was dominated by grain (Table 2). They occupied 52.3% area of agricultural land. Among the cereals the largest surface was occupied by the winter wheat. Cereal yields were higher than provided for the country by the GUS (Rocznik..., 2005). In addition to cereals, a considerable area of fields was sown to industrial plants – mostly rapeseed, and fodder.

Among the special branches occurring in the farms we should distinguish the horticultural production, aimed mainly at fruit-growing and cultivation of vegetables (farms no.: 1, 2, 7, 16, 20). A small acreage (1 ha) of the farm no. 18 was devoted to the cultivation of willow. Moreover, farm no. 2 in the area of 0.21 ha conducted cultivation of plants under covers, mostly cucumbers and tomatoes under glass and foil. Farm no. 1 has a significant area of orchards and berries – 405 ha. Apart from farm no. 1 the orchard was also run by farms no. 7, 8, 18, 20.

The level of mineral fertilisation in the farms was very high (Table 1). The NPK input was, on average, 204 kg per 1 ha AL, ranging from 0 to 317 kg ha⁻¹ AL, which is considerably more than the country's and the region's averages. Farm no. 24 did not buy any mineral fertilisers in the studied period. Deficiencies of nutrients were supplemented only by the purchased manures and those produced in the farm. Nitrogen accounted for 54%, phosphorus (P₂O₅) for 15% and potassium (K₂O) for 31% of the applied fertilizers. In the analysed period the average use of the phosphorus in the group of the studied farms was 29.8 kg P₂O₅·ha⁻¹. The high level of fertilisation of phosphorus (over 50 kg P₂O₅·ha⁻¹ AL) was recorded in farms no. 4, 8, and 21. In the period, 26 farms did not purchase any mineral fertilizers.

The possession of livestock was a characteristic feature of all selected large scale farms in the study, giving a steady income from the sale of livestock or livestock products. The amount of livestock units (LSU) in farms ranged from 0.25 to 1.23 LSU ha⁻¹ AL (on average 0.64, Table 1). Rearing of the cattle was conducted in each farm, and its share in the inventory structure was on average as much as 81.4%. The cattle load of 1 ha AL was on average 0.52 LSU (0.1–1.0 LSU ha⁻¹ AL). Rearing of the cattle...
in most cases was oriented to the production of milk. Fat-
tening of animals and sale of the beef livestock resulted
from the possession of calves from in-house livestock, or
removing culled pieces from the herd, and was rather an
additional activity. The pigs in the inventory structure was
15.9%. In farm no. 11 the production of the pork was domi-
nant, and in farms no. 2, 7, 20, 22, next to the cattle, it con-
stituted the second important direction of animal produc-
tion, and represented a similar level of intensity. The pig
stocking rate calculated from the average annual figures in
the farms conducting the breeding of pigs was quite low
and ranged from 0 to 0.73 LSU per 1 ha AL (on average
0.1 LSU ha⁻¹ AL).

Besides cattle and swine, the large scale farms also
reared sheep and horses. Flocks of sheep were held in
19.2%, and horses in 30.8% of farms. The size of sheep
herd in farms having this group of animals was on average
annually from 3.6 (farm no. 15) to 167.3 LSU (farm no.
17), while horses from 1.3 (farm no. 6) to 117.2 LSU (farm
no. 5). Farm no. 5 run the breeding of thoroughbred saddle
horses and only in this farm the breeding of horses was on
a very high level. In other farms the horse herds were of no
importance in the general livestock turnover. considering
all studied large scale farms, one farm averaged 6.6 LSU of
these animals.

In addition to the above-mentioned animals one of
the farms (no. 8) run the breeding of poultry. The aver-
age amount of poultry per year, per 1 ha in this farm, was

<table>
<thead>
<tr>
<th>Farm No.</th>
<th>Area of AL [ha]</th>
<th>Specialisation</th>
<th>Other animals LSU·ha⁻¹ AL</th>
<th>Mineral fertilisers</th>
<th>NPK summary [kg·ha⁻¹ AL]</th>
<th>ratio N:P₂O₅:K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2254.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.29</td>
<td>208.1</td>
<td>1.025:0.60</td>
</tr>
<tr>
<td>2</td>
<td>343.7</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.25</td>
<td>184.9</td>
<td>1.027:0.58</td>
</tr>
<tr>
<td>3</td>
<td>1713.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.47</td>
<td>235.9</td>
<td>1.031:0.63</td>
</tr>
<tr>
<td>4</td>
<td>589.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.70</td>
<td>280.6</td>
<td>1.032:0.83</td>
</tr>
<tr>
<td>5</td>
<td>1891.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.09</td>
<td>145.8</td>
<td>1.037:0.62</td>
</tr>
<tr>
<td>6</td>
<td>1447.5</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.53</td>
<td>133.1</td>
<td>1.052:0.79</td>
</tr>
<tr>
<td>7</td>
<td>3395.5</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.71</td>
<td>192.3</td>
<td>1.028:0.65</td>
</tr>
<tr>
<td>8</td>
<td>389.7</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.77</td>
<td>194.2</td>
<td>1.018:0.40</td>
</tr>
<tr>
<td>9</td>
<td>1016.5</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.40</td>
<td>113.8</td>
<td>1.020:0.64</td>
</tr>
<tr>
<td>10</td>
<td>1018.5</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.54</td>
<td>158.4</td>
<td>1.020:0.41</td>
</tr>
<tr>
<td>11</td>
<td>1097.0</td>
<td>cereals</td>
<td>pigs/dairy cattle</td>
<td>0.23</td>
<td>250.2</td>
<td>1.045:0.90</td>
</tr>
<tr>
<td>12</td>
<td>1316.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.76</td>
<td>237.0</td>
<td>1.007:0.58</td>
</tr>
<tr>
<td>13</td>
<td>2042.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.83</td>
<td>179.0</td>
<td>1.048:0.54</td>
</tr>
<tr>
<td>14</td>
<td>528.1</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.60</td>
<td>150.8</td>
<td>1.036:0.44</td>
</tr>
<tr>
<td>15</td>
<td>364.5</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.77</td>
<td>194.2</td>
<td>1.018:0.40</td>
</tr>
<tr>
<td>16</td>
<td>988.0</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.47</td>
<td>153.2</td>
<td>1.019:0.33</td>
</tr>
<tr>
<td>17</td>
<td>2806.9</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>0.76</td>
<td>272.1</td>
<td>1.024:1.00</td>
</tr>
<tr>
<td>18</td>
<td>10887.0</td>
<td>cereals</td>
<td>dairy cattle/horses</td>
<td>0.29</td>
<td>246.2</td>
<td>1.022:0.58</td>
</tr>
<tr>
<td>19</td>
<td>614.0</td>
<td>cereals</td>
<td>dairy cattle/horses</td>
<td>0.42</td>
<td>282.0</td>
<td>1.031:0.66</td>
</tr>
<tr>
<td>20</td>
<td>3150.8</td>
<td>cereals</td>
<td>dairy cattle/horses/pigs</td>
<td>0.94</td>
<td>303.6</td>
<td>1.029:0.79</td>
</tr>
<tr>
<td>21</td>
<td>373.2</td>
<td>cereals</td>
<td>dairy cattle/horses/pigs</td>
<td>0.79</td>
<td>317.0</td>
<td>1.027:0.73</td>
</tr>
<tr>
<td>22</td>
<td>292.5</td>
<td>cereals</td>
<td>dairy cattle/horses/pigs</td>
<td>0.95</td>
<td>162.0</td>
<td>1.041:0.41</td>
</tr>
<tr>
<td>23</td>
<td>3535.4</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>1.00</td>
<td>257.1</td>
<td>1.027:0.66</td>
</tr>
<tr>
<td>24</td>
<td>233.0</td>
<td>cereals</td>
<td>dairy cattle/pigs</td>
<td>1.08</td>
<td>0.0</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>975.9</td>
<td>feed plants</td>
<td>dairy cattle</td>
<td>0.52</td>
<td>233.1</td>
<td>1.017:0.39</td>
</tr>
<tr>
<td>26</td>
<td>195.0</td>
<td>cereals</td>
<td>dairy cattle</td>
<td>0.81</td>
<td>140.8</td>
<td>1.034:0.44</td>
</tr>
</tbody>
</table>

# nitrogen as 1
0.1 LSU. Over the years, the animal production was maintained at a constant level, and changes in the inventory occurred in a very short range. The animal production in the analysed farms was strongly associated with the crop production. Animal husbandry to a large scale modified the structure of crops, in which the large scale farmers had to consider the type and the area of fodder sown. The scale of production affected the economy of fertilisers, as well as the amount of purchased feed and fertilisers. Keeping livestock in agricultural farms entails the formation of large amounts of excrements, which in the form of manure can be a valuable complement of mineral nutrients in the soil. The amount of the produced solid manure per 1 ha of agricultural land (AL) averaged 6.7 t·ha⁻¹ per farm, and that of liquid manure 3.2 t·ha⁻¹.

Because natural fertilisers, apart from nutrients, enrich the soil with organic matter, the total amount of natural fertilizers produced by large farms was used to raise their own crops. Some farms bought manure, limiting or completely reducing the purchase of mineral fertilisers (farm no. 24).

Analysis of the phosphorus balance

The average value of the phosphorus balance obtained based on the field surface balance stood at the level of 15.3 kg P₂O₅ ha⁻¹ AL, with fluctuations from -13.4 to 59.6 kg P₂O₅ ha⁻¹ AL (Table 3). The highest percentage of the results (53.8%) ranged from 0–30 kg P₂O₅ ha⁻¹ AL. 23.1% of the results was in the range of 30–60 kg P₂O₅ ha⁻¹ AL and the same number of farms showed the negative balance. The amount of phosphorus added to the soil with mineral fertilisers were much lower than nitrogen or potassium, which could affect the nutrient balance. According to the Code of Good Agricultural Practice (Kodeks..., 2004) the phosphorus balance can be balanced in soils with the average content of available forms of this nutrient. In soils with a low and very low content of phosphorus it is recommended to use approx. 50% larger doses of fertilisers in relation to their uptake by crops, and in soils with high and very high content, doses of fertilisers should be reduced by 50% in relation to the uptake. The share of soils with a low and very low content of phosphorus in the studied NVZ’s (apart from the catchment of the River Orla) was small, therefore, it can be assumed that the balance of the nutrient should be close to zero.

The utilisation of phosphorus in 6 farms was greater than 100%. This can indicate the insufficient complementation of the macronutrient in soils of these farms and the plants using a certain pool of soil reserves. The average utilisation of phosphorus by the plants was high and stood at the level of 75.8%, with fluctuations from 42.1 to 130.3% (Table 3). Analysing individual elements of the input and output it can be noticed that the largest amounts of phosphorus were brought with mineral fertilisers and manures, and removed with the main crop.

The balance calculated with the farm gate method showed more favourable results than the field surface (Table 4, Fig.
The phosphorus balance in the group of studied farms was close to balanced (8.1 kg P$_{2O_5} \cdot$ha$^{-1}$ AL), which confirms similar dependencies in the field surface balance. Considering the results it can be noticed that the significant share involved farms where balances were negative (34.6%). In more than half of the farms (53.8%) the results were within the range of 0–30 kg P$_{2O_5} \cdot$ha$^{-1}$ AL. Only in 3 farms the balance was greater than 30 but smaller than 60 kg P$_{2O_5} \cdot$ha$^{-1}$ AL. The utilisation of phosphorus was from 29.2 to 396.9%, averaging 110.1% (Table 4). The main source of phosphorus input came from mineral fertilisers and purchased concentrates and feeds. Phosphorus in large quantities was removed from farms as sold crops and animal products (mainly milk).

According to Toczyński et al. (2013) the acceptable balance of phosphorus for the Wielkopolska region ranges in the scope -3.5–1.5 kg P ha$^{-1}$ (-8.0–3.4 P$_{2O_5}$), for Dolny Śląsk region -1.1–3.9 kg P ha$^{-1}$ (-2.5–8.9 P$_{2O_5}$) and for Lubuskie -2.1–2.9 kg P ha$^{-1}$ (-4.8–6.6 P$_{2O_5}$). Based on the field surface balance, 7 farms fell within this norm, and in the case of the farm gate balance – 5 met the requirement. In summary, it can be stated that the balance results obtained with the farm gate method presented similar tendencies as those produced by the field surface analysis.

Comparing the obtained balances in individual farms it can be observed that the calculated balance using the farm gate method most often showed lower values than the field surface balance (Fig. 2). In four farms quite a large discrepancy of results was observed. In farms no. 10 and 18 results of the farm gate balance were much higher than calculated with the field surface method. The differences in balances were mainly influenced by the animal production. These two farms bought considerable amounts of industrial fodder (concentrates), reaching 63 kg P$_{2O_5}$ ha$^{-1}$. The sold animal products, livestock and animal death were in total at the level slightly exceeding 5 kg P$_{2O_5}$ ha$^{-1}$, and thus the amounts of phosphorus taken out of the farm were disproportionate in relation to its income. In the case of farms no. 24 and 25 the farm gate balances in turn were much lower than the field surface balance. Farm no. 24 did not purchase any mineral fertilisers. The phosphorus input in the farm gate balance was small. The sale included approx. half of the collected crops and animal products and livestock. The ratio of input to output in this farm amounted to 1:3. In farm no. 25 the difference between balances resulted from large quantities of the sold animal products, mostly milk. As per 1 ha of the farm 34 kg P$_{2O_5}$ ha$^{-1}$ was sold.

The non-parametric analysis was used for the assessment of differences between results of two analysed balances – test of order of the Wilcoxon pairs. The analysis showed that differences between results of two balances were significant (Table 5, Fig. 3). In addition, correlation

Table 5. The results of the test Wilcoxon’s sequence pairs.

<table>
<thead>
<tr>
<th>A pair of variables</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSB &amp; FGB</td>
<td>2.908068</td>
<td>0.003637</td>
</tr>
</tbody>
</table>

FSB – the field surface balance, FGB – the farm gate balance.

Fig. 2. Formation of the phosphorus balance calculated by two methods.
coefficients (r) Pearson were calculated to demonstrate the relationship between the balance of both analysed balance sheets on one side and various elements of input and output, certain characteristics of farms, like agricultural area, stocking density, participation of cereals, legumes, root crops, industrial and fodder in crop structure on the other. The results of correlation clearly indicate that in the balance sheet of phosphorus in the field surface methodology the greatest impact on balance have used mineral fertilisers (Table 6). In the farm gate balance sheet, elements which may significantly affect its result are purchased mineral fertilisers and introduced into a farm concentrates and feeds (Table 7).

**Table 6. Correlation coefficients (r) Pearson for the field surface balance of phosphorus and elements of input and output and selected characteristics of the farm.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL area</td>
<td>-0.28972</td>
</tr>
<tr>
<td>Deposition</td>
<td>0.159602</td>
</tr>
<tr>
<td>Mineral fertilizers</td>
<td><strong>0.760093</strong></td>
</tr>
<tr>
<td>Manures</td>
<td>0.368646</td>
</tr>
<tr>
<td>Sowing material</td>
<td>0.045139</td>
</tr>
<tr>
<td>Plowed by-product and catch crops</td>
<td>0.335266</td>
</tr>
<tr>
<td>Main crops</td>
<td>0.204882</td>
</tr>
<tr>
<td>By-product and catch crops harvested from the field</td>
<td>0.337754</td>
</tr>
<tr>
<td>The share of cereals</td>
<td>0.424447</td>
</tr>
<tr>
<td>The share of papilionaceous</td>
<td>0.099961</td>
</tr>
<tr>
<td>The share of root plants</td>
<td>-0.274257</td>
</tr>
<tr>
<td>The share of industrial plants</td>
<td>0.203149</td>
</tr>
<tr>
<td>The share of feed plants</td>
<td>-0.056259</td>
</tr>
</tbody>
</table>

Marked correlations are significant at p < 0.05000

**Table 7. Correlation coefficients (r) Pearson for the farm gate balance of phosphorus and elements of input and output and selected characteristics of the farm.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL area</td>
<td>-0.233428</td>
</tr>
<tr>
<td>Mineral fertilisers</td>
<td><strong>0.638950</strong></td>
</tr>
<tr>
<td>Purchased manures</td>
<td>-</td>
</tr>
<tr>
<td>Purchased animals for breeding</td>
<td>-</td>
</tr>
<tr>
<td>Concentrates and feeds</td>
<td><strong>0.512538</strong></td>
</tr>
<tr>
<td>Purchased sowing material</td>
<td>0.059903</td>
</tr>
<tr>
<td>Sold commodity crops</td>
<td>0.387691</td>
</tr>
<tr>
<td>Sold animal products</td>
<td>0.201360</td>
</tr>
<tr>
<td>Sold animal</td>
<td>-0.085663</td>
</tr>
<tr>
<td>Animal death</td>
<td>0.006080</td>
</tr>
<tr>
<td>Animal density</td>
<td>0.165260</td>
</tr>
<tr>
<td>The share of cereals</td>
<td>-0.074958</td>
</tr>
<tr>
<td>The share of papilionaceous</td>
<td>0.148021</td>
</tr>
<tr>
<td>The share of root plants</td>
<td>0.427272</td>
</tr>
<tr>
<td>The share of industrial plants</td>
<td>-0.043348</td>
</tr>
<tr>
<td>The share of feed plants</td>
<td>-0.172475</td>
</tr>
</tbody>
</table>

Marked correlations are significant at p < 0.05000

**Fig. 3. Box-plot for differences in results based on the two analysed balances – the field surface balance (FSB) and the farm gate balance (FGB).**

Table 6. Correlation coefficients (r) Pearson for the field surface balance of phosphorus and elements of input and output and selected characteristics of the farm.

Table 7. Correlation coefficients (r) Pearson for the farm gate balance of phosphorus and elements of input and output and selected characteristics of the farm.

**Conclusions**

1. The comparative analysis showed that the results of the phosphorus balance obtained based on two different methodological approaches, despite significant differences in results, indicate similar trends. Both methods can be used for monitoring agricultural pollution but each of them in different contexts.

2. Due to the statistically significant differences in results the two analysed balance methods should not be used interchangeably. It is necessary to take into account differences between the balance results in the case of comparison results obtained from the different methods.

3. The phosphorus balance calculated using the field surface method was on average higher by 7.2 kg P$_{2}$O$_{5}$·ha$^{-1}$ AL. The higher balance was affected mainly by manures produced and used in-house, which constituted approx. 31% of the input.

4. Results of the phosphorus balance, obtained from the farm gate balance, were higher than results of the field surface balance in six farms. In two analysed farms, the differences were significant (approx. 29 and 58 kg P$_{2}$O$_{5}$·ha$^{-1}$).
The higher balance in the farms was affected by the significant amounts of industrial fodder (concentrates) and feed supplements purchased by farmers. In both cases the primary activity involved the breeding of dairy cattle.

5. The maximum values of the balance in both balances remained at a similar level, reaching approx. 60 kg P$_2$O$_5$·ha$^{-1}$ AL. These are values significantly exceeding the recommendations for this region. In the case of the field surface balance 7 farms, in the case of the farm gate balance 5 farms met the standard.

REFERENCES


Abstrakt. Zachowanie fosforu w glebie jest istotnym zagadnieniem zarówno ze względów produkcyjnych, jak i środowiskowych. Zminimalizowanie presji na środowisko ze strony rolnictwa wymaga między innymi rozpoznawania czynników decydujących o procesach sorpcji biogenów w glebie. Celem pracy była analiza złożoności retencyjnych oraz parametrów sorpcji fosforu w glebach płowych i czarnych ziemiach w układzie katenalnym moreny dennej. Korzystając z analizy regresji wstecznej opracowano równania umożliwiające oszacowanie parametrów sorpcji Langmuira w oparciu o podstawowe właściwości gleby. Wykazano, że parametr a (maksymalną ilość fosforu, jaką może zatrzymać faza stała gleby) oszacować można w oparciu o zawartość węgla organicznego, amorficznych tlenków glin, wapnia wymienionego i fosforu przyswajalnego. Natomiast parametr sorpcji Langmuira „b” kształtowany był przez zawartość frakcji ilowo-tej, tlenków glinu i żelaza oraz amorficznych form żelaza.

Słowa kluczowe: fosfor, sorpcja, izoterma Langmuira

WSTĘP

Intensyfikacja produkcji rolniczej i związane z tym zwiększone zużycie nawozów fosforowych spowodowały istotne zmiany w środowisku rolniczym. Stosowane dawki nawozów, odbiegające od rzeczywistego zapotrzebowania roślin, przyczyniły się do akumulacji fosforu w glebach i późniejszego jego rozproszenia w środowisku, powodując przyspieszoną eutrofizację wód śródlądowych. Ładunek fosforu wynoszony z gleby wraz z wodami płynącymi ze zlewni, związany jest z ukształtowaniem terenu, jego użytkowaniem, warunkami meteorologicznymi, zasobnością gleby oraz pojemnością sorpcyjną gleby względem tego biogenu (Jadczyszyn i in., 2014; Sapek, 2014).


Celem niniejszej pracy było określenie zdolności retenckich gleb względem fosforu oraz oszacowanie parametrów sorpcji w glebach płowych i czarnych ziem ośrodkowych w katenie falistego moreny Pojezierza Poznańskiego z wykorzystaniem podstawowych właściwości gleb.

MATERIAŁY I METODY


Celem niniejszej pracy było określenie zdolności retenckich gleb względem fosforu oraz oszacowanie parametrów sorpcji w glebach płowych i czarnych ziem ośrodkowych w katenie falistego moreny Pojezierza Poznańskiego z wykorzystaniem podstawowych właściwości gleb.

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