Agrovoc descriptors: phosphorus, nitrogen, analytical methods, sustainability, soil deficiencies, soil fertility

Agris Category Code: P35

Nitrogen and phosphorus budgets in Poland as a tool for sustainable nutrients management

Jerzy KOPIŃSKI [1], Arkadiusz TUJAKA [1], Janusz IGRAS [1]

Received January 10, 2006; accepted March 31, 2006
Delo je prispelo 10. januarja 2006; sprejeto 31. marca 2006

ABSTRACT

In the paper the nitrogen and phosphorus balances calculated according to OECD methodology are presented on regional and country levels. For the whole Poland the balance of nitrogen shows surplus of about 45 kg N*ha^{-1} a^{-1} with high variability among the different regions (voivodships). The balance of phosphorus for the country is slightly positive but low P surpluses, and in some regions even deficits raise the concern of not sustainable phosphorus management practices. The balance of phosphorus was confronted with the content of available phosphorus in the soils.

Key words*:* nitrogen balance, phosphorus balance, OECD methodology, Poland

IZVLEČEK

BILANCA DUŠIKA IN FOSFORJA NA POLJSKEM KOT ORODJE ZA TRAJNOSTNO UPRAVLJANJE S HRANILI

Avtorji po metodologiji OECD obravnavajo izračun bilance dušika in fosforja na regionalni in državni ravni. Za povprečje celotne Poljske je saldo dušika približno +45 kg N.ha^{-1}.a^{-1}, z veliko variabilnostjo med posameznimi vojvodstvi. Bilanca fosforja je na ravni države rahlo pozitivna, vendar pa nizek presežek ali celo negativen saldo fosforja dopušča sklep, da na Poljskem s fosforjem ne gospodarijo na trajnostni način. Bilanco fosforja so primerjali s količino razpoložljivega fosforja v tleh.

Ključne besede: bilanca dušika, bilanca fosforja, Metodologija OECD, Poljska

1 INTRODUCTION

Contemporary agriculture has to meet the demand of society for ample and healthy food, sustain farmers and their family and to be environmentally friendly. These objectives are quite often inconsistent and farmers are facing serious difficulties in undertaking the proper decisions. Polish agriculture is extremely heterogeneous in respect of the farm size, natural conditions for crop production, intensity level and utilisation of the potential productivity [Krasowicz 1966]. This heterogeneity concerns as well the management of nutrients [Igras et al. 2003]. In integrated

[1] Institute of Soil Science and Plant Cultivation – State Research Institute Puławy Czartoryskich 8, 24-100 Puławy, Poland, ij@iung.pulawy.pl

agriculture the cycle of nutrients: fertilizers-soil-plants should be as closed as possible. Natural ecosystems are characterised by almost entirely closed cycle of nutrients but at the expense of a very low productivity. Agroecosystems are aimed at high yields of crops which means the high demand for nutrients removed from the field with the plant products. Nutrients removed must be replenished in form of mineral fertilizers and/or manure. In mixed and animal farms the majority of crop production is used to feed the animals and nutrients are distributed in small proportion to end animal products (meat, milk, eggs) and in much higher proportion to the excrements and further to manure. Theoretically it gives the good opportunity to close the cycle of nutrients by manure application in the field. In practice the cycle animal-manure-soil-plant is extremely complicated due to its biological character and connected with losses of nutrients by dispersion to the environment. The surplus of nutrients poses the treat for the environment while their deficit damages the soils fertility. Therefore nutrient balances became the very essential part of the decision support systems in integrated agriculture and since 1991 are made obligatory for the countries belonging to OECD. Poland has accessed OECD in 1996 and Institute of Soil Science and Plant Cultivation in Puławy was obliged by the Ministry of Agriculture and Rural Development to calculate nitrogen balances and since 2002 phosphorus balances as well. These balances are made on the country level and on the regional level and delivered yearly to OECD Secretariat.

2 METHODS

Nitrogen and phosphorus balances are calculated according to uniform methodology elaborated and developed by OECD [OECD 1999, 2003, 2004]. In fact these are the soils surface nutrient balances in which the total area of the country is treated as one big " field ". In soil surface nutrient balance soil is regarded as a "black box" and the measurable inputs and outputs of nutrients are taken into consideration only. On the input side the amount of nutrients in mineral fertilizers and manure and on the output side nutrients removed with the yield of crops are the main elements of this balance. In case of nitrogen the amounts of nutrient in atmospheric deposits and fixed by symbiotic and free living bacteria are included on input side as well. For both nutrients the recognition of input in seeds and tubers is recommended by OECD but it is often passed by in balances prepared by several countries [Hansen 2000]. The schematic diagram of nitrogen and phosphorus balances is presented on Fig. 1. From soil surface balance the surplus or deficit of nutrient can be calculated but this method does not explain the processes of nutrient transformation in the soil-plant – atmosphere system. The surplus of nutrient means both its accumulation in the soil, that concerns mainly phosphorus, and the losses to the ground water and/or to the atmosphere, that concerns mainly nitrogen. In turn the deficit of nutrient means its releasing from the soil reserves.

Table 1. Elements of nitrogen and phosphorus balances in Poland

Specification	Elements of nitrogen N and/or phosphorus P balances
S_{min}	Mineral fertilizers
S_{org}	Manure
S_{msi}	Seeds and tubers
N_{sym}	Biologically fixed nitrogen
N_{atm}	Nitrogen in atmospheric deposits
S_{wyn}	Uptake with crop yield
SNB	Nitrogen balance $SNB = {}_{org} + S_{min} + S_{msi} + N_{sym} + N_{atm} – S_{wyn}$
SPB	Phosphorus balance $SPB = S_{org} + S_{min} + S_{ms} – S_{wyn}$

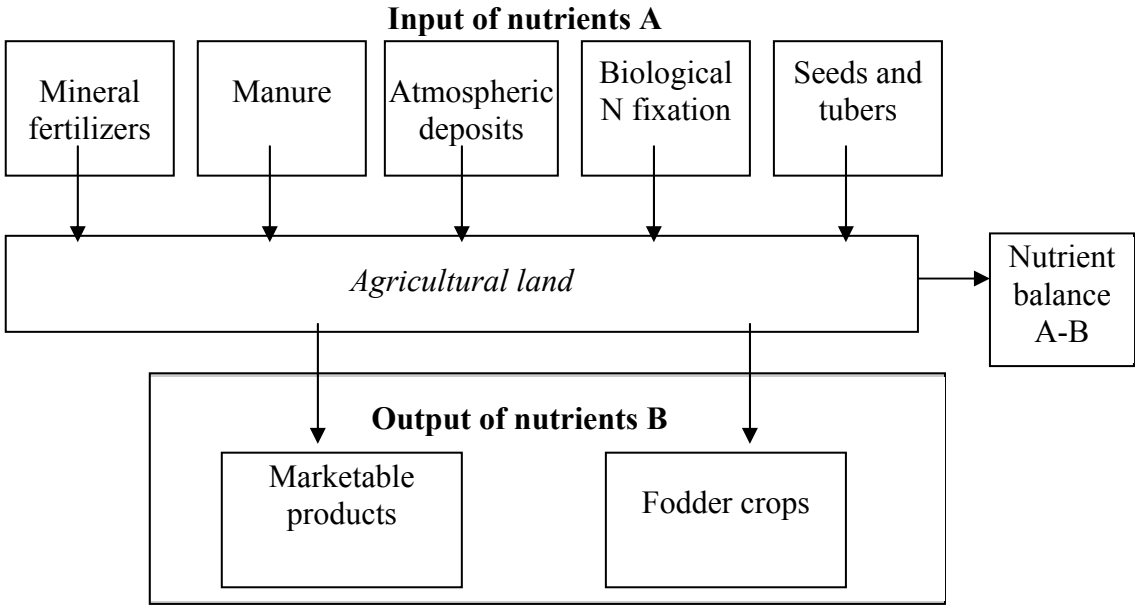

Fig. 1. Elements of the nitrogen and phosphorus, soil surface balances according to OECD

In Poland the nitrogen and phosphorus balances are calculated on the basis of date from Main Statistic Office, published in Statistical Yearbooks. The elements of these balances are given in table 1.

The amounts of nitrogen and phosphorus,S_{min},S_{org} in mineral fertilizers come directly from the Statistical Yearbook and the amounts in manure are calculated on the basis of information concerning the number and kind of animals in the country. In calculations the number of so called animal places i.e. the average, yearly number of animals is included.

The amounts of nutrients in seeds and tubers ,S_{msi} are calculated from the information on the area of main crops and standard values of sowing (planting) density times the content of N and P in these materials.

The amount of nitrogen biologically fixed, S_{sym} by Rhizobia its calculated as the product of leguminous crop area and standard fixing coefficients [Kerschberger et al. 1997] and nitrogen fixed by free living bacteria as a standard value of 4 kg $N*ha^{-1}$.

The amount of nitrogen in atmospheric deposits, S_{atm} is estimated for the whole area of Poland as 17 kg $N*ha^{-1}*year^{-1}$[Szponar 1996].

The uptake of nitrogen and phosphorus with crop yield,S_{wyn} is calculated separately from marketable crop and fodder crop from the crops area and the average yields times the content of N and P in these products [Fotyma et al. 1995, Karklins 2001].

3 RESULTS

3.1 Gross balance of nitrogen at regional and country level for the years 2002-2004

In the table 2 the elements of nitrogen balance as the 3 years averages for 16 regions (voivodshoips) and the whole Poland are presented. On the input side mineral

ferilizers have the biggest share, followed by manure. Much smaller are the amounts of nitrogen from atmospheric deposits and nitrogen fixed biologically (Fig. 2).

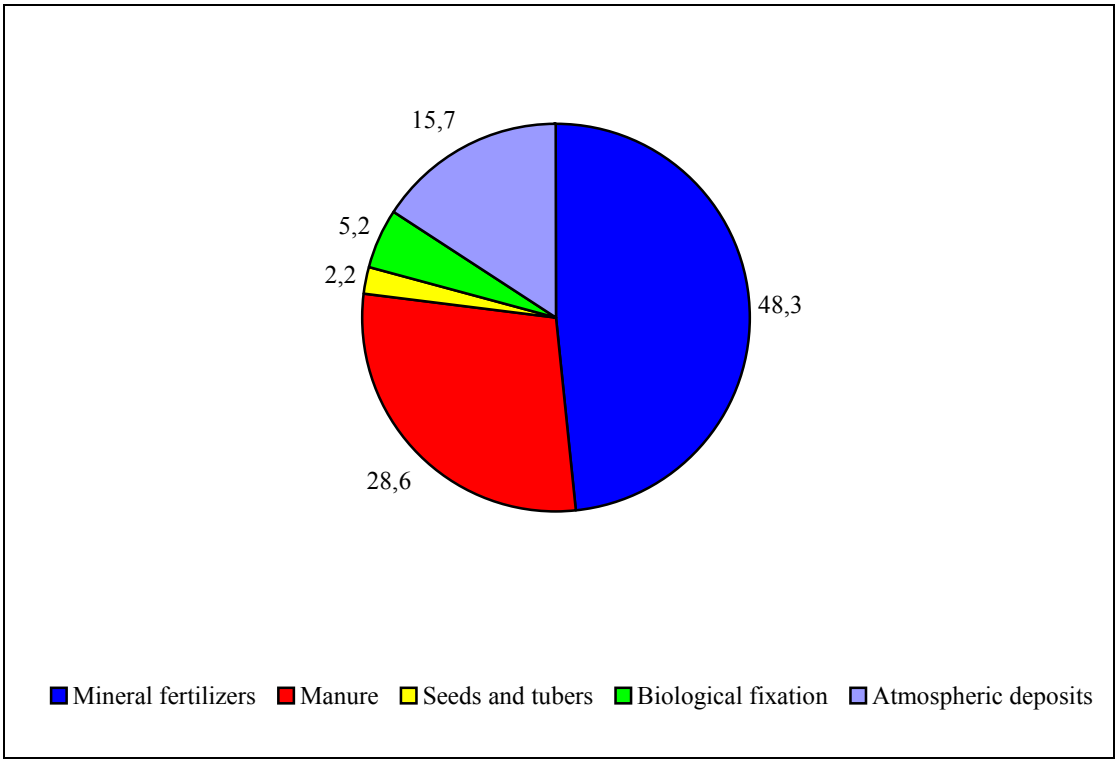

Fig. 2. The share of nitrogen from different sources in nitrogen input, [%].

Table 2. Nitrogen balance on regional and country level, averages for 2002-2004

Voivodships (see Fig. 3)	Elements of N balance acc. to table 1, kg N*ha^{-1}							NUE %
	S_{min}	S_{org}	S_{msi}	N_{sym}	N_{atm}	S_{wyn}	SNB	
Dolnośląskie	44.9	14.0	2.6	4.7	17.0	67.0	16.1	80.6
Kujawsko-pomorskie	86.5	38.3	2.9	6.2	17.0	75.6	75.2	50.1
Lubelskie	48.1	25.8	2.7	6.4	17.0	61.3	38.7	61.3
Lubuskie	59.9	18.7	2.1	5.0	17.0	43.2	59.5	42.0
Łódzkie	63.7	36.5	2.6	5.4	17.0	58.1	67.1	46.4
Małopolskie	37.5	33.4	2.1	6.6	17.0	63.9	32.7	66.2
Mazowieckie	36.2	35.5	2.2	5.5	17.0	57.7	38.8	59.8
Opolskie	74.7	25.9	3.0	5.2	17.0	87.8	37.9	69.8
Podkarpackie	25.9	24.4	2.1	5.2	17.0	54.5	20.1	73.1
Podlaskie	45.1	41.3	2.0	5.2	17.0	66.9	43.7	60.5
Pomorskie	61.0	25.5	2.6	5.9	17.0	60.3	51.6	53.9
Śląskie	39.6	29.9	2.1	5.3	17.0	60.3	33.5	64.3
Świętokrzyskie	39.3	26.6	2.4	6.8	17.0	53.6	38.4	58.2
Warmińsko-mazurskie	50.9	29.9	2.1	5.7	17.0	62.2	43.3	59.0
Wielkopolskie	64.2	47.0	2.8	6.0	17.0	72.7	64.3	53.0
Zachodnio-pomorskie	64.1	13.8	2.3	4.8	17.0	51.7	50.3	50.7
Poland	52.4	31.0	2.4	5.7	17.0	62.7	45.8	57.8

For the most European countries the main output of nitrogen goes through fodder crops grown on arable land and grassland. In Poland however nitrogen removal with

marketable crops is much higher than with fodder crops due to low density of cattle. The average surplus of nitrogen for the whole Poland was about 46 kg N*ha^{-1} which corresponds to almost 60 % of nitrogen utilization efficiency NUE from all registered sources. The value of NUE is comparable to this in other EU countries [Kopinski et al. 2001].

Nitrogen surpluses and values of NUE differ considerably between the regions (Fig. 3). It can be attributed mainly to the differences in the productivity of agricultural land [Fotyma et al 1998, Kopiński et al. 2001]. These differences are the result of both different natural conditions for crop production (climate, soil) and different level of agriculture development among the regions [Kuś et al. 2001].

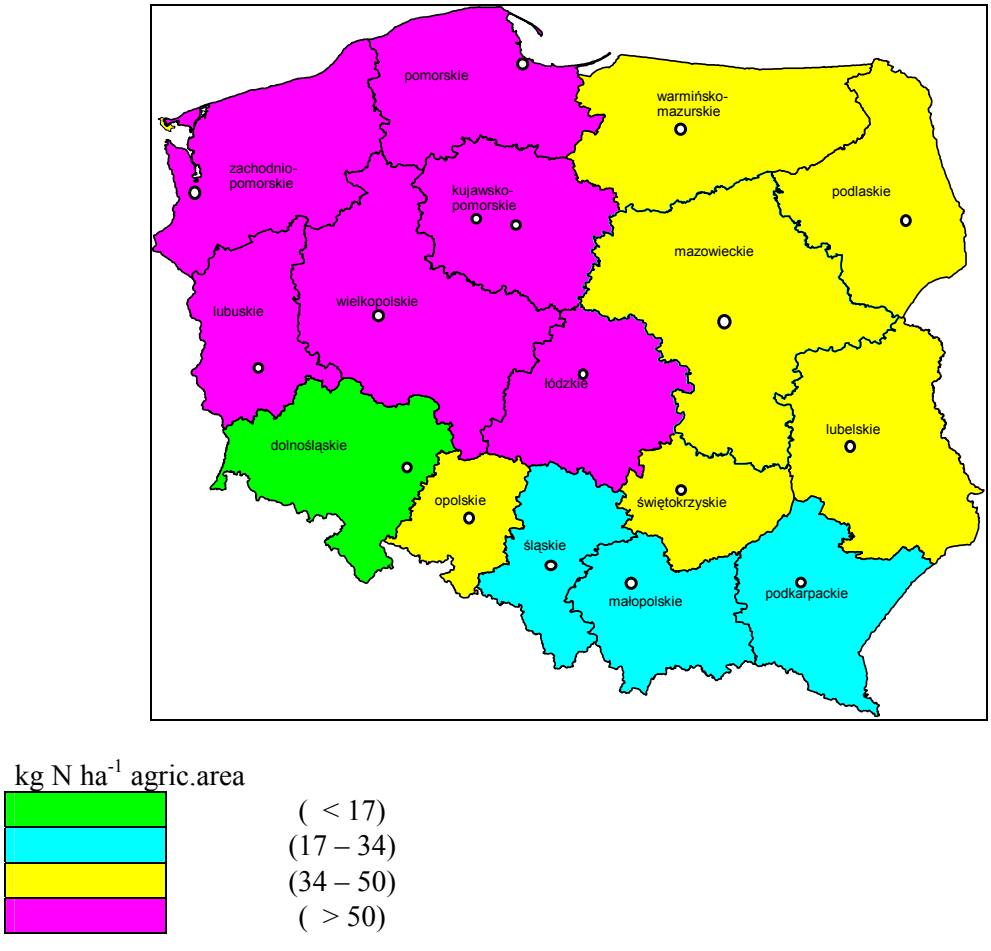

Fig 3. N surpluses in the regions of Poland, averages for 2002-2004 kg N*ha^{-1}.year^{-1}

The highest surpluses of nitrogen are recorded in North-West Poland and particularly in Wielkopolskie and Kujawsko-Pomorskie voivodships. It can be explained by high amounts of nitrogen provided with mineral fertilizers and manure. The intensity of crop production is here pretty high but nitrogen utilization from fertilizers NUE left much to be desired. The smallest surpluses of nitrogen appeared in South Poland i.e., in śląskie, małopolskie and podkarpackie voivodhips and particularly in dolnośląskie voivodship. The last voivodship is characterised by high crop productivity and simultaneously the input of nitrogen in fertilizers is below the average value for the whole Poland. Therefore nitrogen surplus is very low indeed and the nitrogen use

efficiency is the highest in comparison to remaining 15 voivodships. It can be concluded that nitrogen management practices are here at the top level.

3.2 Balance of phosphorus at regional and country level for the years 1999 – 2003

The elements of phosphorus balance as the 5 years averages for 16 regions (voivodshoips) and the whole Poland are presented in table 3. The average surplus of phosphorus for the whole Poland was about 3 kg P*ha^{-1} which corresponds to round 80 % of phosphorus utilization efficiency PUE from all registered sources. The differences in end phosphorus balances among the voivodships are much smaller than those for nitrogen. In two voivodships only phosphorus balances show the deficit of this nutrient, which obviously is exploited from the soil reserves. It is interesting that in both these voivodships the crop productivity is one of the highest in Poland and phosphorus output with crop yield is particularly high. For almost all remaining voivodships the values of phosphorus surpluses and phosphorus utilization efficiency are very close to the averages for the whole Poland (Fig. 4).

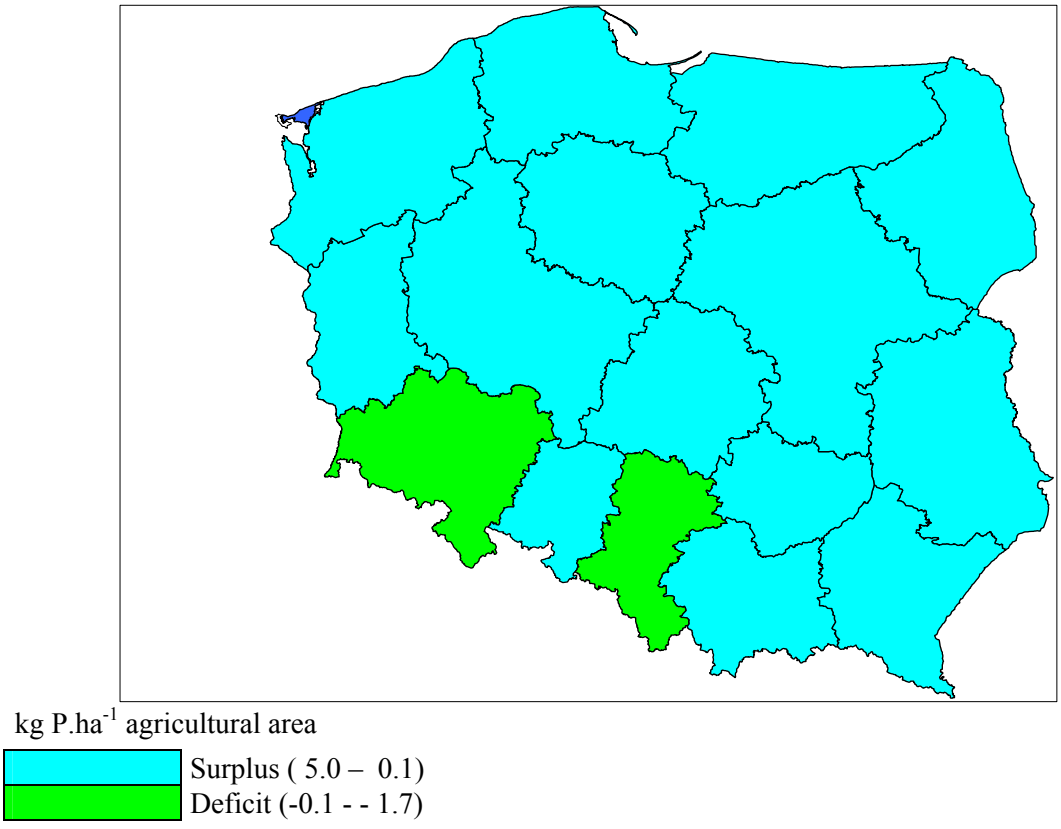

Fig. 4: Phosphorus surpluses and deficits in regions of Poland

The situation in respect of phosphorus balance seems to be satisfactorily for environmentalist but left much to be desired for agronomist. Low surpluses, or even deficits of phosphorus mean that only small amounts of this nutrient are accumulated in the soils increasing the natural soil fertility. In fact the phosphorus balance should be confronted with the actual status and the long-term trends in development of the content of available forms of this nutrient in the soils [Fotyma 1999]. According to the last estimation made by Central Agrochemical Laboratory [Lipiński 2005] 38% of

soils in Poland show very low and low, 26% - medium and 36 % high and very high content of available phosphorus (Fig. 5).

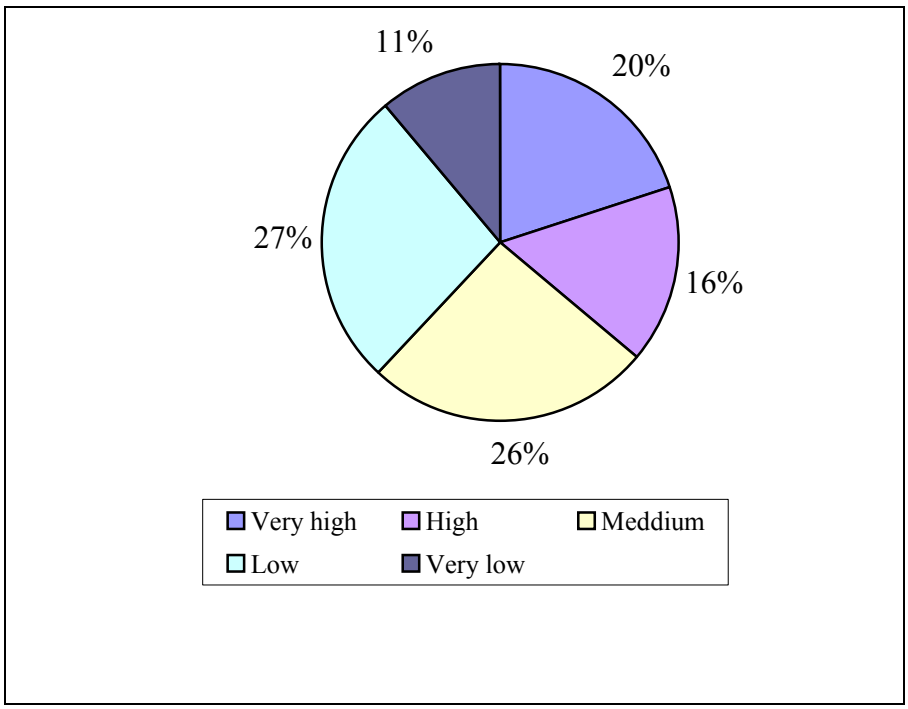

Fig. 5: The content of available phosphorus in the soils of Poland

Table 3. Phosphorus balance on regional and country level, averages for 1999-2003

Voivodships (see Fig. 3)	Elements of phosphorus balance acc. to table 1, [kg P.ha^{-1}]					PUE %
	S_{min}	S_{org}	S_{msi}	S_{wyn}	SgNB	
Dolnośląskie	7.9	3.5	0.6	13.5	-1.5	113
Kujawsko-pomorskie	7.7	7.9	0.7	14.6	1.6	90
Lubelskie	8.1	5.3	0.7	11.7	2.4	83
Lubuskie	7.8	3.7	0.5	8.1	3.8	68
Łódzkie	5.3	7.1	0.7	11.0	2.1	84
Małopolskie	8.0	6.9	0.5	11.1	4.4	72
Mazowieckie	7.8	6.4	0.6	10.8	4.1	73
Opolskie	10.2	6.1	0.7	18.1	-1.1	106
Podkarpackie	6.0	5.1	0.5	9.6	2.0	83
Podlaskie	7.4	7.2	0.6	10.6	4.6	70
Pomorskie	13.0	5.4	0.6	10.9	8.1	57
Śląskie	6.7	6.1	0.5	10.7	2.6	80
Świętokrzyskie	6.8	5.5	0.6	10.1	2.7	78
Warmińsko-mazurskie	5.4	4.9	0.5	9.9	1.0	92
Wielkopolskie	8.0	10.6	0.7	14.6	4.7	76
Zachodnio-pomorskie	7.2	3.1	0.6	10.0	0.8	92
Poland	7.6	6.2	0.6	11.7	2.8	81

According to the fertilizers recommendations the rates of phosphorus fertilizers for the soils showing very low P content should be by 50 %, and for soils showing low P content by 25 % higher than the uptake of this nutrient with the crop yield. Taking

into consideration this approach the phosphorus management practices on the substantial area of Poland could be hardly recognised as sustainable.

4 CONCLUSIONS

Gross nitrogen balance in Poland for the years 2002-2004 shows the surplus of about 45 kg N*ha^{-1} of agricultural area.

The highest surpluses of nitrogen are recorded in North-West Poland, particularly in wielkopolskie and kujawsko-pomorskie voivodships which may raise some concern of environmental pollution.

Low nitrogen surpluses in South-West Poland coupled with high crop productivity prove the good nitrogen management practices in this region of Poland.

The phosphorus balance in the country is slightly positive but the surpluses of this nutrient are rather low and in 2 regions they turn into deficiencies, which confronted with poor phosphorus status of the soil indicate not sustainable phosphorus management practices.

5 REFERENCES

Fotyma, M.. Zapotrzebowanie rolnictwa polskiego na nawozy. Stan i perspektywy rynku nawozów mineralnych i produkcji rolnej w Polsce. 1999, Puławy, 87-104.

Hansen,J.Nitrogen balances in Agriculture. Luxembourg: Statistics in focus – environment and energy.2000. T 8 – XX.

Igras, J. Kopiński, J. Lipiński, W.Nutrient balances in Polish agriculture. Annales of the Polish Chemical Society. Lublin,2003 Vol. 2, Part II, 713-718.

Karklins,A. Model for the calculation of nutrient offtake by crop: „offtake" model. Nawozy i Nawożenie - Fertilizers and Fertilization. 2000,1(6), 63-74.

Kerschberger,M. Franke,G. Hess,H. Anleitung und Richtwerte fur Nahrstoffvergfleiche nach Dungeverordnung. 1997, Jena: Thuringer Landesanstalt fur Landwirtschaft, 74 pp .

Kopiński ,J. Fotyma, M.Bilans azotu w krajach Unii Europejskiej na podstawie danych OECD. Pam. Puł., Puławy.2001.124, 255-262.

Krasowicz, S. Intensywność organizacji produkcji rolnej w różnych warunkach przyrodniczo-ekonomicznych. (W:) Niektóre problemy organizacji produkcji rolniczej. IUNG Puławy.1996. R(333), 35-62.

Kuś ,J. Jończyk,K. Kamińska, M.Regionalne zróżnicowanie produkcji rolniczej w latach 1988-1998. Systemy informacji i wspierania decyzji w rolnictwie. Pam. Puławski. 2001. 124, 263-272.

Lipiński, W. Zasobność gleb Polski w fosfor przyswajalny.Nawozy i Nawożenie – Fertilizers and Fertilization.2005.1, 49-54.

OECD. National Soil Surface Nutrient Balances: explanatory notes to interpret the data sheets. OECD Secretariat Paris 1999.

http://webdomino1.oecd.org\comnet\agr\aeiquest.nsf

OECD.Gross Nitrogen Balances. Handbook. 2004 .The 2nd Draft. OECD Secretariat Paris.

http://webdomino1.oecd.org\comnet\agr\aeiquest.nsf

OECD/Eurostat Phosphorus balances,2003.

http://webdomino1.oecd.org\comnet\agr\aeiquest.nsf

Szponar, L. Pawlik–Dobrowolski, J. Domagała, R. Twardy ,S. Traczyk, I. Bilans azotu, fosforu i potasu w rolnictwie polskim. Aneks - Nadmiar azotu w rolnictwie zagrożeniem zdrowia człowieka. Prace IŻŻ, Warszawa.1966. 80, 10-27.