The paper presents the results of a study of the influence of the depth of the main plowing and fertilizer systems on the weediness of sugar beet sowings and its productivity. Investigations of the depth of plowing for sugar beet which were carried out with the long application of different fertilizer systems indicate that deep plowing influences the distribution of weed seeds both to the plow and to the submerged soil layer. Localization of weed seeds in the upper soil layer with plowing by 20 cm leads to a significant increase in the weediness of crops. The greatest amount of weeds in sugar beet crops was in organic and organo-mineral fertilizer systems with plowing by 20 and 30 cm. The total number of weeds in all variants was 50 and 62 pieces/m2. When plowing at 40 cm they were half as small.

The yield of sugar beet roots was highly dependent on growing conditions. Long-term use of appropriate fertilizer systems in crop rotation increased the yield of root crops at different depth of basic plowing at 4,7–19,1 t/ha. As a result of an increase in the depth of the basic tillage of 30 to 40 cm in the average for three years the yield of sugar beet increased by 2,2–5,1 t/ha in all variants of the experiment. With an increase in plowing depth from 20 to 40 cm in insufficient precipitation the yield of root crops increased by 4,0–5,9 t/ha and in the more humid year by 6,2–8,5 t/ha. In the average for three years of research the sugar content of root crops in experiments was within 14.4–15.3 %. In our experiments the factory output of sugar was 3,63–5,66 t/ha. The increase in plowing under sugar beet from 20 to 40 cm after long-term use of different fertilizer systems allowed to increase the factory output of sugar by 0,36–0,75 c/ha or by 7–13 %.

***Key words**: plowing depth, fertilizer systems, weeds, sugar beet, factory output of sugar, yield.*

UDC 631.8

VARIATIONS IN MINERAL FERTILIZERS CONSUMPTION IN POLAND AND THEIR EFFECT ON THE ENVIRONMENT IN 1990-2015

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У статті звернуто увагу на несприятливі аспекти сільськогосподарської діяльності при використанні мінеральних добрив. В післявоєнний період проблема ризиків для навколишнього середовища, викликаних надмірним використанням мінеральних добрив, була відсутня. Проте в наступні роки відбулося значне зростання внесення мінеральних добрив і у 1965-1970 роках зростання було більш ніж удвічі, і наступні періоди характеризувалися систематичним збільшенням. Ця ситуація збереглася до 1990 року, коли економічна ситуація змусила фермерів обмежувати витрати на сільськогосподарське виробництво, що, як стверджувалося, мало б принести користь навколишньому середовищу. У цьому випадку економічна ситуація "змусила" пом'якшення негативного впливу на навколишнє середовище. Проте кількість добрив систематично зростала протягом наступних років, в спробі збільшити випуск продукції, в середньому дорівнюючи 140 кг NPK / га у Польщі у 2013 році. Споживання мінеральних добрив у Польщі з 1995 по 2013 рік збільшилося більш ніж на 57%. З іншого боку, споживання зареєстровано на рівні 123 кг / га.

***Ключові слова**: мінеральні добрива, субсидії, вапно.*

Introduction. Agricultural production as a sector of the national economy,

despite its decreasing percentage in GDP, continues to play a major role as food supplier, while the decrease of this GDP percentage is primarily due to the significant growth of other sectors, mainly services, and the increasing work efficiency in non-agricultural sectors. Wicki and Grontkowska noted that '(…) *in the field of agribusiness, farming generally only maintains the previously recorded level of production, while the realistic growth in the sector is based on the increase of processing level and added value in produce and food processing*[1]. However, apart from positive effects, agricultural production tends to deliver more and more products which are undesirable in the social perspective. These are mainly concerned with the condition of the natural environment which is being polluted as a side effect of agricultural production enhancement.

As indicated by research works of many authors [2], detailed studies of agricultural production and its impact on the natural environment are gaining importance, both in their positive and negative aspect. Their usefulness is taken into account in the field of implementation of the agricultural policy or creating intervention mechanisms. Research and studies in this field can be helpful in finding an answer to the question of what should be done to improve the status of the environment.

Those factors in agriculture which have the most considerable adverse effect on the environment are gaining crucial importance in the perspective of the Common Agricultural Policy. Because elimination of negative aspects typically involves limitation of agricultural production, the problem is not easy to solve. Here, we can point to excessive growth of mineral fertilizer usage in agriculture, leading to higher yields but at the same time having an adverse effect on the quality of produced food and causing negative environmental consequences (pollution).
Intensive fertilization of farmland also has certain other consequences which are hazardous for human health. Consumption of plants contaminated with high dosage of fertilizers can be hazardous, particularly for children. As Dobrzańska points out, chemical contaminants '*... are currently the one most dangerous factor that has a negative effect on human health, while many chemicals are released into the environment intentionally, albeit unreasonably, for economic purposes*'[3].

In Poland, the condition of the natural environment is still considered relatively good, as compared to other EU Member States. However, the hazards are gaining strength, particularly in the context of increasing production intensity, aimed at maximizing incomes. Therefore, the issue is valid and requires continuous monitoring. Therefore, the main purpose of this paper is to present and evaluate the changes in mineral fertilizers usage in Poland. The paper points to certain adverse aspects of agricultural activities involved in use of production resources of industrial origin. Specifically, the volumes of used mineral fertilizers were studied, also broken down to specific types of fertilization (measured as quantities of pure ingredients). Research materials were obtained from publications and data of the Central Statistical Office of the Republic of Poland (GUS), IUNG-PIB Institute of Soil Science and Plant Cultivation - State Research Institute, Eurostat, and available literature.

Use of mineral fertilizers in Poland - analysis results

Pollution of surface waters and the soil/water environment, resulting from

inadequate use of mineral fertilizers, qualifies as a key hazard for the environment which is associated with intensive agricultural production: These contribute, *inter alia*, to landscape changes, or extinction of many plant and animal species. Release of harmful chemicals to surface and underground waters is assessed as the one most important of the above mentioned factors. In the case of agriculture, it would be difficult to precisely determine its significance in this respect, as it is not possible to single out that part of pollution which is generated by specific types of economic activities. However, farming seems to be playing an important role here, as it is the function of more than 60% of land area in Poland.

As Czyżyk points out on the basis of his research, the values of mineral fertilizers consumption, particularly for nitrogen-based fertilizers, are too high at farming establishments involved in intensive plant production, exceeding the recommended values for sustainable farming. Figure 1 presents the changes in mineral fertilizers use in Poland during 1990-2015. Following a major decrease of mineral fertilizer use during the initial period of transformation, due to deteriorating financial condition of farming establishments, the following years were characterized by slow growth, up until 2013.

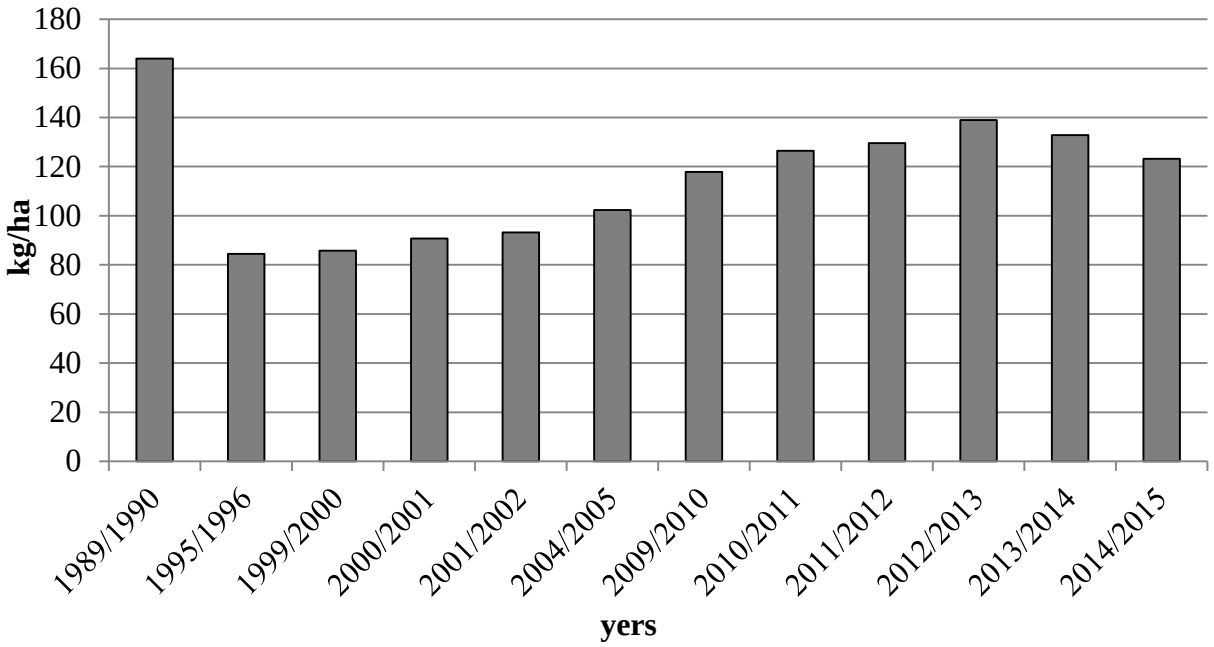

Figure 1. Mineral fertilizers use in Poland in selected years of the period from 1990 to 2015 [NPK kg/ha]

Source: Means of Production in Agriculture in the 2002-2007; Means of Production in Agriculture in the 2011/2012; 2012/2013 farming year, Warsaw; Statistical Year Book of Republic of Poland 2016. Warsaw.

The two latest years of review are again characterized by reduced consumption. However, it is difficult to determine at the moment whether this tendency will be permanent. 1990 was the last year preceding the political transformation. It also marked the end of a relatively "good" period for farmers when prices of purchased production resources of non-agricultural origin were attractive enough to allow for high consumption of materials. This was particularly the case with State-Owned Agricultural Holdings (Polish abbreviation: PGR),

where production intensity was high.

It was further related to extensive use of mineral fertilization. The 1990s were characterized by a major decrease of consumption of mineral fertilizers, even by half during the initial period (from over 160 kg NPK/ha to approx. 80 kg NPK/ha). During the following years, use of fertilizers did increase slightly, yet only after 2004 was there an observable significant growth of fertilizer consumption. This growth particularly concerned nitrogen-based fertilizers, the use of which grew by over 50% during the period from 2004 to 2013 (Fig. 2).

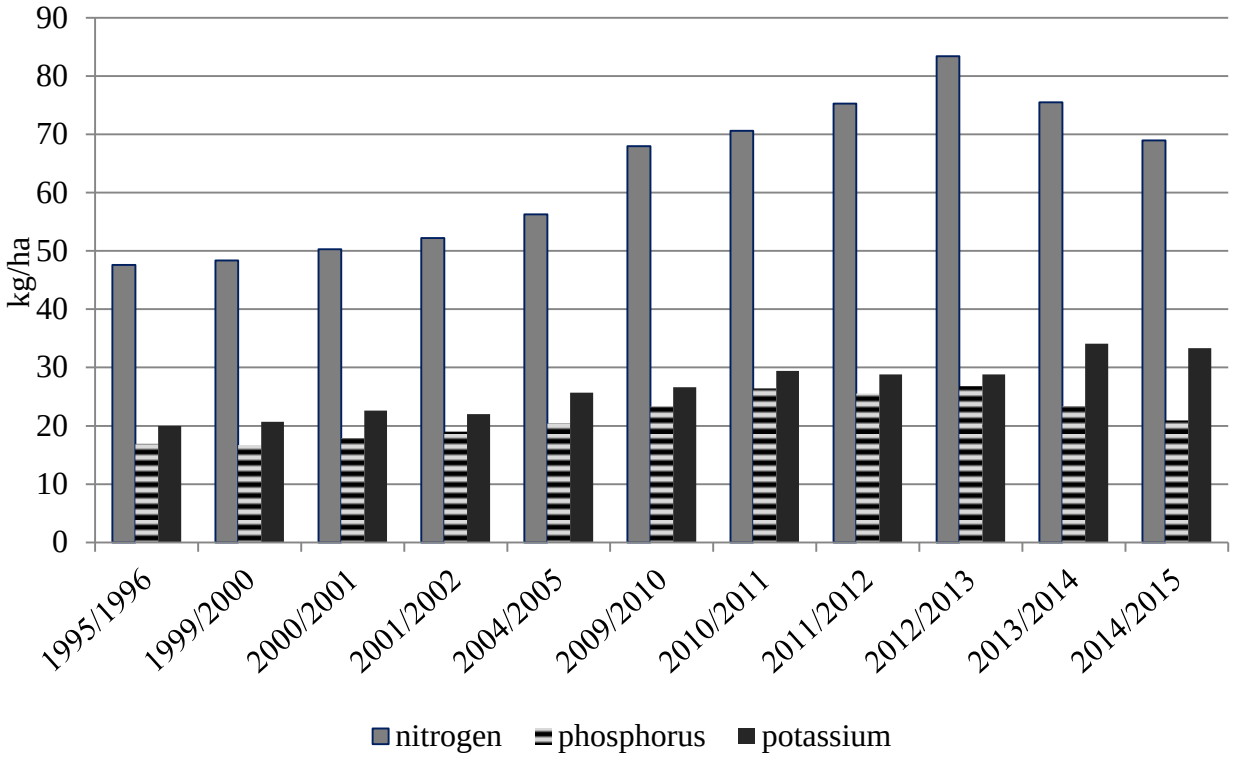

Figure 2. Nitrogen, phosphorus and potassium use in selected years of the period from 1995 to 2013 [kg/ha]

Source: Means of Production in Agriculture in the 2002-2007; Means of Production in Agriculture in the 2011/2012; 2012/2013 farming year, Warsaw; Statistical Year Book of Republic of Poland 2016. Warsaw.

A major increase in the use of fertilizers after 2004 can be a highlight of the role and significance of direct payments, which contributed to higher production efficiency in the farming industry. However, in terms of preservation of environmental resources, excessive use of fertilizers (mainly those based on nitrogen and phosphorus) is responsible for higher nitrogen and phosphorus contents in soil. Nitrogen and phosphorus compounds flowing by rivers to the Baltic Sea are the primary causes of eutrophication. Of the 9 countries of the Baltic Sea drainage area, use of artificial nitrogen- and phosphorus-based fertilizers per hectare was highest in Germany (172 T/kha) and Poland (148 T/kha), while it was lowest in Russia (13 T/kha).

The last two years (2014-2015) were characterized by decreasing consumption of nitrogen and phosphorus fertilizers. On the other hand, potassium

fertilizers exhibited a minor increasing tendency.

Soil acidification appears to be an important environmental issue, which is also related to agricultural activities. Farmland soil should have pH values ranging from 5.0 to 7.0. pH value below 4.5 indicates a risk of soil degradation through acidification. According to the data of the Central Statistical Office of the Republic of Poland, liming is necessary on approx. 22% of all areas, needed on 16% and recommended on 17% of soil surfaces. Filipek and Skowrońska point out that soil acidification causes a number of negative consequences, namely lower productivity and yield, poorer availability of nutrients for plants. In addition, soil buffering capacity and resistance to degradation processes is deteriorated. Soil acidification occurs in Poland on a continuous basis. With the surplus of precipitation over evaporation, precipitation waters flush the basic components (mainly calcium and magnesium) deeper into the soil.

The applied fertilizer doses, particularly with regard to nitrogen and potassium fertilizers, affect the pH values of soil. This has been confirmed by the outcomes of a long-term research project carried out at Dąbrowice Fertilization Orchard. With the increase of nitrogen and potassium dosage, pH and magnesium contents were decreasing significantly, particularly in the upper layers.

According to Filipek and Skowrońska, special attention should be drawn to changes of N:P:K values and proportions of nitrogen in fertilization, as nitrogen is the ingredient which is predominantly responsible for soil acidification. Phosphorus fertilizers, on the other hand, contribute to acidification to a lesser extent. According to the data of the Central Statistical Office of the Republic of Poland, this proportion used to vary in the past years (table 1).

1. Changes in N:P:K proportions, and proportion of nitrogen in overall fertilization during the period from 1980 to 2015

Lata	Stosunek N:P:K			Percentage of nitrogen in overall mineral fertilization [%]
	N	P	K	
1980	1	0,61	0,74	42,5
1990	1	0,59	0,79	42,0
1995	1	0,29	0,24	56,3
2000	1	0,35	0,43	56,4
2005	1	0,36	0,46	55,0
2010	1	0,34	0,39	57,7
2015	1	0,30	0,48	56,8

Source: own study based on: Statistical Yearbook of Agriculture of Republic of Poland.

The proportion of nitrogen had been increasing up until the beginning of the second decade of the 21st century, to reach as much as 60% in 2013. This proportion in total fertilization was reduced again during 2014-2015, to ca. 57%. With inadequate N:P:K proportions, nutrient availability in soil deteriorates (Fig. 3).

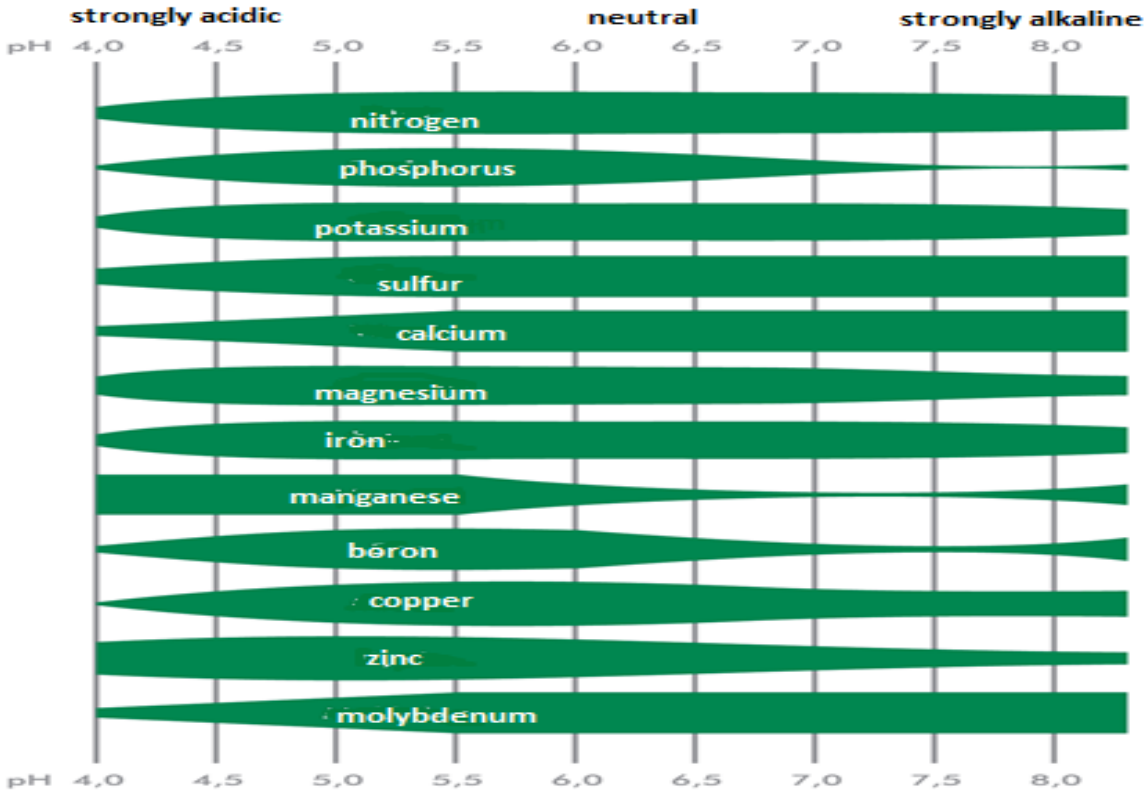

Figure 3. Soil pH vs. availability of nutrients

Source: Grześkowiak A., 2015: Zakwaszenie gleb powoduje nierównomierny wzrost i plonowanie. https://polifoska.pl/porady [Access: 20.12.2016].

Grześkowiak points out that the optimum pH values depend on the mechanical composition of soil, and should be the following:

- for very light soil: 5.1-5.5;
- for light soil: 5.6-6.0;
- for medium soil: 6.1-6.5;
- for heavy soil: 6.6-7.0;
- for organic, peat soil: <4.5.

In excessive acidification conditions, fertilizers are often observed to show poorer activity. Liming accelerates decomposition of organic substance and nitrification, which are most effective with weak acidic or neutral pH. In acidic soils, magnesium is typically present in a form which is not available to plants. With reasonable use of lime-based fertilizers with magnesium contents, absorption of the latter by plants tends to improve. According to Kliza-Kołubowicz, after liming, organic fertilizers will mineralize sooner and will earlier activate nutrients which are in turn better used by plants. It should be further pointed out that organic fertilizers used with simultaneous liming contribute to improved physical properties of soil.

Losses of washed-out calcium typically exceed 6-8 times the quantity of displaced magnesium, although sodium ions are transferred deeper as well, together with potassium ions, the latter to a much lesser extent. Depending on soil type, losses per hectare are estimated as follows on a yearly basis: 200 to 1500 kg CaO;

20 to 40 kg MgO; and 15 to 60 kg K. The soil acidification process is further significantly affected by the forms of mineral fertilizers used in farming, particularly nitrogen and potassium fertilizers. The vast majority of these fertilizers are acidic physiological fertilizers. As much as 5.2 kg $CaCO_3$ is needed to neutralize the consequences of using 1 kg nitrogen applied in the form of ammonium sulfate.

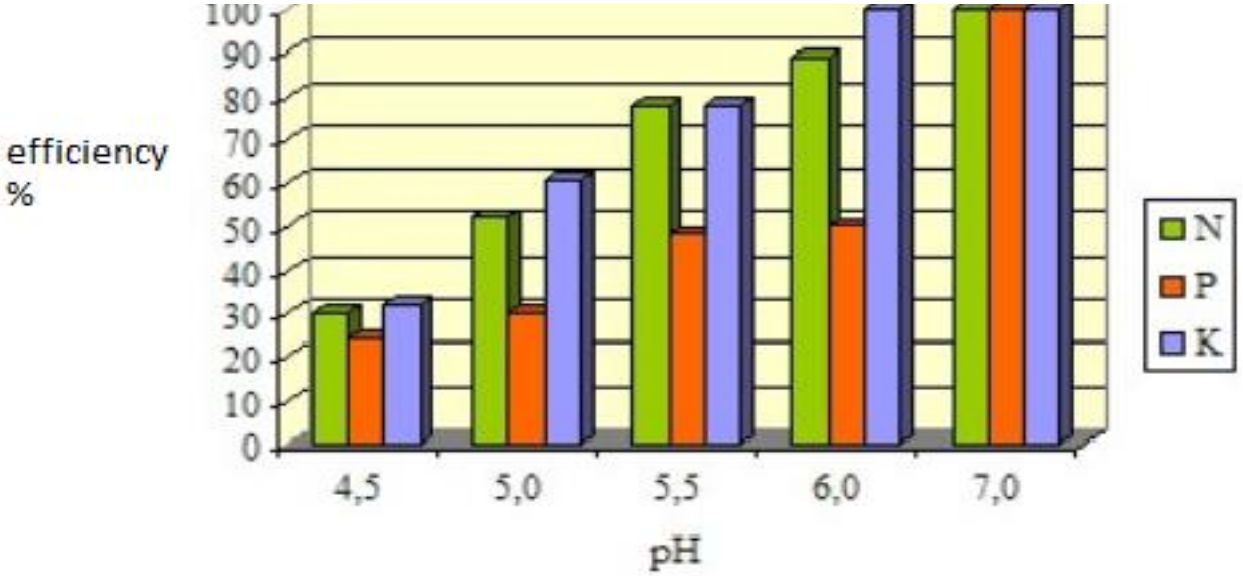

Figure 4. Macronutrients absorption efficiency vs. pH growth
Source: Buckman H.C, Brady N.C.: 1971. Gleba i jej właściwości. PWRiL, Warszawa: za: Kliza-Kołubowicz G., 2006: Wapnowanie gleb w Polsce. Instrukcja upowszechnieniowa nr 128. IUNG-PIB Puławy.

Acidification also results in lower availability of nutrients for plants, particularly phosphorus, magnesium and molybdenum. In addition, these nutrients are washed down to deeper layers of soil. Soil acidification reduces the humus content in soil. This, in turn, involves deterioration of the soil's buffering capacity. In this way, ingredients which may become hazardous in larger quantities improve in mobility. This is particularly an issue for heavy metal ions. Among the heavy metals, excessive dissolved manganese has a toxic effect on acidic soils. Both acidifying substances and released metal ions can be washed off to surface water or absorbed by plants from the soil solution. This results in lower soil fertility, lower biomass production and deterioration of biomass quality. Acidification also affects the proportions and activity of microorganisms. *Azotobacter* and microorganisms co-existing with most leguminous plants, among others, will be growing poorly and slowly. Also, the intensity of nitrogen absorption from the atmosphere is impaired in them.

Storage of fertilizers is an important aspect. Calcium-based fertilizers cannot contact natural fertilizers directly. If they were, ammonia losses would occur as a result of certain chemical reactions, polluting the atmosphere, and causing acidification of soil as soon as it gets to the surface.

Research shows that farmers expect to receive financial aid for utilizing their

land in accordance with environmental protection assumptions. These demands are mainly concerned with higher prices of produce, or guaranteed prices. This method of compensation for economic profits lost as a consequence of complying with environmental protection requirements would be perceived by farmers as encouraging to comply with these requirements. Research projects have proven that farmers were less attracted by compensation in the form of environmental/agricultural payments, as they considered such payments encouraging only at 200% of the current level at the minimum.

Summary

Use of mineral fertilizers in Poland was highly volatile during the last 20 years, depending primarily on the circumstances surrounding the framing industry. The political changes at the turn of the 1980s and the 1990s have contributed to a major reduction of mineral fertilizer consumption in agriculture. In 1989, 164 kg NPK would be used in Poland on average per 1 hectare of farmland. In the following years, intensity of fertilization decreased strongly (more than twice). It was mainly due to a major growth of prices of agricultural production resources. Poland's accession to the EU contributed to higher use of mineral fertilizers, mainly as a consequence of subsidies received for production.

On the other hand, use of fertilization lime decreased. This was due to withdrawal of subsidies in 2004. Analysts of the Central Statistical Office of the Republic of Poland emphasize that the level of lime fertilization continued to be low during the 2013/2014 season, at approx. 48 kg/ha, but an increasing tendency could be observed.

Generally, it should be emphasized that the changes in the structure of fertilizer use in Poland are disadvantageous. They cause major threats to the quality of soil, air and water, which people have to use in order to survive. Therefore, the following claim by Kronenberg and Lattacher needs to be concurred with: ***"Unless we start to care about the value of produce again, about the production conditions and the value of farmers' work, then we are heading for a dreary future and perspective for our health and our children's and grandchildren's living conditions".***

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Аннотация

B. Gołębiewska
Variations in mineral fertilizers consumption in Poland and their effect on the environment in 1990-2015

Использование минеральных удобрений в Польше было крайне неустойчивым в течение последних 20 лет, в зависимости от обстоятельств, связанных с развивающейся промышленностью. Политические изменения на рубеже 80-х и 90-х годов способствовали значительному сокращению потребления минеральных удобрений в сельском хозяйстве. В 1989 году в Польше в среднем на 1 гектар сельскохозяйственных угодий использовалось 164 кг NPK. В последующие годы интенсивность внесения удобрений значительно снизилась (более чем в два раза). В основном это связано с существенным ростом цен на сельскохозяйственные ресурсы. Вступление Польши в ЕС способствовало более высокому использованию минеральных удобрений, главным образом вследствие субсидий, полученных для производства.

С другой стороны, уменьшилось использование извести. Это произошло из-за отмены субсидий в 2004 году. Аналитики Центрального статистического управления Республики Польша подчеркивают, что уровень внесения извести в течение сезона 2013/2014 года был низким, приблизительно 48 кг/га, но наблюдалась тенденция к возрастанию.

Как правило, следует подчеркнуть, что изменения в структуре использования удобрений в Польше являются невыгодными. Они вызывают серьезные угрозы качеству почвы, воздуха и воды, которые люди должны использовать для выживания. Поэтому следующее требование Кроненберга и Латчерара должно быть согласовано с: «Если мы не начнем заботиться о стоимости продукта снова, о производственных условиях и ценности работы фермеров, тогда мы движемся к унылому будущему и перспективам для нашего здоровья и условий жизни наших детей и внуков».

***Ключевые слова**: минеральные удобрения, субсидии, известь.*

Annotation

B. Gołębiewska
Variations in mineral fertilizers consumption in Poland and their effect on the environment in 1990-2015

Use of mineral fertilizers in Poland was highly volatile during the last 20 years, depending primarily on the circumstances surrounding the framing industry. The political changes at the turn of the 1980s and the 1990s have contributed to a major reduction of mineral fertilizer consumption in agriculture. In 1989, 164 kg NPK would be used in Poland on average per 1 hectare of farmland. In the following years, intensity of fertilization decreased strongly (more than twice). It was mainly due to a major growth of prices of agricultural production resources. Poland's accession to the EU contributed to higher use of mineral fertilizers, mainly as a consequence of subsidies received for production.

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***Key words**: mineral fertilizers, subsidies, lime.*