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The balance of phosphorus in the agriculture of Poland

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Abstract. Agriculture is a major factor interfering in the natural cycle of nutrients, particularly through the intensification of production. Phosphorus compounds are regarded as the most hazardous threat generated by farming. The balances of phosphorus, as one of many agroenvironmental indicators, are very important source of information about rural influence on formation of environment conditions. They apply to all levels of agriculture, starting with a single cultivated field, through the farm, up to the catchments, regions and whole countries.

Regarding NUTS 0 level, Poland belongs to the group of countries with the lowest balance of phosphorus from among the other UE and OECD countries taken into comparison in the paper. The greater values of phosphorus balance were noticed in the countries with intensive agriculture i.e. in Germany and Denmark.

The study of national and regional phosphorus balance (soil surface nutrient balance according to OECD) showed that the difference stems from the climatic and soil conditions as well as from phosphorus management practices. The differentiation of phosphorus balance on the greatest river catchments level in Poland was not found, whereas a larger diversity, concerning the range of phosphorus management propriety, was found at a province level (NUTS 2).

key words: phosphorus balance, efficiency use, OECD methodology

INTRODUCTION

Frequently, many countries have been taking into account the issue of limiting environmental hazards derived from agricultural production. Modern farming practices significantly interfere in the natural nutrient cycle, particularly through the intensification of production (Górka et al., 1998; Krasowicz et al., 2009). Phosphorus compounds are often regarded as one of the most serious threats generated by agriculture. Integrated agriculture has to maintain realistic standards in a possibly closed nutrient cycle: fertilizers – soil – plants. It is possible to talk about an entirely closed rotation under the conditions of natural ecosystems without removing the plant mass. The reverse is true of agriculture, as it aims at the highest yield for the usable parts of plants. The mineral elements are removed in the above-mentioned plant crops and their loss has to be balanced by natural and mineral fertilizers. The cycle of mineral within a farm depends on the animal stock. The livestock achieves the nutrients from farm and imported fodder stuffs, nevertheless it returns them as natural fertilizers. In such complicated cycles, losses of the elements in the soil and plant system appear. Elements, especially phosphorus that is unused in agricultural production may lead to a contamination of ground and surface waters (eutrophication). A deficit of nitrogen or either phosphorus can bring about a degradation of soils and consequently a decline in their production capability (Ilnicki, 2004; OECD, 2006).

The phosphorus balance, being recognised as one of the many agro-environmental indicators, is a very important data source regarding the influence of agriculture on the environment. At the same time, it supports the farming management decision-making system that is important from the point of view of rural and environmental policies in the country (Faber, 2001; OECD, 2008; Parris, 2007). The budget of phosphorus is also an invaluable source for an evaluation of fertilizers, pesticides, and energy for the majority of the OECD member countries. The nutrient balances are calculated for each level of agriculture, starting with a single arable field through to a farm level, up to the catchment areas, also including regions and whole countries. The results of the balance calculations become more important when they are combined with the status of a soil's fertility and with the quality of ground and surface waters (Igras and Lipiński, 2005). A positive balance should be identi-

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fied with an accumulation in soil (increase of abundance) or with the losses of nutrients (not taken up by plants). This may lead to economically inefficient rural production in a longer perspective and also to an environmental risk of phosphorus displacement in ground waters. If all the above are taken for granted, and with the exception of soils with low and very low fertility, a sustained high level of balance is inadvisable. Contrastingly, a negative balance indicates a fertiliser dose that is too low according to the nutrient requirements of plants, which may cause a decrease in soil content of available phosphorus and consequently cause a degradation of the soil (Gosek, 1997).

A comparison of the phosphorus balance in Poland in conjunction with other selected Baltic countries as well as a presentation into the diversity of balances in particular regions and main catchment basins of Poland were the aims of the paper.

METHODS

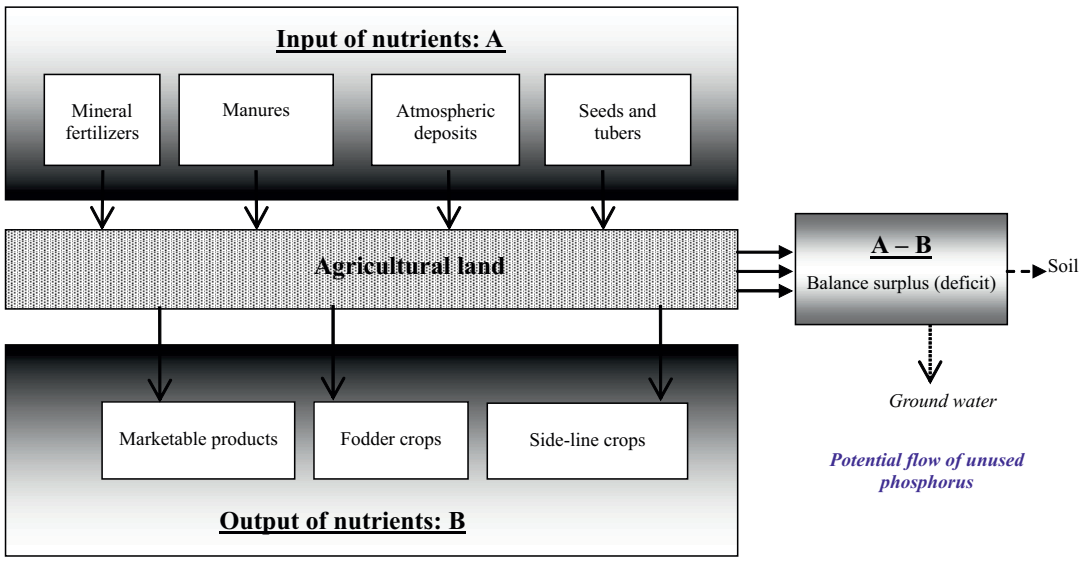
The balance of phosphorus prepared on a field, farm, region and country level is an essential tool for an advisory service concerned with sustainable phosphorus management in agricultural production. For the purposes of drawing up a phosphorus balance at a national and regional agriculture level, a sophisticated method "soil surface nutrient balance" developed by OECD was adopted in IUNG. The main goal of this method is an evaluation for the amount of mineral elements in the soil. An optimisation of the on-farm use of nutrients (control of nitrogen or phosphorus inputs and outputs) seems to be necessary, which is especially important for maintaining the balance of the ecosystems. The main elements of phosphorus balance are, on the input side, the amount of nutrients in mineral fertilizers and manure and on the output side the nutrients removed with the yield of crops (Fig. 1).

The national and regional phosphorus balances are calculated based on the data from the Main Statistical Office (GUS). The paper presents the national, regional and catchment balances for the period of 2002–2008. Despite the fact that the nutrient balances are usually prepared for each year, a complete evaluation of balances should be performed for a minimum of three years (Kopiński, 2006; Tujaka, 2007) in order to reduce the impact of variable weather conditions. The time period mentioned above is often accepted for any kind of OECD reports (OECD, 2005).

The data connected with the phosphorus content in mineral fertilizers were derived directly from the GUS Statistical Yearbooks (Środki produkcji…, 2002-2008), whereas the amount of phosphorus in manure was calculated and based on information contained in the GUS data (Użytkowanie gruntów…, 2002-2008) and the coefficient of the phosphorus supply from different natural fertilizers (Duer et al., 2004; OECD, 2008; Produkcja upraw…, 2002-2008).

The amount of phosphorus introduced into the seed material was determined by using information on the area of the main crops, and the standard values of sowing (planting) density that was multiplied by the content of N and P in these materials.

The amount of phosphorus from air deposition was assumed at a rate according to OECD calculations at 0.22 kg P ha^{-1} $year^{-1}$ for the whole country as well as separate regions of Poland (OECD, 2005).



Source: OECD, 2006

Fig. 1. Main elements of the phosphorus soil surface balance according to OECD.

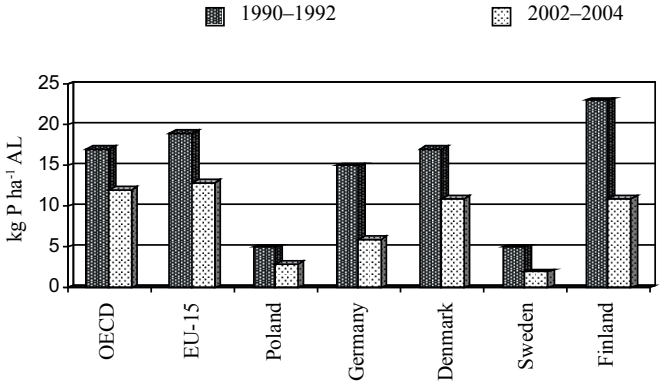
The uptake of phosphorus in the crop yield was calculated separately for the marketable crop. The fodder crop, side-line crop, the catch crop, as well as the average yields were multiplied by their content of N and P (Fotyma et al., 2000).

The comparison of international phosphorus balances was made and based on OECD data (OECD, 2008).

The phosphorus balance on the catchment level was calculated on the basis of the weighted average values at a regional balance level, including the area of particular voivoidships within the catchment basins (Igras, 2004).

RESULTS AND DISCUSSION

There has been intensive and regular mineral and organic fertilization in many regions of Eastern Europe as well as locally in Poland. Consequently, this has led to a considerable accumulation of phosphorus in the soils that exceeds the nutrient requirement of plants (Csatho et al., 2007; Fotyma, 2003; Sibbesen and Runge-Metzger, 1995). The results of a phosphorus balance for Poland as compared to other Baltic countries affiliated to the OECD are presented in Figure 2. The above comparison is very important because of a potential threat from surpluses of nutrient elements in the Baltic Sea basin, which have been transported by rivers from the rural areas. The largest part of Poland's territory is situated within the borders of two the greatest rivers catchments i.e. Vistula and Oder, which drain their waters into the Baltic Sea. In examining the data, one may conclude that on one hand, the highest surpluses of phosphorus, exceeding 10 kg P ha^{-1} AL (AL = Agricultural Lands), was determined in the countries with intensive farming (the high doses of mineral fertilization and the high quantity of animal stock) but, on the other hand, a huge effort is put into environment protection in these countries. Phosphorus surpluses have decreased by about 30% within 12 years for the majority of the "old" EU countries. First and foremost, it results from a reduction in the use of phosphorus fertilizers. It is possible to observe a similar degree of reduction in Poland in the estimated period of time. However, Poland and Sweden showing an amount of P balance at 2–3 kg P ha^{-1} AL, are ranked among the countries with the lowest values of P surpluses among other EU and OECD countries (Fig. 2).



Source: Author's compilation based on OECD data (OECD, 2008)

Fig. 2. The balance of phosphorus in time periods 1990–1992 and 2002–2004 in Poland against a background of selected Baltic countries.

As is shown in Table 1, the average phosphorus surplus for Poland accounts for 3.9 kg P ha^{-1} AL. It is connected with the high phosphorus efficiency which amounts to 78% from each source. The values of the phosphorus balance indicate a variety variation from region to region (averaged over the period from 2002 to 2008). However, the balance of P for particular regions and nationwide do not suggest any potential risk for soil and water environment. Only the P balance in the province of Dolnośląskie had a deficit in the phosphorus balance amounting to -1.1 kg P ha^{-1} AL as a result of the phosphorus reserves running down in the soil. The province of Dolnośląskie is renowned for its very favourable soil and climatic conditions. The region has the highest plant productivity coefficient and a great potential of phosphorus being removed with crops. However, the region has the lowest intensification of animal production, which points to an insufficient supply of organic matter introduced to the soil and a high rate of nutrient removal with crops. The decline of available phosphorus forms in soils of these regions caused by a deficiency in the P balance, may contribute to a serious hazard of soil degradation according to the long term perspective.

The majority of regions reveal a positive phosphorus balance ranging from 0.1 in the Opolskie region to 14.5 kg P ha^{-1} AL in Wielkopolskie. The low surpluses or a deficit in phosphorus means that only small quantities of this element are accumulated in soils, which increases its fertility (Fotyma, 1999). These surpluses are indispensable, especially in regions with a low and very low content of soil available phosphorus, e.g. in the Podkarpackie, Podlaskie, Śląskie and Świętokrzyskie regions. The low surpluses of P might be regarded as acceptable if the soils of Poland were steadily provided with an available source of phosphorus. Unfortunately, data from the Regional Agrochemical Laboratory reveal that only 36% of soils in Poland show as high and very high, 26% - medium, low and very low content of available phosphorus (Igras and Lipiński, 2005). The largest area of soils with high and very high content of available phosphorus appears to occur in the provinces of Wielkopolskie (54% AL), Kujawsko-Pomorskie (51%), Opolskie (45%) and Pomorskie (44%). On one hand, Wielkopolskie is characterized by the lowest use efficiency of phosphorus (67%) as compared with other regions of Poland, but looking at it from another perspective, this region has the largest area with the high

Table 1. The national and regional phosphorus balance (average for 2002–2008).

Voivodships	The values of phosphorus balance							Phosphorus use efficiency (output/input) [%]
	Thousand tonnes						surplus per unit [kg P ha^{-1} AL yr^{-1}]	
	input of P				output of P	difference (balance)		
	total	including separately						
		mineral fertilizers	manure	other sources				
Lubuskie	7.6	5.2	2.2	0.2	4.7	2.9	6.1	61.8
Pomorskie	15.1	9.8	4.9	0.4	10.0	5.1	6.4	66.2
Wielkopolskie	44.2	20.5	22.8	0.9	29.7	14.5	8.1	67.2
Mazowieckie	36.8	20.1	15.8	0.9	26.6	10.2	4.7	72.3
Śląskie	8.6	5.1	3.3	0.2	6.2	2.4	4.8	72.1
Łódzkie	20.3	11.0	8.7	0.6	14.8	5.5	4.9	72.9
Podlaskie	18.5	9.5	8.6	0.4	14.5	4.0	3.7	78.4
Warmińsko-mazurskie	15.2	8.1	6.8	0.3	12.2	3.0	2.9	80.3
Małopolskie	11.6	6.3	5.0	0.3	9.3	2.3	3.1	80.2
Świętokrzyskie	9.2	5.5	3.4	0.3	7.4	1.8	3.0	80.4
Lubelskie	24.6	15.7	8.1	0.8	20.1	4.5	3.0	81.7
Kujawsko-pomorskie	22.6	12.4	9.7	0.5	18.6	4.0	3.8	82.3
Podkarpackie	9.6	5.6	3.7	0.3	8.1	1.5	1.9	84.4
Zachodniopomorskie	12.0	8.5	3.1	0.4	10.8	1.2	1.2	90.0
Opolskie	11.0	7.4	3.4	0.2	10.9	0.1	0.2	99.1
Dolnośląskie	14.2	10.5	3.3	0.4	15.3	-1.1	-1.0	107.7
Poland	**281.4**	**161.1**	**112.8**	**7.5**	**219.2**	**62.2**	**3.9**	**77.9**

Source: Own studies

Table 2. The main river catchments balance of phosphorus in Poland, flowing into the Baltic Sea (average for 2002–2008).

Catchment	The values of phosphorus balance (P)							Phosphorus use efficiency (output/input) [%]
	thousand tonnes						Surplus per unit [kg P·ha^{-1} AL yr^{-1}]	
	input of P				output of P	difference (balance)		
	total	including						
		mineral fertilizers	manure	other sources				
Vistula river	151.4	85.8	61.6	4.0	117.6	33.8	3.8	77.7
Oder river	104.5	59.8	42.0	2.7	82.1	22.4	4.1	78.6
Pomeranian rivers:								
– directly flowing in the Baltic Sea	12.8	8.6	3.8	0.4	9.8	3.0	3.6	76.6
– flowing in Vistula lagoon	9.7	5.4	4.1	0.2	7.5	2.2	3.5	77.3
Neman river	2.3	1.2	1.1	0	1.8	0.5	3.7	78.3
Total river catchments delivering waters to the Baltic sea	**280.8**	**160.7**	**112.6**	**7.5**	**218.7**	**62.1**	**3.9**	**77.9**
Other catchments	0.6	0.3	0.2	0.1	0.5	0.1	1.6	83.3
Poland	**281.4**	**161.1**	**112.8**	**7.5**	**219.2**	**62.2**	**3.9**	**77.9**

Source: Own studies

and very high content of available soil phosphorus content (54% AL) and the highest share of phosphorus derived from animal production. With all of the above take into consideration, it seems to be very important to put a much greater effort into environment protection through decreased fertilization rates, rather than trying to increase the soil's fertility to ensure higher crop yields (Tujaka, 2007).

Because of the high percentage of farmland in the total area of Poland, the monitoring of nitrogen or phosphorus balance as well as controlling the water quality have a particular significance for environment preservation in the basin of the Baltic Sea (Parris, 2007). The main components of the phosphorus balance calculated for the largest river catchments in Poland that drain their waters to the Baltic

Sea are presented in Table 2. Each catchment was selected according to the volume of global balance of phosphorus. The calculated values reflect the regional differentiation of conditions and farming intensity in Polish agriculture. Based on the volume of phosphorus balance amounting to 3.5–4.1 kg P ha^{-1} AL, it is hard to find a definite distinction between the largest water basins in Poland. Moreover, it is necessary to emphasize this based on the P balances, as it is difficult to determine the volume of nutrient loading from rural areas that are transferred to ground and surface waters and subsequently to the Baltic Sea. Nevertheless, an increase in the efficient use of fertiliser in Polish rural production would be the most desirable direction for any change (Igras and Lipiński, 2005).

CONCLUSIONS

Poland with the surplus of 3.9 kg P ha^{-1} AL belongs to the countries with the lowest phosphorus balance. The higher positive balances are recorded in other Baltic countries affiliated to the OECD, particularly with intensive agriculture (Germany, Denmark, and Finland).

The highest positive balance of phosphorus (14.5 kg P ha^{-1} AL) were recorded in the province of Wielkopolskie, while the lowest amounted to -1.1 kg P ha^{-1} AL in the province of Dolnośląskie. The estimation of regional phosphorus management indicates a potential threat derived from surpluses as well from deficits in phosphorus.

No differentiation was found in the phosphorus balance in the greatest river catchments level in Poland. The balances were within a range of 3.5–4.1 kg P ha^{-1} AL.

The quantitative characteristics of phosphorus balance prove a great regional variability of agriculture in Poland. The differences stem from the climatic and soil conditions as well as from phosphorus management practices.

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