N and P Farmgate Balances in Arable and Mixed Bulgarian Farms Before EU Accession

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Abstract

Increasing nutrient loads in European agriculture was the reason for the application of farm gate nutrient balance approach and improvement of nutrient management by re-examining the routine agricultural practices. Before European Union (EU) accession the nutrients loads in Bulgarian agriculture were very low on average. Applied chemical fertilisers in last years at country scale were as follows N - 31 kg.ha^{-1}, P_2O_5 - 5.6 kg.ha^{-1} and K_2O - 0,6 kg.ha^{-1}. Regardless the low fertiliser's utilisation in vegetable farms and in mixed farms nutrients loads are significant and conditions of environment pollution could be observed. Other source of pollutions are the non-intensive farms on acid soils where low fertiliser rates are applied, but the low yield and nutrients uptake are causing positive nitrogen balance. This paper reports on the farm gate nitrogen (N) and phosphorus (P) balances of typical Bulgarian arable and mixed farms calculated for 2007 and 2008. The farm gate nutrient surpluses/deficits varied significantly between the farm type within one year and between the different years. This could partly be explained by the different level of utilisation of chemical fertilisers and reutilisation of available farmyard manures. Calculated N and P balances clearly reflected the lower grain crop yields in 2007 due to the dry weather conditions in the active season, which strongly affected the arable farms from the Central part of Bulgaria. Nitrogen surplus was observed in vegetable farms, mixed farms and in the larger farms which were fertilising with adequate fertiliser rates. Surplus of P was observed only in intensive vegetable farms and mixed farms. The farm gate P deficit in most of the selected farms indicated a soil mining

and is a warning for possible future crop deficiencies and yield reduction. Some of the fertiliser application tendencies are also valid for the current time.

Key words: farm gate N and P balance, Bulgaria, soil mining, nutrient losses, pollution, sustainability

Introduction

Bulgarian agricultural practices were much less intensive than in Western Europe. The nutrients load in Bulgarian agriculture were very low on average. Chemical fertilisers application were as follows N - 31 kg.ha^{-1}, P_2O_5 - 5.6 kg.ha^{-1} and K_2O - 0,6 kg.ha^{-1} (Koutev et al., 2006). Regardless the low general fertiliser's utilisation in vegetables farms and mixed farms, nutrient loads are significant and conditions of environment pollution could arise. Other sources of pollution are the non-intensive farms on acid soils, where low fertiliser rates are applied, but the low yield and nutrients uptake is causing positive nitrogen balance.

Agricultural activity is a major pollutant source of surface waters with biogenic elements also in Bulgaria. Large quantities of nitrogen and phosphorus in the watersheds fall may provoke eutrophication. This causes ecological changes associated with loss of plant and animal species, reducing the ecological status, and affects negatively the water used for drinking and household use.

From 2007, Bulgaria is a member of the EU and has to follow EU regulations adopted in 90ties from the country. One of the most important problems is the fulfilment of the good agricultural practices for manure management.

As a consequence of the low fertiliser rates, input trends of nitrates for two four-year periods 2000-2003 and 2004-2007 showed a decreased concentrations in groundwater, especially in shallow ones. There has been some increase in concentrations in the karst waters. The average content of nitrates varies from 8 to15 mg.l^{-1} in all studied regions.

Last year's studies showed that a decreasing trend of annual average concentrations of nitrate nitrogen occurred, while phosphates have slightly increased trend. But as regards the rates of P fertilisers' applications, it could be mainly a result of soil erosion and household source because of the detergent application increase. Average concentrations of nitrate nitrogen do not exceed the rate for first class quality of water (5 mg.l^{-1}), and phosphate - standards for receiving water second category - 1 mg.l^{-1}. (Annual State of the Environment Report - 2007, Executive Environmental Agency). The trends in nitrate content changes in groundwater for the two four-year periods 2012–2015 and 2016–2019 show different ratios of trends at monitoring points in different types of exposed groundwater according to the depth of the water level. For Type 0 waters - the shallowest exposed groundwater, the percentage of points with a trend of insignificant changes in nitrate concentrations (31.15%) and points with a strong increase in concentrations (31.15%) predominates. For Type 1a groundwater, the percentages of points distributed across the five types of trends are

almost equal, with a very slight dominance of points with a trend of insignificant changes in nitrate concentrations (23%). For Type 1b waters with a groundwater level of 15-30 m, no significant dominance of any trend is observed, with the highest percentages being points with trends of slight decrease from 5 to 1 mg/l (25.4%) and slight increase in nitrates from 1 to 5 mg/l (27.1%). For the deepest exposed groundwater (Type 1c), the highest percentage is of monitoring points with a slight increase in nitrates from 1 to 5 mg/l (50%). For covered groundwater of Type 2, there is a slight dominance of points with insignificant changes in nitrate concentrations (36.9%). For karst springs, the highest share is of points with insignificant changes in nitrate concentrations (38.5%), (Annual State of the Environment Report - 2021, Executive Environmental Agency).

Optimal management of N and P in agriculture implies rational utilisation of N and P in all stages of applied technologies. To improve N and P use efficiencies, it is needed to take measures at farm level because intervening in one step of the nutrient cycle may affect N and P flows elsewhere, e.g. good composting practices of farmyard manure will conserve most of the nutrients, but high application rate could be hazardous for the environment, or covering slurry storage reduces direct ammonia emissions, but most of that ammonia volatilise soon after slurry application if immediate ploughing is not done or low-emission techniques are applied (Aarts et al., 1992).

The farm gate nutrient balance approach has become a key element in the nutrient legislation of Bulgaria. Farmers have to balance the major inputs and outputs in such a way that the annual surplus does not exceed a permitted threshold, which may be specified as a function of crop and soil type. The positive influence of whole-farm nutrient balances in the European countries was the creation of awareness among farmers and re-examination of routine practices (De Clercq et al., 2001; Öborn et al., 2003, Schröder, J.J et al., 2003.).

The calculation of farm gate nutrient balances of non-intensive agriculture can also help to improve the N and P managements by closely looking into the farming practices. The level of farmyard manures reutilisation and mineral fertilisation, based on prior soil sampling and analyses are the major practices to be improved. Farmers could understand easily the need for more balanced fertilisation not only with nitrogen fertilisers, and also the need for acid soils melioration. To evaluate nutrients economy in Bulgaria, the N and P balances of 15 typical arable and mixed farms from different regions were calculated for 2007 and 2008.

Materials and Methods

1. Selection of farms

Climatic and soil conditions in Bulgaria are very different in North and South Bulgaria. In North Bulgaria the climate is moderate continental and Chernozem soils have prevalence. Climate in South Bulgaria is continental with Mediterranean influence and Cinnamonic soils are most frequent. The country is divided in 6

agriculture zones – 3 in North and 3 in South Bulgaria. Farms were selected from Central North Bulgaria, Central South Bulgaria and from Northeast Bulgaria, where the most intensive grain crops and oil crops production exists.

Three main legal types of farms were defined in the Agricultural Census (Ministry of Agriculture and Foods, 2003). The first legal type is the agricultural trading societies with 352.5 ha average arable land. The second legal type is the cooperative farms with 592.7 ha arable land. The third legal type is the private family farms with only 1.4 ha. The number of the trading societies and the agricultural cooperatives is about 1% of all farms but their arable lands are about 70%. Number of private farmers was 648 274 and it is representing about 99% of all farmers. At the same time, they are labouring only 30% of the 3.2 million of hectares arable land in Bulgaria. Little part of private farmers – 16745, own more than 5 ha, and it represents 51% of lands laboured by private farmers. Trading societies and cooperative farms produce for the market, while private farms produce mainly for their own consumption. Vegetable farms are only a small part of the arable lands – 75 000 hectares, which is 2,3% from arable lands and they are distributed in all agriculture regions. The most intensive practices are effectuated in these areas, and for them the obtained data for nutrient balances are valuable.

In order to represent the large variety of farms in Bulgaria, besides regional principle, the selection of the farms was based on legal type of farm, type of farming and farm size (Fig. 1 and Table 1). Farms with arable land were presented in this article.

Table 1. *Some general information of the selected farms*

No	Type of farming	Legal type of farm	Area, ha	
			2007	2008
1	Mixed – cattle for meat	State	95	95
2	Arable – potatoes	Private	6	6
3	Arable – potatoes	Private	43	46
4	Arable	Cooperative	193	226
5	Arable	Private	550	670
6	Arable	Cooperative	2770	2670
7	Arable	Private	733	700
8	Arable	Private	2734	2843
9	Arable - vegetables	Private	4	4.2
10	Arable – vegetables	Private	16	13
11	Mixed – dairy cows	Private	39	39
12	Arable - vegetables	Private	0.79	0.79
13	Mixed – dairy cows	Trade society	2030	3030
14	Arable	Private	206.5	213
15	Arable	Cooperative	265.3	244

Remarks:

i. *The farm No1 is mixed farm with cattle for meat production. In the moment the heard is increasing and only young male calves are sold. That is why the nutrients output is very low.*

ii. *Study data for farm No4 is for 2006 and 2007 caused by cessation of activities*

iii. *The variety of crops in arable farms usually includes wheat, barley, maize, sunflower and rapeseed.*

iv. *The vegetables grown in horticulture farms are usually tomatoes, peppers, egg plants and cabbage.*

v. *Farms No 9 and 10 are with drip irrigation and fertigation.*

vi. *In Farm No12 the fertilisation is mainly by farmyard manure and irrigation is by furrows.*

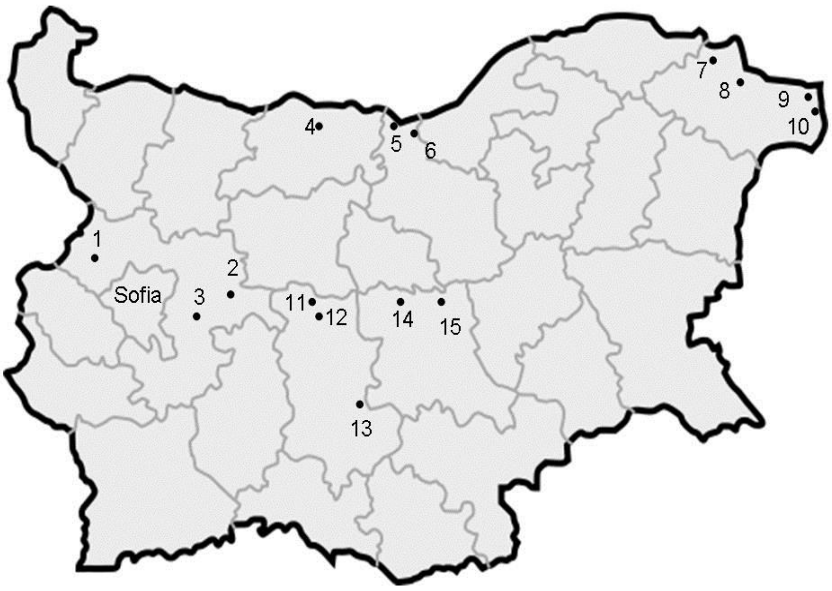


Fig. 1. *Location (●) of the selected farms*

2. Measurement of soil parameters

Soil sampling of the studied farm has been carried out to 20 cm depth from several augurings in one bulk sample for 4 hectares about. In case of large fields 50 – 100 ha, sampling of the representative parts of these fields was done. Sampling was done after harvest – from July to September in 2007 and 2008. This is a period without important rainfalls, and the content of mineral nitrogen does not change significantly. Some fields were sampled in both years and good reproducibility of results was observed.

Inorganic nitrogen was analysed by the Bremner - Keeney method of determination of inorganic nitrogen in soils (1966). Available phosphorus was analysed by acetate-lactate method (with similar range of results as Egner-Riem-Domingo method) which is official in Bulgaria (Ivanov, 1984). Soil pH was analysed in water and KCl.

3. *Measurement of plant, fodders and manures parameters*

Methods of plant, manures and fodders analyses

Sampling of plant, manures and fodders were done directly in farms from stored products – one mixed sample per product (or per crop from different field). Plant, manures and fodders analyses were made after wet digestion in sulphuric acid according to Kjeldahl procedure for nitrogen and wet digestion with spectro-photometric determination for phosphorus by molybdenum blue method (Mincheva and Brashnarova. 1975).

4. Calculation of a farm gate nutrient balance

Balance calculation for arable farms is relatively simple. The input flow is represented by nutrients in the chemical fertilisers and output flow by nutrients in the production for the market. Rarely farmyard manure is obtained from animal farm.

On mixed farms, there is both animal and plant production and internal nutrient flows exist between the animal and plant compartments. The manure from raising cattle is used on the farm and animals are fed mostly by roughage produced on the farm. To calculate a nutrient balance at farm level only the external flows must be taken into consideration. Internal flows of nutrients in farms are very important to be studied, because the efficiency of utilisation of crops as fodders and reutilisation of farmyard manures in the farm could be estimated. Otherwise, the stored as waste farmyard manure could be calculated as 100% reutilised in farm fields and environment pollution hazard would not be revealed as well the lost amount of money.

With each load of products brought into or removed from a farm, N and P are brought in or out at the same time. The amounts of products bought or sold in 2007 and 2008 were collected for each farm. At the start and at the end of 2007 and 2008 the stock of the animals, roughage, concentrates, manure, mineral fertilizers, animal products, plant products and seeds were recorded. The stock differences were calculated as the stock at the beginning minus the stock at the end of the year. A positive stock difference hence indicates an increase of the stock, and a negative stock difference shows a reduction of the stock. Most of the farms had not stocks from the year before because of their bad finances. They are buying the minimum needed and all production is realised in the market. Stocks were calculated only for mixed farms because of their long-term activities.

The total amount of input and output products and stock was estimated by the difference of obtained production and sold production. The total amounts of N and P in the input and output of animals, roughage, concentrates, manure, mineral fertilizers, animal and plant products and seeds were calculated by own data obtained during the study for each farm, available national data and using the international average N and P percentages (D'Haene et al., 2004, 2006, 2007).

An average atmosphere N deposition of 10 kg N ha^{-1} was adopted (Klein et al., 2007) measured in frames of international project by Norway Meteorological Institute. An average N_2 fixation of 60, 40 and 20 kg N ha^{-1} was used for the

calculations for alfalfa, beans and peas, and soybeans, respectively (Merbach, 1984; Csathó and Radimszky, 2005). Similar results for nitrogen fixation are presented by Pachev, I. (Dobrudzha Agricultural Institute, unpublished data) for Bulgarian agriculture – up to 60 kg $N.ha^{-1}$ for the alfalfa, up to 50 kg $N.ha^{-1}$ for the peas and up to 30 kg $N.ha^{-1}$ for red and white clover.

For input or output products, the variation N and P of our data and national data average of N and P were examined (Table 2). Differences of values were observed because of the amounts of analysed samples, years of analyses, different soil and fertilisation conditions.

Project data for barley, wheat and alfalfa are lower than national averages and it is due to the low level of agriculture practices in some of the farms and the yields with low quality in 2007. A study of the N and P percentages of plant parts and seeds of the major crops (wheat, maize, barley and sunflowers) in fertilization experiments showed under satisfactory fertilization a maximum error of 25% (D'Haene et al., 2004). However, in the case of over fertilization or deficiency of the soil, the variations of N and P percentages can be higher. Over fertilization can increase the percentage of P in maize significantly. Due to a P deficiency of the soil the percentage of P in grains can be 30% less than under optimal fertilization (Kádár, 2000). The percentage of N of fodders for different animals showed an error between 2% and 24% for the N for all studied samples.

Our measurements of the nutrients in different types of manures have variability from 12% to 34%. A maximum error of the percentage of N and P of manure of 30% was observed by Oenema and Heinen, 1999 and Mulier et al., 2001.

Table 2. *Average content of N and P in real data obtained in frames of the project and national data obtained from different sources (%)*

Crops	**Project data**		**National data**	
	N	**P**	**N**	**P**
Barley	1.65 ± 0.13	0.25 ± 0.07	1.79 ± 0.07	-
Maize	1.57 ± 0.08	0.16 ± 0.02	1.47 ± 0.06	-
Rapeseed	3.39 ± 0.27	0.60 ± 0.03	-	-
Wheat	1.78 ± 0.05	0.32 ± 0.02	2.08 ± 0.04	-
Sunflower	2.62 ± 0.15	0.41 ± 0.04	-	-
Alfalfa	2.34 ± 0.06	0.27 ± 0.10	3.37 ± 0.08	-
Potatoes	0,30 ± 0,08	0,06 ± 0,024	0.31 ± 0.01	-
Cow's milk	-	-	0.53 ± 0.002	-
Cows fodders	-	-	2.29 ± 0.15	0.25 ± 0.02
Pigs fodders	-	-	2.56 ± 0.12	0.26 ± 0.02
Poultry fodders	-	-	2.88 ± 0.08	0.28 ± 0.01
Farmyard manure	0.45 ±0.09	-	0.48 ± 0.06	0.17 ± 0.03

Preferred N fertilizer in Bulgaria is the ammonium nitrate - 72,5% of all nitrogen application. Nitrogen applied as NP is 15,6%, as urea is applied 9,4% of the nitrogen N and 2,5% is applied as NPK (IFA, 2007). The principal source of P applied in Bulgaria is in the form of NP fertilisers – 53,8%. Triple super phosphate and NPK fertilizers are included with 23,1% each (IFA, 2007). The maximal difference of percentage of N, P and K accepted by the Bulgarian Law to the guaranteed value of these N fertilizers is 10% of the active substances but not more than 2% of the fertiliser mass (Ordinance, 2003).

The maximum error on N deposition and N_2 fixation was assumed to be 10% and 20%, respectively based on data from Mulier et al. (2003).

The maximum error of the nutrient composition of total animals i.e. bones, meat, intestines plus skin, and animal products is about 5 and 10% (Oenema and Heinen, 1999; Mulier et al., 2003).

The total input, total output, surplus/deficit and nutrient use efficiency (NUE) were calculated as follows:

Total input = Input (animals + roughage + concentrates + manure + mineral fertilizers + seeds + deposition + fixation) [kg nutrient] (1)

Total output = Output (animals + mortality + animal products + plant products + manure + stock difference) [kg nutrient] (2)

Surplus/deficit = Total input – total output [kg nutrient] (3)

Marketable products = Output (animals + animal products + plant products) [kg nutrient] (4)

NUE = Total output / total input x 100 [%] (5)

The total input, total output and surplus/deficit of the arable and mixed farms were also calculated per hectare in order to simplify the comparison between farms. The N and P balances were calculated using an Excel programme programmed with Visual Basic.

The economic situation of Bulgarian agriculture does not permit to have stocks in the farms. Farmers only bought the needed input products and sold all their output products in same agricultural year (before new yields arrive). That is why stocks have not major role in balance calculations. Stocks were evaluated only for mixed farms in our case.

5. Statistics

Analysis of variance (ANOVA) was used to assess the effect of year and type of farming on mineral fertilizer input, total input, surplus/deficit and nutrient use efficiencies using the Statgraphics software Centurion XVI.

Results and Discussion

1. Soil parameters of the selected farms

The soils of farms 1-10 are different type of Chernozems (based on the Bulgarian soil classification system). The Chernozems (mostly corresponding to Chernozems and Phaeozem according to WRB) generally have a deep humus layer with high organic matter and colloid content. These soils are well aerated and well supplied with plant nutrients. The soils of farm 11-15 in the South of Bulgaria are Cinnamonic soils (mostly corresponding to Chromic Cambisols according to WRB) with an organic matter content that is lower than in the Chernozems and a humus layer that is not deep. Soil fertility of these soils is moderate, and it is strongly correlated with the soil texture and soil pH. Usually soils with more clay are more fertile. The combination of low clay content and low soil pH is the worst for soil fertility.

Based on the scale for P availability assessment of Bulgarian soils the studied farms were classified in Table 3 as follows: 10 of farms have soils with very weak P availability, 2 of farms have soils with weak P availability, 2 of farms have soils with medium P availability and only 1 has soils with good P availability. Such results are consequences the 20 years of very low P fertilisation application and the very negative balance of phosphorus. Highest content of mineral nitrogen after the harvest was found in vegetable farms soils (farm 9 and 10) which correlate with the balance surplus data. At this time the autumn rains have not provoked yet nitrates leaching down soil profile and obtained results for the mineral nitrogen are close to the real situation.

Table 3. Agrochemical parameters of soils from studied farm after harvesting

Farms	Texture	pH	Humus	N min	N min	P_2O_5	P_2O_5	Soil P
		(H2O)	%	$mg.kg^{-1}$	$kg.ha^{-1}$	$mg.kg^{-1}$	$kg.ha^{-1}$	availability
1	Sandy loam clay	5.5	1.9	8.2	24.6	54	162.0	Very weak
2	Sandy clay	5	2.1	10.3	30.9	201	603.0	Good
3	Sandy clay	5.1	1.9	13.2	39.6	43	129.0	Very weak
4	Sandy loam clay	7.7	2.0	13.7	41.2	105	315.0	Weak
5	Sandy clay	7.6	2.1	10.4	31.2	79	237.0	Weak
6	Sandy clay	7.7	2.1	12	35.9	131	393.0	Medium
7	Sandy clay	6.9	2.1	18.9	56.8	14	42.0	Very weak
8	Clay loam	6.8	2.3	12.6	37.9	46	138.0	Very weak
9	Sandy clay	6.4	2.1	33.5	100.5	13.9	41.7	Very weak
10	Sandy clay	7.6	2.1	22.3	66.9	137	411.0	Medium
11	Sandy loam	5.5	1.4	10.5	31.4	34	102.0	Very weak
12	Sandy loam	5.5	1.4	10.5	31.4	35	105.0	Very weak
13	Sandy	5.1	1.5	12.5	37.2	57	171.0	Very weak
14	Sandy loam	4.7	1.5	17.1	51.3	52	156.0	Very weak
15	Sandy loam	5.7	1.1	13.9	41.6	41	123.0	Very weak

2. Nutrient inputs and outputs of Bulgarian farms

Fertilisers application in Bulgaria is usually very low in last years – less than 35 kg of N per hectare, less than 6 kg of P_2O_5 (2,6 kg of P) per hectare and less than 1 kg of K_2O per hectare. Prior investigations (Nikolova, 2006) showed that nutrient balances of arable farms are negative. Mixed farms have positive balance for nitrogen and phosphorus. The applied method for balance calculations do not include the nitrogen input with atmospheric deposition. Average balance for arable farms is -77,6 $kg.ha^{-1}$ for nitrogen and -30.3 $kg.ha^{-1}$ for phosphorus as P_2O_5 (13,2 $kg.ha^{-1}$ as P). Balances in mixed farms are positive – 33,55 kg.ha-1 for nitrogen and 18,05 $kg.ha^{-1}$ for phosphorus as P_2O_5 (7,8 $kg.ha^{-1}$ as P).

We have 5 farms that are utilizing even less nitrogen fertilizers than the average for the country in 2007 and 2008 (tables 6 and 7) and only 2 farms in 2007 and 3 in 2008 that are applying more than 100 kg of nitrogen per hectare. For the P fertilizers application, the reality is stronger – 9 farms in 2007 and 10 in 2008 are utilizing less than the average for the country or are not utilizing P fertilization. Average amounts of fertiliser nutrients in all farms are higher than country level – 71,4 kg N.ha-1 and 6,5 P.ha-1 and it is mainly due to vegetable farms.

The main input flows of nutrients on the mixed farms are mineral fertilisers and fodders. Mineral fertilisers are the most important input flow on the arable farms. Mainly because of financial reasons some farmers bought mineral N fertilizers instead of mineral compound fertilizers and the phosphorus input as fertiliser is low. The main output product on the mixed farms is the animal production – milk, meat etc. On the arable farms main output flow was plant products.

Nutrient balances of studied farms in general are slightly positive for nitrogen and negative for phosphorus. Vegetable farms and farmyard manure application are related with strongly positive nitrogen balance and positive phosphorus balance. Surplus in Bulgarian farms are lower as compared to nutrient surplus in Hungarian farms in which the nutrients surpluses were several times lower than in West European countries (D'Haene et al., 2007).

Example of the look of the balance sheet of the calculation software was given for a dairy cow's farm (farm No11), Table 4. Mineral fertilisers and animal production (milk) were the main input and output product for nitrogen balance, respectively 1054 kg (36,3% of N input) and 1134 kg (39% of N input). Second input flow for the nitrogen was the roughage –741.7 kg (22.5% of N input), (Table 4). For the phosphorus it is the first input flow – 177.1 kg and 93.6% of P input. The phosphorus output with animal production was 189 kg (99.9% of the P input). The NUE% for nitrogen balance of this farm is in the optimal range for mixed farm (25%-50%). The NUE percentage for phosphorus balance outside of the frames of normal limits – 108.1% and it is a sign of soil mining.

Table 4. *Input and output parameters in dairy cows farm (No 11)*

	N	P	% N of input	% P of input
Input				
Roughage	741,7	177,1	25,5%	93,6%
Seeds	59,4	12,1	2,0%	6,4%
Fertilizers	1054,0	0,0	36,3%	
Deposition	390,0	0,0	13,4%	
Fixation	660,0	0,0	22,7%	
Output				
Animals	57,0	15,5	2,0%	8,2%
Mortality	38,0	11,1	1,3%	5,9%
Animal products	1134,0	189,0	39,0%	99,9%
Total input	**2905,1**	**189,2**		
Total output	**1229,0**	**215,6**		
Surplus	**1676,1**	**-26,4**		
Surplus per ha	**43,0**	**0,7**		
EFFICIENCY (NUE) (%)			**41,0%**	**108,1%**
RECOVERY (%)			**42,3%**	**114,0%**
SURPLUS (%)			**57,7%**	**-14,0%**

3. Differences in nutrient balances between 2007 and 2008

The farm survey was implemented in two very different years as weather point of view. In 2007 the climatic conditions were not suitable for normal yields production – rains in the active season were very rare and even missed in some places. For this year the rainfalls were 15% more than in average but they influenced more the next year yields. In 2007 the yields were very low, and the nutrients output as well (Table 6). In the next year the rainfalls were similar but optimally distributed in time. The difference between 2007 and 2008 in inputs, outputs and surplus for N and P are statistically significant ~~by~~ according to the multiple range test of these balance parameters (Table 5).

Because of the low yields in 2007 a surplus of N was observed in 14 farms - from 22.3 to 157 kg $N.ha^{-1}$. Only in one farm a deficits of 28,7 kg $N.ha^{-1}$ existed due to the very low N fertilizers input – 4,7 kg $N.ha^{-1}$ (Table 6). In 2008 the climatic conditions were very favourable for agriculture and in 6 farms a deficit of nitrogen was observed. In 2007 the phosphorus surplus was observed in 5 farms only. The deficits of P in 2008 increased due to the higher yields and outputs.

Table 5. *Multiple Range Tests of all balance parameters for Farms by Years at 95% LSD*

Years	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
2007	15	7,67	0,85	A
2008	15	8,33	0,85	B

* Different letters denote a statistically significant difference between variants.

Table 6. *Parameters of NP balances in studied farms in 2007 (kg.ha^{-1} and %)*

Farms	N fertiliser	N input	N output	N surplus/ deficits	N surplus/ deficits %	P fertiliser	P input	P output	P surplus/ deficits	P surplus/ deficits %
1*	0,0	32,3	1,2	31,0	96,2	0,0	4,9	0,3	4,6	94
2	62,5	79,8	37,2	42,7	53,4	5,3	6,8	7,8	-1,0	-16
3	4,7	22,7	51,5	-28,7	-126,3	1,2	2,7	8,6	-5,9	-215
4	21,5	36,3	14,0	22,3	61,5	0,0	0,6	2,6	-2,0	-349
5	59,7	73,1	30,8	42,3	57,9	1,6	2,3	4,3	-2,0	-87
6	42,8	58,5	35,6	22,9	39,1	3,6	3,9	5,3	-1,4	-35
7	76,3	87,7	35,8	51,8	59,1	7,2	7,5	4,9	2,6	35
8	82,0	98,8	56,2	42,6	43	0,0	0,3	7,7	-7,4	-2239
9	217,0	227,8	75,0	152,8	67,1	20,8	20,9	11,5	9,5	45
10	69,4	79,4	39,3	40,1	50,5	2,3	2,3	5,7	-3,4	-150
11*	30,1	81,8	36,5	45,3	55,4	0,0	5,8	6,5	-0,6	-10
12	181,0	192,4	35,1	157,0	1,7	34,8	35,1	5,1	29,9	85
13*	12,1	78,2	21,8	56,4	72,1	0,0	9,4	3,7	5,7	61
14	70,0	83,8	30,2	53,6	64	0,0	0,7	3,7	-3,0	-417
15	39,1	52,1	18,2	33,9	65,1	0,0	0,5	2,6	-2,1	-375

*Mixed farms

The limits of the surplus for a good nutrients balance management must be between 25% and 50% for arable farms (50% to 75% for NUE), and 50% and 75% for mixed farms (25% to 50% for NUE). In case of lower surplus values, a soil mining is observed and in case of higher values extra quantities of nutrients stay in soil after the harvest and they represent possible hazard for the environment. Above parameters of surplus and NUE are based on the average nutrients losses levels during the crop vegetation and internal nutrients flows evaluation as farmyard manure in mixed farms. Surplus values (Table 6) are showing that excessive nitrogen could stay in the soil and to be a menace for the environment in studied farms fertilisation level only in very bad for crop growing climatic conditions. Nitrogen fertilisation at the same level in optimal weather conditions in 2008 changes the situation from environment pollution hazard to soil mining (Table 7). Optimal climatic conditions in 2008 induced strong P deficits in farms and increased the soil mining.

Farms No 14 and 15 are on soils with very low pH (Table 3, tables 6 and 7). More than 20 years no liming was effectuated there. Applied nitrogen inputs could not improve the yields significantly. The rate of nitrogen application was relatively low,

but in the same time significant amounts from fertiliser nitrogen remains in soil after harvest. Lack of good agricultural practices could provoke environment pollution even in low inputs farms with significant nutrients deficits.

Table 7. *Parameters of NP balances in studied farms in 2008 (kg.ha^{-1} and %)*

Farms	N fertiliser	N input	N output	N surplus/ deficits	N surplus/ deficits %	P fertiliser	P input	P output	P surplus/ deficits	P surplus/ deficits %
1*	0,0	33,8	1,3	32,5	96,2	0,0	5,3	0,3	4,9	94
2	62,5	79,8	106,8	-27,0	53,4	5,3	6,8	22,7	-15,8	-233
3	7,4	25,3	97,4	-72,1	-126,3	2,0	3,4	16,2	-12,8	-375
4	18,4	30,0	33,1	-1,6	61,5	0,0	0,5	5,8	-5,3	-1156
5	54,5	67,3	78,2	-10,9	57,9	0,7	1,2	1,2	-9,3	-767
6	37,0	52,8	56,6	-3,9	39,1	1,4	1,7	7,9	-6,1	-351
7	72,9	84,4	113,9	-29,5	59,1	12,8	13,1	14,5	-1,4	-11
8	87,9	104,6	102,2	2,4	-43	4,2	4,6	13,1	-8,5	-187
9	213,8	224,5	76,0	148,6	67,1	27,6	27,8	11,7	16,2	58
10	133,5	143,5	40,5	102,9	50,5	1,9	1,9	5,8	-3,9	-208
11*	27,0	74,5	31,5	43,0	55,4	0,0	4,8	5,5	-0,7	-14
12	169,6	181,0	41,6	139,2	81,7	33,0	41,6	6,1	27,1	82
13*	10,5	61,3	17,5	43,8	72,1	0,0	6,4	3,0	3,4	54
14	68,0	81,6	42,8	38,8	64	0,0	0,7	6,0	-5,3	-793
15	71,8	85,3	22,9	62,3	65,1	0,0	0,7	3,9	-3,2	-185

*mixed farms

3.4. Arable versus mixed farms

Different practices in arable and mixed farms – utilisation of own farmyard manure, reutilisation of all crop production in the animal production, makes nutrients pathways different for both farm types. ANOVA estimation of data for all farms shows that for studied balance parameters the difference between practices in two farm types is statistically significant (Table 8).

Table 8. *Multiple Range Tests for balance parameters by Farm type*

Farm type	*Count*	*LS Mean*	*LS Sigma*	*Homogeneous Groups*
arable	24	7,59	0,92	A
mixed	6	9,64	2,39	B

Different letters denote a statistically significant difference between variants.

Contrast	*Sig.*	*Difference*	*+/- Limits*
arable - mixed	*	-2,05053	0,414713

* denotes a statistically significant difference.

It is well seen (Fig. 2 and 3) that in 2007 the nitrogen and phosphorus inputs were lower than in 2008 for arable farms. In same time the surplus is higher. It is due to the

climatic conditions in 2007, when the outputs where lower because of the very low yields. The inputs and surplus for mixed farms was higher in 2007, but it seems to be more stable system of nutrient balance point of view and climatic conditions do not affect them very strongly. Comparison of inputs and surplus for the phosphorus in arable and mixed farms shows more clearly the difference of the nutrients balance in both farm types (Fig. 3). The trends are similar as for nitrogen, but the very low P inputs and increased output in 2008 changes the surplus existing in 2007 to a deficit in 2008 for the arable farms.

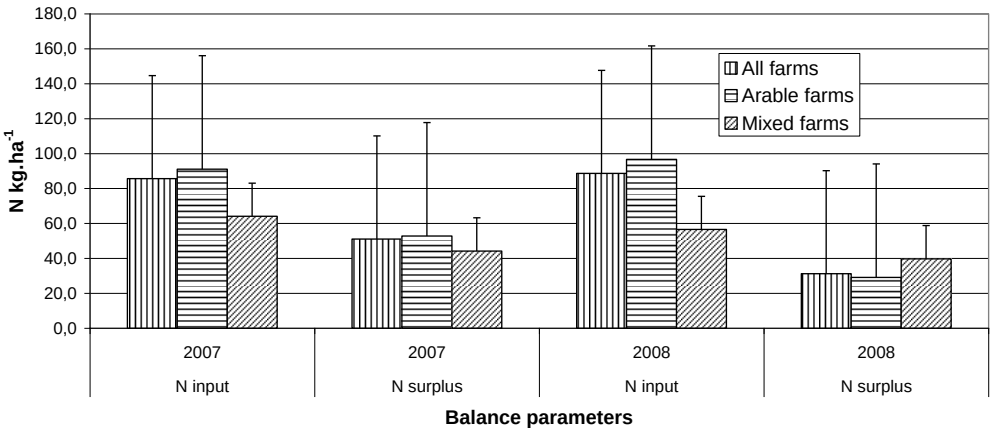


Fig. 2. *Nitrogen input and surplus in different farm types for 2007 and 2008*

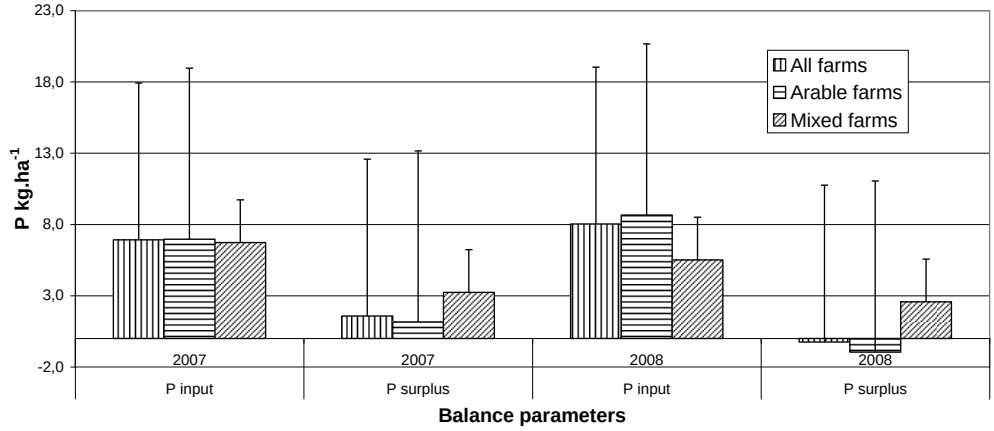


Fig. 3. *Phosphorus input and surplus in different farm types for 2007 and 2008*

3.5. Private versus cooperatives in arable farms

Legal status of farms was a significant factor in nutrient management. Better nutrient management was observed in private farms. Average input of nitrogen with fertilisers for private farms was 94 kg N.ha^{-1}. The input for the cooperative farms was 38,4 kg N ha^{-1}. The surplus was 47 kg N.ha^{-1} and 22,1 kg N ha^{-1} respectively. The input of P with fertilisers was 11,5 kg P ha^{-1} for private farms and 0,8 kg P ha^{-1} for cooperative farms. Phosphorus is in very low surplus for private farms 0,3 kg P ha^{-1} and in deficits for cooperative farms – 3,5 kg P ha^{-1}. ANOVA treatment has shown statistically significant difference between these parameters depending on farms legal status. All mixed farms were private, and they were excluded from the comparison.

3.6. Soil mining

Soil mining in the studied farms for the studied period has two main reasons – low rates of fertiliser's application and very good yields in 2008 due to the climatic conditions. More than 20 years of low nutrients input decreased soil stocks of the phosphorus to extremely low levels (Table 3). During our study in separate fields P over fertilisation traces were found. The politic in agriculture before political changes in 1989 was that P fertilisation has an aim to build up P reserves in soil at optimal levels for different soil types. The state supplied cooperative farms with the needed fertilisers, but as it seems some of them distributed P fertilisers closer to the farm and preferred to spend the finances previewed for fertilisers spreading activities for other purposes. The practices of government support of fertilisation have stopped in 1990 and the phosphorus now is usually in the output flows and very rarely in inputs.

The soil reserves of mineral nitrogen are very variable, but the residual nitrogen in soil after the harvest in dry conditions could be an index for the balance of the nitrogen in soil and the farm balance. Results obtained after the analyses of more than 350 soil samples from most of the field of studied farms showed that usually the amounts of inorganic nitrogen remaining after the harvest are low – in only 4 from 15 farms the amounts are higher than 50 kg N per hectare for the ploughing layer. Highest amounts were found in farms No 9 and 10 which are specialised in intensive vegetable production (Table 3). It is related partly with the surplus of N in these farms (tables 6 and 7). The exceptions come from farm No12 which is a vegetable farm, too, but it is applying large amounts of farmyard manure, and the calculated surplus is very positive. The inorganic soil nitrogen amount after harvest is not so high because of the slow mineralization processes of the organic nitrogen of the manure. This is another confirmation of the theory for the benefits of organic fertilisation on the soil fertility.

The low rates of nitrogen fertilisers application are enough for maintain positive balance in extremely unfavourable conditions such as in 2007, when only one farm had a negative balance. The number of farms with negative N balance increased to 6 (from 15) in 2008 when the climatic conditions were favourable and yields were higher than average. The nitrogen deficits per hectare in some farms reach 70 kg and

it shows that the soil mining for the nitrogen is real and the extensive agricultural practice are not suitable for soil fertility maintaining (Tables 6 and 7).

If farmers want to reach yields common for the period before 1989, they must increase the utilisation of mineral and organic fertilisers and to improve agriculture technologies applied.

While for the nitrogen some natural input sources are available – nitrogen fixation from the atmosphere by the leguminous plants and nitrogen depositions by the precipitations, for the phosphorus only mineral and organic fertilisers could improve the P regime of soils. Lack of P fertilisation in last decades caused a soil mining and in 14, from 15 farms the phosphorus fertilisation is strongly recommended, and only in one farm normal yields are possible without P fertilisers.

Phosphorus surpluses are observed in mixed farms and farms with intensive vegetable production. All arable farms were with P deficits and continue to contribute to the soil mining. Amounts of phosphorus in deficit in different farms varied from 1.0 to 7.4 kg $P.ha^{-1}$ for 2007 and from 0,7 to 15,8 kg $P.ha^{-1}$ in 2008. These P amounts are from 2 to 5 times higher than the average P fertilisation rates for the country and every year we continue with agricultural practices away from balanced P management.

The soil mining and the very low application of P fertilisers are the cause of the low quality of wheat produced in Bulgaria in last years – as a consequence lower price of the wheat and lower incomes for the farmers were obtained. Such example is valid for other crops, too.

Our results showed that compared to prior investigations, where average negative balances before 2006 were discussed (Nikolova, 2006), in the studied 2007-2008 period the highest negative balances occur.

3.7. Possibilities for improving the nutrient use efficiency

The biggest problem for the improving of nutrient use efficiency and other agriculture practices comes from the land property. Even farmers with very large number of lands and good financial status have in their own property only small part of the land. Major part is rented, and farmers do not want to care for a land which could be changed the next year. That is why the preference of nitrogen fertilisers is obvious. In the same time fertilisers with long-term effect on soil fertility as phosphorus, potassium and organic fertilisers are not applied. Different antierosion technologies which are related with nutrient balance are not applied because of the same reason.

The farm gate nutrient balances of Bulgaria were lower than those calculated in Western-European countries with a more intensive agriculture (De Clercq et al., 2001) and lower than calculated in Hungary (D'Haene et all, 2007). To improve nutrient management on farms with a more intensive agriculture several general measures have been suggested: to manage manures as fertilisers and not as a waste, better storage of manure and increasing of manure reutilisation rate, increasing the

number of mixed farms, increasing the part of leguminous in the crop rotations, increasing the rate of fertiliser application based on soil sampling and nutrients balance calculation, low emission housing, restricted grazing and rationalized ration for animals by combining grass products with low N-feeds such as maize silage and roughage (Kuipers and Mandersloot, 1999; Mulier et al., 2001; Tunney et al., 2003).

Statistical data is showing that one of the problems with nutrients balance and environmental pollution is related with the fact that 2% of farms in Bulgaria are animal producers without lands. These farmers own 38% of the poultry, 28% of the pigs, 6% of the buffalo, 3% of the cattle and sheep and 2% of the goats. Such farmers usually dispose of the farmyard manure as garbage and not as a valuable fertiliser. Implementations of rules for disposal of farmyard manures and slurries have to be controlled by the Governmental agencies and services for avoiding the environmental pollution by stored organic wastes. Rules for spreading these amounts of manures in arable farms must be created.

Yearly more than 11 million of tons of farmyard manure are produced in Bulgaria with about 60 000 tons of N, 30 000 tons of P_2O_5 and 35 000 tons of K_2O. In 2007 in Bulgarian agriculture 174 000 tons of farmyard manures on 85 000 ha were applied. This represents about 1.6% of available manures. Decrease of farmyard manure application was observed comparatively to 2006, in which 296 000 tons were applied. Farmyard manure was applied mainly on vegetables, potatoes, orchards and vineyards. (Anonymous, *National service of Plant Protection*). The other 98.4% of the manures have to be transferred from waste and polluting source stored around farms and villages to a valuable renewable source of nutrients. Such measures will improve the sustainability of Bulgarian agriculture.

These data show that not only farmers without land manage manures as waste and not as fertiliser. Farmers paying for several hundred tons of nitrogen fertilisers per year are storing their own manure in the environment and are causing pollutions but are not investing in spreading machines.

Manures are the most important source of nutrients for improvement of Bulgarian farms nutrients balance and some of the Governmental activities must be concentrated in this domain. Such measures will improve the sustainability of Bulgarian agriculture.

Introducing the calculation of nutrient balances in Western-European countries has indicated that rationalization of fertilization is the first and most frequently used measure taken to improve nutrient management (Kuipers and Mandersloot, 1999; Swensson, 2003). Utilisation of software for nutrients balance calculation by farmers is a strong tool for self-control and costless way to find the right decisions for fertilisers application and optimisation of nutrients supply of crops in the farm.

Since animal production in Bulgaria is based mainly on (farm grown) roughage, mineral fertilizers are the main input products of both arable and mixed farms and improvement of nutrient use efficiency should start in the plant unit. This can be done by a change in crop rotation or fertilization. N_2 fixation can be an

important input of N in extensive agriculture. Crop rotation with N_2 fixating green manure, which is ploughed into the soil, also adds organic matter to the soil. By including deep rooted plants in the crop rotation system, the soil conditions are improved. The deep-rooted plants can also take up nutrients in the subsoil which can otherwise be lost (Németh, 1995; Berzsenyi et al., 2000). These nutrients are directly utilised by crops for building yields or transferred to higher soils layers in roots and available for next year crops.

Larger farms usually organise their fields in large blocks. The spatial variability of large fields increases significantly (Bogaert, N., et al., 2000; Neményi, M. et al. 2003). The uniform fertilisation does not permit the optimal efficient utilisation of applied fertilisers, because in some places the applied fertiliser rate is lower than needed and in other places it is higher than need. That is why it is recommended to organise soil sampling based on GPS application. In such way the utilisation of fertiliser spreading technique with GPS module will improve the fertiliser efficiency.

There is no law which obliges farmers to have their soils regularly analysed in Bulgaria. This is one of the reasons that farmers do not care about the fertility of their own lands. When they will know about, more farmers will improve fertilisation practices. A new law resolving problems of soil fertility maintenance by farmers utilising the lands and not only by their owners will result in better nutrients balance in Bulgarian agriculture and improved environment status.

Conclusion

Calculating the nutrient balances for more than one year excludes the influences of weather and fertilization that are important on a crop season level. The calculated P deficits of ten of the fifteen Bulgarian farms demonstrated a process of soil mining. The low N surpluses or even N deficits indicated that the (potential) N losses into the environment are lower than those from the intensive agriculture in most Western-European countries with higher N surpluses. However, farms with intensive vegetable production, farms with strongly acid soils which do not utilise liming products, as well animal and mixed farms with low reutilisation of farmyard manure and slurries could be responsible for environment pollution. The low N and P surpluses and deficits do not allow increasing the nutrient input without rationalization and fertilization should be based on soil and manure sampling.

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