Instytut Uprawy
Nawożenia i Gleboznawstwa
Państwowy Instytut Badawczy

HR EXCELLENCE IN RESEARCH

SYNOPSIS

**presenting the main scientific achievement,
reported as the subject of habilitation proceedings,
as well as other scientific achievements**

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I. Name and surname: Jarosław Stalenga

II. Diplomas and scientific degrees

1996 - Master's degree in environmental protection
Catholic University of Lublin, Faculty of Philosophy
Master's thesis: **"The role of crop rotation in organic farming"**
Promotor: dr hab. Szczepan Lekan

2001 – PhD degree in the field of agricultural sciences
Institute of Soil Science and Plant Cultivation in Puławy
PhD thesis: **"Assessment of the nutritional status of winter wheat and spring barley in different crop production systems"**
Promotor: prof. dr hab. Jan Kuś

III. Information on previous employment in scientific institutions

1996-2001 – PhD student (PhD Studies)
Department of Systems and Economics of Crop Production,
Institute of Soil Science and Plant Cultivation in Puławy

2001-until now - Assistant professor
Department of Systems and Economics of Crop Production,
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IV. Indication of the main scientific achievement in accordance with Art. 16 para. 2 of the Act of 14 March 2003 on academic degrees and titles (Journal of Laws No. 65, item 595 as amended)

a) Title of the main scientific achievement

ASSESSMENT OF NUTRIENT AND SOIL ORGANIC MATTER MANAGEMENT IN ORGANIC FARMING

b) List of publications constituting the main scientific achievement

1. **Stalenga J. (60%)**, Jończyk K., Kuś J. **2004.** Bilans składników pokarmowych w ekologicznym i konwencjonalnym systemie produkcji roślinnej (*Nutrient balance in the organic and conventional crop production systems*). *Annales UMCS, Sectio E,* 59(1):383-389. In Polish.
(MNiSW score = 4)

2. Jończyk K., **Stalenga J. (50%) 2006**. Wykorzystanie różnych metod do oceny bilansu azotu w ekologicznym i konwencjonalnym systemie produkcji* (Bilans azotu w ekologicznym i konwencjonalnym systemie produkcji oceniany z wykorzystaniem różnych metod**).
(*Use of different methods to evaluate nitrogen balance in organic and conventional crop production system* (Nitrogen balance in organic and conventional crop production system evaluated with the use of different methods**)*) *Journal of Research and Applications in Agricultural Engineering* 51(2):68-73. In Polish.
(MNiSW score = 3)

*The title of the publication given in the table of contents of the journal.
**The title of the publication given in its heading on page 68 of the journal.

3. Stalenga J. 2007. Applicability of different indices to evaluate nutrient status of winter wheat in the organic system. *Journal of Plant Nutrition* 30: 351-365.
(MNiSW score = 10), *IF_{2007} = 0,593*

4. Stalenga J. (70%), Jończyk K. **2007.** Reakcja wybranych odmian pszenicy ozimej na uprawę w systemie ekologicznym *(Performance of selected winter wheat cultivars in organic system)*. *Biuletyn IHAR* 245: 29-46. In Polish.
(MNiSW score = 4)

5. Stalenga J. (90%), Kawalec A. **2008.** Emission of greenhouse gases and soil organic matter balance in different farming systems. *International Agrophysics* 22: 287-290**.**
(MNiSW score = 6)

6. Stalenga J. (60%), Jończyk K. **2008.** Gospodarka składnikami pokarmowymi oraz bilans glebowej materii organicznej w systemie ekologicznym ocenione modelem NDICEA. (*Nutrient management and soil organic matter balance in the organic system assessed by the NDICEA model)*. *Journal of Research and Applications in Agricultural Engineering* 53(4): 78-84. In Polish.
(MNiSW score = 4)

7. Stalenga J. 2009. Plonowanie, stan odżywienia oraz efektywność wykorzystania składników nawozowych (NPK) przez dawne i współczesne odmiany pszenicy ozimej uprawiane w ekologicznym systemie produkcji roślinnej. *(Yielding, nutritional status and effectiveness of nutrient (NPK) utilization by old and modern winter wheat cultivars in organic crop production system)*. *Journal of Research and Applications in Agricultural Engineering* 54(4): 106-119. In Polish.
(MNiSW score = 4)

8. **Stalenga J. 2010.** Ocena stanu zrównoważenia gospodarki nawozowej w wybranych gospodarstwach ekologicznych w rejonie Brodnicy. *(Assessment of the sustainability of nutrient management in selected organic farms in the Brodnica region)*. *Journal of Research and Applications in Agricultural Engineering* 55(4): 117-120. In Polish.
(MNiSW score = 6)

9. **Stalenga J. (83%)**, Kopiński J. **2018**. Is it possible in specialized organic farms to maintain in soil appropriate content of nutrients and organic matter? *Journal of Research and Applications in Agricultural Engineering* 63(3): 86-91.
(MNiSW score = 12)

10. **Stalenga J. (80%)**, Kopiński J. **2018.** Nutrient balance and share of green fields in organic farms with different production profile. *Polish Journal of Agronomy* 35: 45-51.
(MNiSW score = 10)

The total score in accordance with the announcements of the Ministry of Science and Higher Education, including the year of publication, is **63**.

Total ***IF*** in the year of publication = **0.593**.

The list and copies of the publications constituting the main scientific achievement are included in Attachment 4. The co-authors' statements of their contribution to the development of these publications, taking into account also my contribution, are included in Attachment 5.

c) Presentation of the objective of the main scientific achievement and the results achieved, including their possible application

INTRODUCTION

The main objective of organic farming is to conduct a profitable agricultural production in accordance with the principles of sustainable farming, whose essential element is rational management of nutrients and soil organic matter (Mäder et al., 2002; Watson et al., 2002a).

Appropriate nutrient management in organic farming should be based on maximizing its biological retention in soil and minimizing nutrient losses caused by excessive mineralization, denitrification and leaching (Davis and Abbott, 2006). The latter process, especially in the case of nitrogen and phosphorus, may be a source of pollution of groundwater and surface waters, contributing to their eutrophication (Andersen et al., 2017).

A key activity of rational management of soil organic matter in organic farming should be maintaining its positive balance through diversified crop rotation with high share of legumes and catch crops, as well as systematic use of manure and other organic fertilizers (Fliessbach et al., 2007).

Calculation of a nutrient balance is one of the most important methods of assessing the sustainability degree of nutrient management. In the case of nitrogen, this balance should show a surplus of 30-40 kg per ha^{-1} of agricultural lands (AL) per year (Kopiński, 2009). This is due to the fact that nitrogen losses through gas emission are unavoidable and also certain amounts of nitrates are leached even under conditions of a very good management. On the other hand, permanent negative nitrogen balance may indicate excessive mineralization of soil humus. Precise calculation of the nitrogen balance in organic farming is a challenge, which results mainly from difficulties in estimating the amount of nitrogen symbiotically fixed by legumes, whose cultivation is the main source of this nutrient to plants (Watson et al., 2002b; Van der Burgt et al., 2006b).

An important element of rational management of nutrients in organic farming is cultivation of appropriate crops and cultivars adapted to the local conditions and specificity of this farming system. Lack of chemical crop protection and fast-acting synthetic mineral fertilizers makes the selection of appropriate cultivars essential for the quantity and quality of crop yields in organic farming. It is assumed that such cultivars should be characterized by, among others, high resistance to diseases (especially fungal diseases), rapid growth, and thus greater competitiveness in relation to weeds (Köpke, 2005; Wolfe et al., 2008).

A serious challenge for rational management of nutrients and soil organic matter in organic farming in Poland, but also in other European countries, is a high share of weak and very weak soils in the structure of arable land use (Report, 2016). It should be noted that the difference in crop yielding between the organic and conventional system on this type of soils is not large, and additionally the price premium for bio-products and subsidies to the organic land make the organic farming a competitive way of management on such soils (Kuś i Jończyk, 2007). On the other hand, the attractiveness of organic farming in relation to intensive (conventional) farming on better, more fertile soils, is not so high, which means that the number of organic farms in such areas is small.

In recent years, it has been observed in organic farming in Poland an advancing specialisation towards crop production and a complete abandonment of animal production. In 2016, as much as 83.2% of organic farms in Poland did not keep farm animals (Raport, 2017). This is very adverse, as it may lead to nutrient and soil organic matter imbalance. In order to avoid such situations, many stockless organic farms purchase organic fertilisers (mainly manure) (Colomb et al., 2013). However, this may increase their carbon footprint and consequently decrease energy efficiency of agricultural production (Wood et al., 2006; Meisterling et al., 2009). In order to limit manure imports, various measures should be implemented in organic farming that could improve soil fertility and maintain a possibly closed nutrient cycle (Möller, 2018; Råberg et al., 2018).

The integration of crop and animal production is a key principle of the so-called ecological recycling agriculture (ERA) concept. A sustainable nutrient balance in this system is ensured by appropriate livestock density adapted to the maximum productivity of fodder crops, which in turn allows the recovery of most of the nutrients taken up by these plants, while minimising the amount of external inputs in the form of purchased feed and manure (Granstedt et al., 2008).

RESULTS OF OWN RESEARCH

The main scientific objectives of the research carried out included:

1. **Evaluation of the effectiveness of nutrient utilization by old and modern winter wheat cultivars in the organic crop production system**
2. **Assessment of the nutrient balance and other elements of nutrient management in the organic crop production system**
3. **Comparison of the sustainability degree of nutrient management in organic farms with different production profile**
4. **Assessment of the soil organic matter balance and greenhouse gas emissions from organic farming**

Ad.1.

The first research activities on the suitability of modern winter wheat cultivars for organic farming was carried out at IUNG already in the late 1990s (Jończyk, 2002). For this purpose, a special field experiment established in 1994 at the Experimental Station of IUNG in Osiny (Lublin Voivodeship) was used. The aim of it is to compare different crop production systems (organic, integrated, conventional in two variants and winter wheat monoculture). The research focused mainly on assessment of the yielding of cultivars, their resistance to fungal diseases and competitiveness in relation to weeds (Kuś and Jończyk, 2018).

A lot of attention was also paid to the evaluation of the nutritional status of plants with nitrogen, phosphorus and potassium. Different methods were used in this evaluation, but mainly chemical ones, including the direct methods such as: critical nutrient range method, DRIS method and NNI test, while SPAD test used was an indirect method based on chlorophyll content. As a result of the research conducted in 1998-2000, it was shown that an important criterion for the assessment of the suitability of cultivars for organic system is their ability to effectively take nutrients from the soil, mainly nitrogen, and their effective redistribution to generative parts **[3]**.

It was also found that achievement of sufficient supply with nitrogen and other nutrients was particularly difficult in early development stages of winter wheat. This is due to the fact that in early spring the course of microbiological processes in soil is slow and even an adequate amount of organic matter may not guarantee sufficient supply with key nutrients to plants **[3]**.

It was also shown that the cultivar Kobra was the most adapted one for organic farming. It was characterized by a higher content of nitrogen and potassium than Juma cultivar, as well as a better nutritional status of these components as evaluated by NNI test and DRIS method **[3]**. At that time, there was no discernment about the performance of old wheat cultivars in conditions of organic farming.

In the years 2003-2007, at the Experimental Station in Osiny mentioned above, six modern cultivars (Kobra, Roma, Korweta, Sukces, Zyta, Mewa), three old winter wheat cultivars: Ostka Kazimierska (in the register of cultivars in 1964), Kujawianka Więcławicka (1967) and Wysokolitewka Sztywnosłoma (1951), as well as the Schwabenkorn cultivar of the winter form of spelt wheat were compared. The studies included, among others, the evaluation of the ability of cultivars to redistribute nitrogen to grain and their nutritional status with nitrogen, phosphorus and potassium **[4, 7]**.

The obtained results showed that the modern high-yielding winter wheat cultivars, i.e. the qualitative cultivars Zyta and Sukces, as well as the bearded cultivar Mewa, were characterized by the ability of higher nitrogen uptake from the soil and its redistribution to generative parts than old cultivars, which indicates that they are more adapted for cultivation in organic farming taking into account the criterion of nitrogen utilization efficiency. It should be noted that modern cultivars yielded approx. 4 t per ha in the assessed period of time, whereas the grain yield of old cultivars was approx. 1.5 t lower **[4, 7]**.

All winter wheat cultivars evaluated were characterized by a sufficient supply of phosphorus. No significant differences in potassium content were found. However, the content of this nutrient was below the lower limit of the reference interval for GS 32-35 determined by Bergmann (1992) **[7]**.

Among the compared winter wheat cultivars, the best nutritional status with nitrogen evaluated by SPAD test was determined for the bearded cultivar Mewa and the cultivar Kobra. The SPAD readings obtained for these cultivars were the closest to their critical values determined by Fotyma (2002). The results also showed that in three years of research, modern winter wheat cultivars usually did not reach the critical values during the vegetation season. However, due to the lack of optimal SPAD values for old winter wheat cultivars, precise evaluation of their nitrogen nutrition status with this test was difficult. In the case of another test - NNI, the results obtained, practically throughout the entire period of study, also indicated a more or less deficient nitrogen nutrient status of the compared winter wheat cultivars **[4, 7]**.

Taking into account the results obtained, it can be concluded that the usefulness of the SPAD test and the NNI index for organic farming is limited. It results from the fact that in this system, the possibilities of practical use of the results of these tests to determine the doses of nitrogen fertilizers are small, due to the ban on the use of synthetic nitrogen fertilizers. In addition, both tests were calibrated under conditions of intensive conventional agriculture which is aimed at obtaining high crop yields, similar to their potential maximum productivity. In organic farming, on the other hand, cereal yields are usually 25-30% smaller than in conventional system (Seufert et al., 2012). The specificity of organic farming (lack of fast-acting mineral fertilizers, chemical crop protection, etc.) causes that the conditions of plant growth and development are different here. It is therefore necessary to search for new methods for assessing the nitrogen status of crops adapted to organic farming or to recalibrate existing tests.

Ad.2.

Assessment of the balance of nitrogen, phosphorus and potassium in the organic crop production system was another objective of the carried out research. This balance was calculated using the NDICEA model, OECD method and MACROBIL program **[1, 2, 6]**. The studies were carried out in the years 1996-2007 on the field experiment established in 1994 at the Experimental Station of IUNG in Osiny, which aims at comparing different crop production systems.

Additionally, the NDICEA model allowed to evaluate other elements of nutrient management, i.e.: dynamics of mineral nitrogen content in soil in 2 layers (0-30 and 30-90 cm), nitrogen leaching and nitrogen losses caused by denitrification **[6]**. The time interval in the NDICEA model is one day, and the main input data include the details of crop management (sowing and harvesting dates, dates and doses of fertilization), basic physical, chemical and biological properties of soil, mineral nitrogen content in soil and weather data. In addition, measured crop yields were entered into the model, which were used, among others, to calculate the nitrogen demand of plants at specific development stages (Van der Burgt et al., 2006a). Few studies indicate that the NDICEA model can be a useful tool to estimate nitrogen uptake or losses in organic farming (Van der Burgt et al., 2006b; Smith et al., 2016).

The OECD method (2006) and MACROBIL program (Fotyma et al., 2001) also use detailed crop management data and measured crop yields to calculate the nutrient balance. On the input side, the amount of nutrients incorporated to the soil in the form of mineral and organic fertilizers as well as seeds and seedlings was taken into account. In the case of nitrogen balance, its deposition was also included and the biological fixation by symbiotic and non-symbiotic bacteria was estimated. The basis for calculations of nutrients taken out of the field was the measured yields of crops and the average content of nutrients in plants. In the case of cereals, the estimated straw yield was also taken into account.

The results of the nitrogen balance in the organic system calculated by the OECD method were ambiguous. In the first period of research (1996-2002), the balance was slightly negative and amounted to -11 kg N ha^{-1} year^{-1} in the whole crop rotation **[1]**. However, in the next period (2003-2005) the balance was already positive and amounted to +11 kg N ha^{-1} year^{-1}. The NDICEA model in the analogous period estimated the nitrogen balance at a similar level of +15 kg ha^{-1} year^{-1} **[2]**. However, in the longer period covering the years 2003-2007, the nitrogen balance calculated by the NDICEA model was more than twice as high and amounted to 33 kg ha^{-1} year^{-1} **[6]**. In the years 2003-2005, the OECD method and the NDICEA model showed a convergence of estimates of the nitrogen balance, both on the input and output side. The amount of nitrogen input estimated by the MACROBIL program was different. The nitrogen balance calculated by this program in the years 2003-2005 was clearly negative and amounted to -33 kg ha^{-1} year^{-1} **[2]**. The differences found between the MACROBIL program and the other two methods resulted primarily from a different method of calculating the amount of symbiotically fixed nitrogen. This calculation is based on special coefficients of symbiotic nitrogen fixation. Most of these coefficients relate the amount of nitrogen fixed to the yield and nitrogen uptake by legumes or their mixtures with grasses, as well as to the amount of nitrogen contained in their residues. However, there are also coefficients that relate the amount of nitrogen symbiotically fixed to the mass of root nodules which are organs of symbiosis between plants and bacteria. Methodological difficulties related to estimating the amount of symbiotically fixed nitrogen by legumes, especially their mixtures with grasses, are pointed out by many authors (Unkovich et al., 2010; Liu et al., 2011; Pietrzak 2011).

The phosphorus balance in the organic system assessed by the OECD method in the years 1996-2002 was negative and amounted to -16 kg P ha^{-1} $year^{-1}$ [1]. A slightly more favourable but still negative result of the balance of this component at the level of -6 kg ha^{-1} $year^{-1}$ was obtained from the NDICEA model simulation in the years 2003-2007 **[6]**. A negative phosphorus balance in the organic system corresponded with its low abundance in the soil, but it was not reflected in the assessed winter wheat phosphorus status which did not show any deficit **[3]**. The factor determining this discrepancy could be the high biological activity of soil, especially the most important in the case of phosphorus, high activity of alkaline phosphatase (Martinique et al., 2018).

In the organic system, the balance of potassium assessed by the OECD method in the years 1996-2002 was very clearly negative and amounted to -131 kg ha^{-1} $year^{-1}$. The main factor that determined this unfavourable result was the output of very large amounts of potassium with the biomass of a clover-grass mixture. In total, for the period of its two-year use, about 600 kg ha^{-1} of potassium was taken out of the system. Additionally, significant amounts of potassium were taken out with the yield of cereal straw and potato tubers. On average during the year, the removal of this nutrient from the soil amounted to about 170 kg ha^{-1}. A significantly different result was obtained when evaluating potassium balance in the years 2003-2007 with the NDICEA model. In this case, it was positive and amounted to 24 kg K ha^{-1} $year^{-1}$. It should be noted that a positive result of the balance for this nutrient was a consequence of application of potassium fertilisers allowed in organic farming such as: kainite or potassium sulphate at a dose of about 70 kg K ha^{-1} $year^{-1}$ since 2002.

The evaluation of soil mineral nitrogen content dynamics with the NDICEA model showed large coincidence with the actual measurements for the top soil layer: 0-30 cm, indicating at the same time the discrepancies for the 30-90 cm layer. Nitrogen leaching estimated for the whole crop rotation was small and amounted to 8 kg ha^{-1} $year^{-1}$ on average. Nevertheless, it was shown that in the autumn-winter period, especially after potato cultivation and after ploughing of a perennial clover-grass mixture, there was a high risk of nitrogen leaching. The amount of nitrogen losses due to denitrification was calculated at the level of 17 kg ha^{-1} $year^{-1}$ on average for the whole crop rotation **[6]**.

Ad.3.

Another objective of the research was to assess the degree of sustainability of nutrient management in organic farms with different production profiles. These studies were carried out in 2008 in 20 farms in the Kuyavian-Pomeranian Voivodeship and in the years 2010-2012 in 30 farms in the Lublin, Podlaskie and Mazovian Voivodeships. The farms were divided into three groups: specialized in crop/vegetable production, specialized in animal production and without a clear specialization (mixed farms). In specialised farms, the dominant branch had at least 60% share in the total gross final production expressed in PLN. The data collected by farmers on the basis of a special questionnaire developed by IUNG-PIB **[8, 10]** constituted the basis for this assessment. Moreover, analyses of soil pH, phosphorus, potassium, magnesium and organic carbon content in soil were carried out in the studied farms **[10]**.

In the evaluated groups of farms, the nitrogen balance ranged from -15.9 to +46.6 kg ha^{-1} year^{-1}, with fluctuations in particular farms from -35 to +89 kg. In the group of farms with crop/vegetable profile this balance was the lowest, especially in 2008 year, for which it amounted to -15.9 kg N ha^{-1} of AL. The most favourable, positive values of nitrogen balance were recorded in the group with animal profile and additionally in the group with mixed production, but only in the farms analysed in the years 2010-2012 **[8, 10]**. The positive result of nitrogen balance in the group specialized in animal production was due to a significant share of legumes (mainly clover-grass mixtures, but also mixtures of cereals with grain legumes) in the cropping structure. In general, despite relatively low yields of fodder crops, supply with nitrogen as a result of its symbiotic fixation ensured was enough for the following crops. Moreover, in stabilized organic farms the biological activity of soil is also high (Martyniuk et al., 2001) and thus the nitrogen fixation by non-symbiotic microorganisms may be even more intensive than in conventional farming.

The phosphorus balance in farms with crop/vegetable and mixed profile was negative and ranged from -2 to -7 kg ha^{-1} year^{-1}. In the group specialized in animal production, the balance of this nutrient was neutral or positive **[8, 10]**. Results of foreign studies (Berry et al., 2003; Gosling and Shepherd, 2005; Korsaeth, 2012) indicate that in organic farms, especially stockless, a negative phosphorus balance may occur, however by appropriate management it is possible to maintain a positive balance. In organic farming, phosphorus losses are usually negligible, and its movement down the soil profile can only occur when the sorption capacity of soil is exceeded, i.e. there is a very high phosphorus content and high soil hydration. Moreover, the phosphorus content in the sold crop and animal products is relatively low. Additionally, certain quantities of phosphorus are delivered with purchased fodder or mineral feed additives. The research conducted in IUNG-PIB shows that in organic farming the soil enzymatic activity is high, which may increase the availability of phosphorus for plants from soil mineral compounds (Martyniuk et al., 2018). In addition, the improved phosphorus supply in the organic system may also be associated with a more intensive development of mycorrhiza. Reports from the literature indicate that organic farming strongly enhances the development of such symbiosis (Gosling et al., 2010; Bedini et al., 2013).

The potassium balance in organic farms is usually negative (Berry et al., 2003; Gosling & Shepherd, 2005; Smith et al., 2016), which is caused by a significant content of this nutrient in the yields of many market crops. In the analyzed groups of farms the potassium balance ranged from -27 to +12 kg ha^{-1} year^{-1}, with fluctuations in particular producers from -68 to +53 kg. Clearly negative values were recorded in the group of farms specialized in crop/vegetable production **[8, 10]**. Although potassium, like nitrogen and phosphorus, is not a biogenic nutrient, but primarily plays a nutritional role, its unbalanced management, especially when there is a high sale of crops, may result in a decrease of soil potassium content, as well as in a deficient nutritional status of plants. The results of foreign studies confirm that it is difficult to maintain a sustainable potassium balance in organic farms (Gosling and Shepherd, 2005; Andrist-Rangel et al., 2007; Korsaeth, 2012), but especially in stockless ones (Smith et al., 2016).

In the groups of organic farms investigated in 2010-2012 no statistically significant differences were found in the content of organic carbon, phosphorus, potassium, magnesium and soil pH. The only statistically significant difference was in the soil pH between the mixed farms and the group specializing in animal production. The chemical analyses showed generally low potassium content in soils in the studied organic farms **[10]**.

Ad. 4.

Another objective of the research was to assess the balance of soil organic matter (SOM) and greenhouse gas emissions: methane and nitrous oxide. The research was carried out in selected organic farms with different production profiles in 2008 and 2010-2012 for SOM balance and in 2004-2005 for greenhouse gas emissions **[8, 9]**. Additionally, the assessment of SOM balance and nitrous oxide emission was performed for the organic crop production system based on data from 1996-2007 from the field experiment established in 1994 in SD IUNG in Osiny, whose aim is to compare different crop production systems **[5]**.

Special coefficients of reproduction and degradation of SOM developed by Eich and Kundler (after Fotyma and Mercik, 1995) were used to assess the impact of crop management on the SOM balance. These coefficients take into account the influence of cultivated crops as well as the impact of organic fertilizers.

On average, the balance of SOM in the studied organic farms was positive and amounted respectively to 0.53 t of dry matter (DM) per ha^{-1} of arable lands in 2008 and 1.67 t of DM ha^{-1} of arable lands for the farms analysed in the years 2010-2012. In producers specializing in crop/vegetable production, a negative balance of SOM was found, ranging from -0.09 t DM ha^{-1} of arable lands for the studied group in 2008 to -0.29 t for the farms assessed in the years 2010-2012 **[8, 9]**. It should be noted that the obtained result for this group could have been much less favourable, if it was not for the fact that some of them purchased manure from the neighbouring conventional farms, which is acceptable from the point of view of legal regulations in force in organic farming. In general, the positive balance of organic matter in the mixed and animal farms was due to 15% share of fodder crops (mainly legumes or their mixtures with grasses) in the cropping structure, as well as by a high livestock density. In the research conducted by Schultz et al. (2014), a significant decrease in the content of SOM in the stockless organic farms with a high share of market crops was found. In this group the content of SOM decreased by as much as 8.4% in relation to the initial value.

The SOM balance calculated for the organic crop production system in Osiny based on data from 1996-2007 was positive and amounted to 1.9 t DM ha^{-1} of arable lands per year. Also in this case the significant, 40% share of fodder plants (grass-clover mixtures) in the cropping structure decided about such a favourable result. The other two systems, conventional and integrated, were characterized by a negative balance, which was a consequence of a large share of cereals and other crops with a negative impact on the SOM balance. A clearly positive SOM balance for organic system indicates that this management creates appropriate conditions to increase soil carbon retention (sequestration).

Another aim of the study was to assess the impact of organic farming on the emission of two greenhouse gases: methane and nitrous oxide **[5]**. The estimation of methane emission includes its emission from intestinal fermentation of ruminants and secretion from organic fertilizers, mainly from manure. The amount of methane emission from intestinal fermentation processes was calculated on the basis of emission coefficients adopted for specific categories of farm animals (Olendrzyński et al., 2007). Emission from organic fertilizers was calculated on the basis of the production of these fertilizers in the farm. The efficiency of methanogenesis for manure was assumed at the level of 0.3 mole/kg of fermented substance (Nalborczyk et al., 1996). The calculation of nitrous oxide emission took into account its secretion from the soil associated with the use of organic fertilizers and biological nitrogen fixation by legumes. Estimated methane and nitrous oxide emissions were presented in CO_2 equivalent units, using appropriate global warming potential (GWP) values (Olendrzyński et al., 2007).

Organic farms evaluated in the years 2004-2005 emitted about 15% less methane than the conventional farms. In terms of CO_2 (in GWP units), these farms emitted about 20% less greenhouse gases (methane and nitrous oxide) per 1 ha of AL than the average in the voivodeship **[5]**.

The emission of nitrous oxide in the organic crop production system in Osiny based on the data from 1996-2007 was about twice lower than in the compared conventional and integrated systems. This was mainly due to the fact that no synthetic nitrogen fertilizers were used in the organic system, which to the greatest extent determine the emission of this greenhouse gas **[5]**.

CONCLUSIONS

1. An important criterion for assessing the suitability of winter wheat cultivars for organic farming is their ability to efficiently take up nutrients from the soil, mainly nitrogen, and redistribute them to generative parts of plants.
2. Achieving sufficient supply of nitrogen and other nutrients by winter wheat grown in the organic system is particularly difficult in its early development stages. This is due to the fact that in early spring the microbiological processes in the soil are slow and even an adequate amount of organic matter may not guarantee sufficient supply with these nutrients.
3. Taking into account the criterion of effectiveness of nitrogen use from soil and its redistribution to generative parts, modern winter wheat cultivars (Zyta, Sukces, Mewa) were more adapted for cultivation in organic farming than old cultivars (Ostka Kazimierska, Kujawianka Więcławicka, Wysokolitewka Sztywnosłoma).
4. The usefulness of the SPAD test and NNI index for the assessment of nitrogen nutrition status of winter wheat grown in organic farming is limited, because they were calibrated in

the conditions of intensive conventional agriculture which is aimed at obtaining high crop yields.

5. The results of the assessment of the nitrogen balance in the organic crop production system obtained using the OECD method, the NDICEA model and the MACROBIL program were ambiguous. The MACROBIL program generated a negative nitrogen balance, while the NDICEA model and partially the OECD method generated a positive result, but at a level not exceeding 35 kg N ha^{-1} $year^{-1}$.
6. The phosphorus balance in the organic system calculated by the OECD method and the NDICEA model was slightly negative and ranged from -6 to -16 kg ha^{-1} $year^{-1}$. Negative phosphorus balance corresponded with low soil content of this nutrient, but was not reflected in the assessed nutritional status of winter wheat with phosphorus.
7. In the organic system, the potassium balance assessed by the OECD method in the years 1996-2002 was clearly negative and amounted to -131 kg ha^{-1} $year^{-1}$. However, in the following years, due to the application of potassium fertilizers allowed in organic farming, the balance of this nutrient was already positive and amounted to 24 kg K ha^{-1} $year^{-1}$.
8. In the compared groups of organic farms with different production profiles, the most favourable, positive values of the nitrogen, phosphorus and potassium balance were recorded in farms specialized in animal production. Whereas, in the group with crop/vegetable profile, the balance of these nutrients had usually negative values. This indicates that farms with such specialisation may have serious difficulties in maintaining a sustainable nutrient balance, which in the long run may lead to a decrease of soil fertility and a deficient nutritional status of crops. The results of chemical analyses confirmed low potassium content in soils in farms with crop/vegetable profile.
9. Organic farms with diversified crop rotations including appropriate share of legumes, as well as applying organic fertilizers were able to maintain positive SOM balance. This indicates that organic farming creates good conditions to increase soil carbon retention (sequestration).
10. The assessed organic farms emitted about 20% less methane and nitrous oxide expressed in CO_2 per ha^{-1} of AL the conventional farms. The emission of nitrous oxide in the organic crop production system was about twice lower than in the conventional and integrated systems.

REFERENCES

1. Andersen J.H., Carstensen J., Conley D.J., Dromph K., Fleming-Lehtinen V., Gustafsson B.G., Josefson A.B., Norkko A., Villnäs A., Murray C. 2017. Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. Biological Reviews 92(1): 135-149.

2. Andrist-Rangel Y., Edwards A.C., Hillier S., Öborn I. 2007. Long-term K dynamics in organic and conventional mixed cropping systems as related to management and soil properties. Agriculture, Ecosystems and Environment 122: 413-426.

3. Bedini S., Avio L., Sbrana C., Turrini A., Migliorini P., Vazzana C., Giovannetti M. 2013. Mycorrhizal activity and diversity in a long-term organic Mediterranean agroecosystem. Biology and Fertility of Soils 49: 781-790.

4. Bergmann W. 1992. Nutritional disorders of plants: development, visual and analytical diagnosis. Gustav Fischer Verlag Jena, Stuttgart, New York, ss. 741.

5. Berry P.M., Stockdale E.A., Sylvester-Bradley R., Philipps L., Smith K.A., Lord E.I., Watson C.A, Fortune S. 2003. N, P and K budgets for crop rotations on nine organic farms in the UK. Soil Use and Management 19(2): 112-118.

6. Burgt G.J.H.M. van der, Oomen G.J.M., Habets A.S.J., Rosing W.A.H. 2006a. The NDICEA model, a tool to improve nitrogen use efficiency in cropping systems. Nutrient management and Agroecosystems 74: 275-294.

7. Burgt G.J.H.M. van der, Topp C.F.E., Watson C.A., Oomen G.J.M. & Rossing W.A.H. 2006b. Predicting soil nitrogen dynamics for an organic rotation using NDICEA. Aspects of Applied Biology 80: 217-223.

8. Colomb B., Carof M., Aveline A., Bergez J.-E. 2013. Stockless organic farming: strengths and weaknesses evidenced by a multicriteria sustainability assessment model. Agronony and Sustainable Development 33:593-608.

9. Davis J., Abbott L. 2006. Soil fertility in organic farming systems. W: Kristiansen P., Taji A., Reganold J. (Eds.) Organic agriculture: a global perspective. CABI, Wallingford, s. 25-51.

10. Fliessbach A., Oberholzer H., Gunst L., Mäder P. 2007. Soil organic matter and biological soil quality indicators after 21years of organic and conventional farming. Agriculture, Ecosystems and Environment 118:273-284.

11. Fotyma E. 2002. Zróżnicowanie odmianowe zawartości chlorofilu w liściach zbóż ozimych. Pamiętnik Puławski 130: 171-178.

12. Fotyma M., Jadczyszyn T., Pietruch C. 2001. A decision support system for sustainable nutrient management for farm level: MACROBIL. Nawozy i Nawożenie 2(7): 7-26.

13. Fotyma M., Mercik S. 1995. Chemia rolna. Warszawa. Wydaw. Nauk. PWN, ss. 356.

14. Gosling P., Ozaki A., Jones J., Turner M., Rayns F., Bending G.D. 2010. Organic management of tilled agricultural soils results in a rapid increase in colonisation potential and spore populations of arbuscular mycorrhizal fungi. Agriculture, Ecosystems and Environment 139: 273-279.

15. Gosling P., Shepherd M. 2005. Long-term changes in soil fertility in organic farming systems in England, with particular reference to phosphorus and potassium. Agriculture, Ecosystems and Environment 105: 425-432.

16. Granstedt A., Schneider T., Seuri P., Thomsson O. 2008. Ecological recycling agriculture to reduce nutrient pollution to the Baltic Sea. Biological Agriculture and Horticulture 26: 279-307.

17. Jończyk K. 2002. Reakcja wybranych odmian pszenicy ozimej na uprawę w różnych systemach produkcji roślinnej. Pamiętnik Puławski 130/I: 339-345.

18. Kopiński J. 2009. Ocena gospodarstw rolniczych o różnej intensywności produkcji na tle wybranych wskaźników agrośrodowiskowych. Roczniki Naukowe SERiA 11(1): 223-228.

19. Köpke U. 2005. Crop ideotypes for organic cereal cropping systems. W: Proceedings of the COST SUSVAR/ECO-PB Workshop on Organic Plant Breeding Strategies and the Use of Molecular Markers, s. 13-16.

20. Korsaeth A. 2012. N, P, and K budgets and changes in selected topsoil nutrients over 10yr in a long-term experiment with conventional and organic crop rotations. Applied and Environmental Soil Science 2012: 1-17.

21. Kuś J., Jończyk K. 2007. Ocena organizacyjna gospodarstw ekologicznych w Polsce. Journal of Research and Applications in Agricultural Engineering 52(3): 95-100.

22. Kuś J., Jończyk K. 2018. Produkcyjne i środowiskowe skutki stosowania różnych systemów gospodarowania w Osinach. W: Marks M., Jastrzębska M., Kostrzewska M.K. (Red.) Eksperymenty wieloletnie w badaniach rolniczych w Polsce. Wyd. UW-M Olsztyn, s. 133-156.

23. Liu Y., Wu L., Baddeley J.A., Watson C.A. 2011. Models of biological nitrogen fixation of legumes. A review. Agronomy and Sustainable Development 31: 155-172.

24. Mäder P., Fliessbach A., Dubois D., Gunst L., Fried P., Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science 296: 1694-1697.

25. Martyniuk S., Gajda A., Kuś J. 2001. Microbiological and biochemical properties of soils under cereals grown in the ecological, conventional and integrated system. Acta Agrophysica 52:185-192.

26. Martyniuk S., Jończyk K., Kozieł M. 2018. Numbers of phosphate solubilizing microorganisms and phosphatases activities in the rhizosphere soil of organically and conventionally grown winter wheat. Journal of Research and Applications in Agricultural Engineering 63(2): 147-150.

27. Meisterling K., Samaras C., Schweizer V. 2009. Decisions to reduce greenhouse gases from agriculture and product transport: LCA case study of organic and conventional wheat. Journal of Cleaner Production 17(2): 222-230.

28. Möller K. 2018. Soil fertility status and nutrient input-output flows of specialised organic cropping systems: a review. Nutrient Cycling in Agroecosystems 112:147-164.

29. Nalborczyk E., Łoboda T., Pietkiewicz S., Siudek T., Machnacki M., Sieczko L. 1996. Emisja gazów cieplarnianych w polskim rolnictwie i możliwości jej redukcji. Część II. Bilans

gazów cieplarnianych w różnych typach gospodarstw specjalizujących się w produkcji roślinnej. Ekspertyza, SGGW, Warszawa 1997.

30. OECD 2006. Environmental Indicators for Agriculture. Public. Service. Paris, vol. 4, chapt. 3.

31. Olendrzyński K., Kargulewicz I., Skośkiewicz J., Dębski B., Cieślińska J., Olecka A., Kanafa M., Kania K. 2007. Krajowa inwentaryzacja emisji i pochłaniania gazów cieplarnianych za rok 2005. Warszawa, Instytut Ochrony Środowiska, ss. 159.

32. Pietrzak S. 2011. Kwantyfikacja azotu wiązanego symbiotycznie przez rośliny motylkowate. Woda-Środowisko-Obszary Wiejskie 11, 3(35): 197-207.

33. Råberg T., Carlsson G., Jensen E.S. 2018. Nitrogen balance in a stockless organic cropping system with different strategies for internal N cycling via residual biomass. Nutrient Cycling in Agroecosystems 112:165-178.

34. Raport 2017. Raport o stanie rolnictwa ekologicznego w Polsce w latach 2015-2016. IJHARS, Warszawa, ss. 103.

35. Report 2016. Facts and figures on organic agriculture in the European Union. European Commission, ss. 47.

36. Schulz F., Brock C., Schmidt H., Franz K.-.P. & Leithold G. 2014. Development of soil organic matter stocks under different ‘farming types’ and tillage systems in the organic arable farming experiment Gladbacherhof. Archives of Agronomy and Soil Science 60: 313-326.

37. Seufert V., Ramankutty N., Foley J.A. 2012. Comparing the yields of organic and conventional agriculture. Nature 485: 229-232.

38. Smith L.G., Tarsitano D., Topp C.F.E., Jones S.K., Gerrard C.L., Pearce B.D., Williams A.G., Watson C.A. 2016. Predicting the effect of rotation design on N, P, K balances on organic farms using the NDICEA model. Renewable Agriculture and Food Systems, 31: 471-484.

39. Unkovich M.J., Baldock J., Peoples M.B. 2010. Prospects and problems of simple linear models for estimating symbiotic N_2 fixation by crop and pasture legumes. Plant and Soil 329 (1-2): 75-89.

40. Watson C.A., Atkinson D., Gosling P., Jackson L.R., Rayns F.W. 2002a. Managing soil fertility in organic farming systems. Soil Use and Management 18(1): 239-247.

41. Watson C.A., Bengtsson H., Ebbesvik M., Løes A.K., Myrbeck A., Salomon E., Stockdale E.A. 2002b. A review of farm-scale nutrient budgets for organic farms as a tool for management of soil fertility. Soil Use and Management 18(1): 264-273.

42. Wolfe M.S., Baresel J.P., Desclaux D., Goldringer I., Hoad S., Kovacs G., Loschenberger F., Miedaner T., Østergard H., Lammerts van Bueren E.T. 2008. Developments in breeding cereals for organic agriculture. Euphytica 163: 323-346.

43. Wood R., Lenzen M., Dey C., Lundie S. 2006. A comparative study of some environmental impacts of conventional and organic farming in Australia. Agricultural Systems 89 (2): 324-348.

V. Presentation of other research achievements

The course of scientific work before obtaining the PhD degree

In 1996-2001 I participated in the PhD Studies at the Institute of Soil Science and Plant Cultivation in Puławy. My research during this period focused on issues related to the assessment of the nutritional status of wheat and barley in different crop production systems, as well as the quality of crops in organic farming. I was also involved in the evaluation of the economic and energy efficiency of the organic and conventional crop production systems. During my PhD studies I completed several foreign scientific internships and study trips. In July 1997 I participated in a study trip to Danish Agricultural Advisory Centre in Aarhus (Denmark) within the project "Development of a Code of Good Agricultural Practice in Poland" **[III.L.5]**. Then, in 1998, I spent three months on a scientific internship at the Research Institute for Agrobiology and Soil Fertility in Wageningen (Holland) within the framework of the project "Database for sustainable agriculture in Poland" **[III.L.1]**. One of the effects of this internship was a report entitled "Agricultural situation in Poland" presenting trends in the most important agricultural sectors in Poland **[II.E.1]**. In 2000, for about 2 months I participated in an internship at the 3rd International Post-Graduate Course on Food Technology at Hebrew University of Jerusalem in Rehovot (Israel) **[III.L.2]**.

In total, during my PhD studies I was the author or co-author of nine publications, including: two scientific publications from category B **[II.D.1; II.D.2]**, one chapter in a monograph in Polish **[II.D.27]**, one scientific report in English **[II.E.1]**, two popular scientific publications **[III.I.1; III.I.2]**, one conference publication in Polish **[II.D.52]** and two in English **[II.D.67; II.D.68]**. I also presented two posters at an international conference **[III.B.3; III.B.4]** and two posters at national conferences **[III.B.1; III.B.2]**.

The course of scientific work after obtaining the PhD degree

After defending my PhD thesis on June 25, 2001, I continued the research issues initiated during the PhD Study. I also undertook scientific work in new areas. In addition to the issues of nutrient and soil organic matter management in organic farming, which I discussed as the main scientific achievement in Section IV, my other scientific activities focused on the following topics:

1. Assessment of the effectiveness of different agricultural systems in biodiversity conservation of selected groups of fauna and flora

There are few publications in literature on the evaluation of the effectiveness of organic farming and the agri-environmental scheme (AES) in biodiversity conservation on farmland in the Central and Eastern European countries. **The knowledge gathered so far and the tools for biodiversity conservation created on its basis have been developed in the conditions of intensive agriculture of Western European countries, which differ significantly from the low-input, fragmented model of agriculture dominating in many parts of Central and Eastern Europe, especially in Poland and Romania.** These issues have been discussed in more detail in a multi-author paper entitled "Harnessing the biodiversity value of Central and Eastern European farmland" **[II.A.2]**.

In order to fill the existing gap, a research in this area was initiated in 2011 within the framework of the project **"Protection of species diversity of valuable natural habitats on agricultural lands on NATURA 2000 areas in the Lublin Voivodeship (KIK/25)" [II.I.3]**, financed from the Swiss-Polish Cooperation Programme **[III.A.4]**. Moreover, in the years 2011-2013, I conducted the research on the effectiveness of agricultural systems with different share of legumes in biodiversity conservation within the **project "Legume-supported cropping systems for Europe" [II.I.2] funded by EU 7th FP [III.A.1]**. In this project I was the coordinator and main contractor of IUNG-PIB. Then, in the years 2014-2016, I coordinated and carried out the research on the impact of various types of agricultural crops on the diversity of selected groups of invertebrates within the statutory activity of IUNG-PIB in the topic entitled **"Assessment of the diversity of selected invertebrates in different types of agricultural crops" [II.I.42]**.

During the implementation of the KIK/25 project three networks of monitoring of biodiversity effects of the AES were created, mainly in Natura 2000 areas. They were used for a detailed assessment of the impact of different agricultural practices on the diversity of plants, spiders, *Orthoptera* insects and birds. The developed networks consisted of special plots located both on arable land and permanent grasslands in the Lublin Voivodeship. Initial results of the project revealed small differences in the species diversity between control plots and plots on which biodiversity conservation oriented AES packages were implemented. Organic farming on arable land supported higher diversity of weeds and *Orthoptera* insects, but no significant differences between the conventional and organic systems were found for the diversity of spiders and birds **[II.D.15; II.D.61; II.B.21]**. The obtained results may **confirm the hypothesis of a significant influence of landscape structure and intensity of crop production in the surroundings of the monitored areas with AES on the species diversity of wild fauna and flora.** The structure of the landscape of the Lublin Voivodeship, which was the background for the research in the KIK/25 project, was characterized by a high fragmentation of agricultural plots and a significant share of non-productive elements such as trees, shrubs, water ponds, etc. On the other hand, the intensity of agricultural production in this region was relatively low as measured by the use of chemical crop protection products and mineral fertilisers.

One of the most important results of the project was the development of a monograph entitled **"Code of Good Agricultural Practices Supporting Biodiversity" [II.D.24]**, of which I was the editor and first author. The impacts of various agricultural practices on arable land, meadows and pastures on flora, spiders, *Carabidaa* beetles, *Orthoptera* insects, bee insects, butterflies and birds were discussed in detail here. A lot of space in the book was devoted to good agricultural practices aimed at conservation of valuable habitats on permanent grasslands. It was also discussed an important topic of effective control of invasive plants. Moreover the book deals with a relatively new and important problem of biomass management from abandoned meadows.

Through another monograph entitled **"Methodology of the development of a system for the monitoring of agri-environmental programme biodiversity results"**, of which I was the editor **[II.D.49]** and co-author of a chapter **[II.D.39]**, the basis for the **implementation of integrated monitoring of biodiversity was created, taking into account various groups of fauna and flora**, as well as for monitoring of the impact of various agricultural practices, including the AES and organic farming on species diversity and the status of natural habitats. The results of the KIK/25 project can serve here as guidelines for the implementation of such measures on a national scale.

The results of the KIK/25 project are particularly important in the context of the work that started in 2017 at the Ministry of Agriculture and Rural Development on a new AES for the years 2021-2027. The monograph prepared in the project titled **"Recommendations for changes in the agri-environmental programme"**, of which I was the editor **[II.D.50]** and co-author of several chapters, is a source of valuable guidelines for the Ministry of Agriculture and Rural Development as to what should be improved in the present and in what direction the work on the new programme should go.

In the years 2011-2013 I conducted the research on the assessment of the effectiveness of agricultural systems with different share of legumes in biodiversity conservation within the framework of the **EU 7th FP project "Legume-supported cropping systems for Europe" [II.I.2]**. In this project I was the coordinator and the main contractor of IUNG-PIB. My own research in the project focused on the assessment of the diversity of weeds and earthworms in different crop production systems, located at the Experimental Station of IUNG-PIB in Osiny. The results of the study showed that the **organic system with 40% share of legumes was characterized by the greatest diversity of weeds, which was on average twice as large as in the integrated (25% share of legumes) and conventional (no legumes) systems**. Moreover, **the largest biomass of earthworms was found in the organic system**, with the largest number of earthworms in the soil under winter wheat and grass-clover mixtures, whereas in the integrated and conventional systems the biomass of earthworms was about 50% lower **[II.D.65]**.

Research within the scope of the IUNG-PIB statutory topic entitled "Assessment of diversity of selected invertebrates in agricultural crops", of which I was the coordinator **[II.I.42]** was conducted in 2014-2016 and their aim was to assess the species diversity and abundance of earthworms, *Orthoptera* insects, spiders, *Carabidae* beetles and invertebrate taxa in arable crops (winter and spring wheat) and in experimental fields with energy crops (willow, *Miscanthus giganteus* and *Sida hermaphrodita*). The research on arable crops was based on a field experiment in which different crop production systems are compared, located in the Experimental Station of IUNG-PIB in Osiny.

The obtained results showed that **there were significantly more taxa in winter wheat in the organic system than in its conventional monoculture [II.D.21]**. **In spring wheat in the organic system there were significantly more spiders than in the integrated and conventional systems and more species than in the conventional fields. In the case of *Carabidae* beetles, no statistically significant differences were found in the number of individuals and their species** in the winter and spring wheat, as well as in the energy crops. **In all types of crops a small number of *Orthoptera* insects was found.** As a result of the conducted research it was found that **the assessed energy crops, especially willow, may create appropriate conditions for development of species-rich agroecosystems, supporting many invertebrate groups, e.g. *Carabidae* beetles, important from the point of view of ecosystem services.** It was also shown that spring cereals were characterized by worse values of diversity indices than winter forms. The results showed that spring wheat cultivated in the organic system, despite the highest number of invertebrates, usually did not maintain high species diversity **[II.D.21; II.E.37]**.

The results obtained in the course of the implementation of the above mentioned projects, the statutory topic and other activities in this area became the basis for the preparation of two scientific publications in category A **[II.A.2; II.A.5]**, four publications in category B **[II.D.15; II.D.18; II.D.19; II.D.21]** and three monographs in Polish **[II.D.23; II.D.24; II.D.25]**. I was also the co-author of one chapter of the monograph in Polish **[II.D.39]**, one chapter of the monograph in English **[II.D.46]**, five conference materials in Polish **[II.D.61; II.D.62; II.D.64; II.D.65; II.D.66]**, four in English **[II.D.77; II.D.78; II.D.79; II.D.80]**, one popular publication **[III.I.5]** and five expert opinions **[III.M.5-III.M.8; III.M.10]**. I presented three posters at international conferences **[III.B.21; III.B.23; III.B.24]** and three at national conferences **[III.B.18; III.B.19; III.B.25]**. I also gave seven lectures at scientific conferences **[II.K.18-II.K.24]** and nine at seminars and workshops **[II.K.30; II.K.47; II.K.53; II.K.60-II.K.62; II.K.64-II.K.66]**. The most important results of the above studies were discussed in detail in four final reports **[II.E.33; II.E.34; II.E.37; II.E.38]**.

An important additional effect of the project were **two PhD theses defended in 2016**, of which **I was the assistant promotor [III.K.1; III.K.2]**.

As a member of the team implementing the above mentioned research topic I received in 2016 the **IUNG-PIB Director's Award for a series of studies on biodiversity conservation, including a monograph entitled "Code of Good Agricultural Practices Supporting Biodiversity" [II.J.3]**, and in 2017 the **Distinction of the Minister of Agriculture and Rural Development** for the achievement entitled "Research on the impact of different agricultural practices on biodiversity and promotion of agricultural systems supporting biodiversity" **[III.D.1]**.

2. Improvement of crop management in organic farming

Research on improvement of management of selected crops in organic farming has been conducted in IUNG-PIB since the mid-1990s. The research concerned such elements as: methods of soil fertility improvement, weed control, optimization of cereal sowing techniques, as well as selection of appropriate cultivars. My scientific activity in this area included research on the evaluation of the suitability of wheat and potato cultivars for organic farming and on methods of soil fertility improvement.

In the case of potato cultivars selection, I conducted the research in the years 1996-1998 in the team headed by prof. Jan Kuś within a project entitled "Development of a model of development and functioning of organic farming" **[II.I.8]** financed by the National Committee for Scientific Research and coordinated by the Logistics Centre of Organic Farming at the

Warsaw University of Life Sciences. The research was conducted on the basis of a special field experiment established in 1994 at the Experimental Station of IUNG in Osiny, whose aim is to compare different crop production systems. Seven potato cultivars (Ania, Irga, Mila, Avalanche, Aster, Sumak, Arkadia) grown in an organic and integrated system were compared. Irrespective of the cultivar, the yield of potato in the organic system, on average for three years of the study, amounted to about 26 t/ha, whereas in the integrated system it was about 35 t/ha. **Lower by ca. 25% yields in the organic system were caused mainly by a significant infestation of leaves by potato blight.** In the organic system, apart from a lower yield, a much lower share of large tubers (with a diameter exceeding 6 cm) and a slightly lower content of starch in comparison to tubers from the integrated system was also found. Early potato cultivars reacted with a lower yield decrease in the organic system compared to cultivars with a longer vegetation period. On the basis of the adopted criteria, it was found that Ania and Irga cultivars were the most useful for organic farming **[II.D.1; II.D.27]**.

In 2003-2006, I conducted the research on the suitability of selected modern and old wheat cultivars for organic farming, as well as on the best criteria for selecting cultivars for this system, as part of my own research project financed by the National Committee for Scientific Research **[II.I.1]**, and in 2002-2004 and 2006-2008, as part of two topics from the statutory activity of the IUNG-PIB on the assessment of the suitability of winter and spring wheat cultivars for organic farming, of which I was also the coordinator **[II.I.32; II.I.36]**.

The research was carried out on the fields of winter and spring wheat in the organic crop production system within the above mentioned special field experiment established in 1994 at the Experimental Station of IUNG in Osiny. Six modern winter wheat cultivars: Kobra, Roma, Korweta, Sukces, Zyta, Mewa and three old cultivars: Ostka Kazimierska, Kujawianka Więcławicka and Wysokolitewka Sztywnosłoma as well as the Schwabenkorn cultivar of spelt wheat were tested. The following modern cultivars of spring wheat were taken into account in the study: Vinjett, Ismena, Koksa, Jasna, Napola, Zebra and Bryza, as well as two old cultivars: Rokicka and Ostka Puławska. The seed of the old cultivars was obtained from the collection of The Plant Breeding and Acclimatization Institute in Radzikowo. The conducted research, among others, included: analysis of the DM accumulation, evaluation of the ability of cultivars to redistribute NPK to grain, evaluation of the NPK nutrient status and uptake of these nutrients from soil, evaluation of competitiveness to weeds, analysis of the Leaf Area Index (LAI), evaluation of stem, root system and leaf infestation by fungal pathogens.

Among the tested winter wheat cultivars, on average for the years 2005-2007, modern **ones, i.e: Zyta - 4.36 t/ha and Roma and Sukces - 4.05 t/ha, were characterized by the biggest and the most stable yields**. **These cultivars yielded about 1.5 t/ha higher than old cultivars.** Among the tested spring wheat cultivars, the highest yields were obtained by elite cultivars Vinjett - 3.23 t/ha and Zebra - 3.13 t/ha. Old spring wheat cultivars yielded at a similar level of about 1.65 t/ha. Zyta, Sukces and Mewa cultivars were the most competitive to weeds. **The majority of the compared winter and spring wheat cultivars showed only a few signs of fungal diseases of the root system and stem base, which was a result of a very favourable crop rotation.** The leaves of Zyta, spelt wheat, Vinjett and Koksa spring wheat cultivars were the least affected by fungal pathogens. **Whereas leaves of old winter and spring wheat cultivars were highly infested by these pathogens.** The results obtained indicate that the **qualitative cultivars Zyta and Sukces, as well as the bearded cultivar Mewa were the most useful for organic farming. Old winter and spring wheat cultivars had low suitability for organic farming due to significantly smaller yields and higher susceptibility to leaf and ear diseases. Spelt wheat, due to its many beneficial characteristics (high competitiveness to weeds, relatively high resistance to disease, etc.), seems to have good perspectives in organic farming. The degree of resistance to fungal diseases, especially of leaves, as well as the ability to effective nutrient uptake from the soil and their productive redistribution to generative parts seem to be an important criterion for the assessment of the suitability of cultivars for the organic system [II.D.11; II.D.13; II.D.29; II.E.4; II.E.13].** The latter criteria and their importance are presented in more detail in the description of one part of my main scientific achievement.

My important scientific activity in this area was also a participation in the years 2004-2018 in implementation of twenty projects concerning cultivar selection for organic farming and improvement of crop management financed from the special subsidy of the Minister of Agriculture and Rural Development for the research in organic farming **[II.I.4; II.I.11-II.I.17; II.I.19-II.I.30]**. In one of them, i.e. in the project "Effective fertilisation in arable crops" carried out in 2011, I was the coordinator **[II.I.4]**.

I conducted the research on the measures of soil fertility improvement in the years 2015-2017 within the project **"Fertility Building Management Measures in Organic Cropping Systems"**, Acronym: FertilCrop **[II.I.5]** within the EU ERA-NET Core Organic+ initiative **[II.I.5]**. In this project, I was the coordinator and main contractor of the IUNG-PIB.

The main objective of the FertilCrop project was to evaluate the existing and to develop new measures to improve soil fertility, mainly in the area of fertilization and soil tillage. Work in the project also included systematization of knowledge on the impact of various practices on arable lands on the dynamics of carbon and nitrogen cycles, in particular on nitrous oxide emissions and nitrates leaching in climatic conditions of Europe, and the development of strategies to reduce nitrogen losses in organic arable crops. An important result of the project was also the development of a database with the results from the IUNG-PIB field experiment comparing different crop production systems located in Osiny. This database was the starting point for FASSET and NDICEA model simulations, especially for generating various scenarios of nitrogen cycles in organic arable crop rotations **[II.E.40]**. As an important part of this activity, a scientific paper entitled **"Simulating soil fertility management effects on crop yield and soil nitrogen dynamics in field trials under organic farming in Europe"**, which I co-authored, was published **[II.A.6]**.

The results obtained in the course of the implementation of the above mentioned projects, the statutory topic and other activities in this area have become the basis for the development of two scientific publications in category A **[II.A.3; II.A.6]** and five publications in category B **[II.D.1; II.D.11; II.D.13; II.D.17; II.D.22]**. I also co-authored two chapters in a monograph in Polish **[II.D.27; II.D.29]**, one chapter in a monograph in English **[II.D.45]**, three conference publications in English **[II.D.74-II.D.76]** and two popular publications **[III.I.4; III.I.6]**. I also presented three posters at international conferences **[III.B.4; III.B.10; III.B.14; III.B.16]**, four posters at national conferences **[III.B.1; III.B.2; III.B.7; III.B.17]**. I also gave three lectures at scientific conferences **[II.K.8; II.K.14; II.K.15]** and six at seminars and workshops **[II.K.31; II.K.36; II.K.38; II.K.43; II.K.44; II.K.58]**. The results of the above studies were discussed in detail in twenty-seven final reports **[II.E.2-II.E.4; II.E.8-II.E.10; II.E.12; II.E.13; II.E.16-II.E.21; II.E.24; II.E.26-II.E.32; II.E.35; II.E.36; II.E.40-II.E.42]**.

As a member of the team implementing the above mentioned issues, **I received two awards of the Minister of Agriculture and Rural Development** for achievements in the field of implementation of progress in agriculture, rural development and agricultural markets. **One in 2006 for the achievement entitled "Developing the scientific basis for organic farming and its promotion and dissemination" [II.J.1]** and the second one **in 2014 for the achievement titled "Evaluation and promotion of the various agricultural production systems" [II.J.2]**.

3. Assessment of the environmental and economic performance of organic farms

In the years 2003-2005, I conducted the research on environmental and economic efficiency of organic farms within the framework of the project **[II.I.10]** financed in two phases from the EU Phare CBC Programme **[III.A.7]**, being a complementary to the international project "Baltic Ecological Recycling Agriculture and Society (acronym: BERAS)", implemented within the framework of the EU INTERREG III B Initiative. The aim of this project was to verify the hypothesis that organic farms implementing the ERA (ecological recycling agriculture) concept are more economically and energetically efficient and emit less biogenic compounds and greenhouse gases than conventional farms. The concept of ERA is based on the principles of organic farming, but includes additional requirements such as a minimum 30% share of legumes in crop rotation, a livestock density of 0.5 to 1 Large Unit/ha and at least 80% self-sufficiency in feed and manure.

The research in the project was conducted in a selected group of organic farms located mainly in the north-eastern part of the Kuyavian-Pomeranian Voivodeship and related to local processors, distributors and consumers of organic food. The scope of research and analyses covered mainly: organizational and production characteristics of farms, evaluation of economic and energy efficiency of agricultural production, nutrient balance and assessment of greenhouse gas emissions. Additionally, consumer attitudes towards organic food and the functioning of local and organic value chains were evaluated.

The results of the conducted research showed that in organic farms there was a systematic improvement of the cropping structure manifesting in a **significant decrease in the share of cereals and at the same time increase of grain legumes, other fodder crops and vegetables**. Moreover, the **level of obtained yields of main crops did not differ from the average for the Kuyavian-Pomeranian Voivodeship**, despite the elimination of synthetic mineral fertilizers and chemical crop protection means. The value of sale in organic farms was significantly affected by **higher (by 10-40%) price of organic products**, especially **large**

price premiums were obtained at the sale of cereals, fruits and vegetables, while **expenditures on the purchase of agricultural means of production were clearly lower than in conventional farms** and therefore small differences in agricultural incomes of the compared farm groups were observed. The research showed that **direct payments and area subsidies for organic farming were the main factor affecting the economic situation of organic farms**. All these subsidies covered in 70% the material and financial outlays on production, and their share in gross final production reached 25%. In the studied organic farms **low energy efficiency of production was found**, because the average value of this indicator was 1.8, with fluctuations from 0.7 in a farm specializing in the production of piglets to 3.7 in a farm specialized in crop production. One of the most important conclusions from the study was that **moderate specialization increased the efficiency of farming**. It was shown that **mixed farms obtained much lower gross final production, direct surplus and personal income in comparison to farms with a clear specialization towards crop or animal production [II.D.28; II.E.5]**.

In the course of the study, nutrient balances were determined for selected organic farms implementing the ERA concept, which allowed to conclude on the potential scale of reduction of nutrient losses from agricultural areas in the Baltic Sea drainage basin. Based on the results obtained, various scenarios of nutrient emission from agricultural areas were developed. In the scenario in which the whole agriculture in the Baltic Sea drainage basin was converted to a system based on the ERA concept, the nitrogen surplus was reduced by approx. 50%, while the surplus P was practically limited to zero **[II.D.12]**.

In the years 2010-2013 I continued my research in this area within the project "Baltic Ecological Recycling Agriculture and Society Implementation", acronym: BERAS Implementation **[III.F.2]**, financed from the Baltic Sea Region Programme 2007-2013 **[III.A.6]**. In this project I was a coordinator and main contractor of IUNG-PIB. The aim of the BERAS Implementation project was to assess the feasibility of implementing ERA-based agricultural systems in the Baltic Sea basin countries. An important result of this project was the preparation of several studies on strategies and plans for conversion of farms to the ERA system, as well as recommendations for sustainable development of farming, especially in the area of linking crop production with animal production **[II.D.40-II.D.43]**.

Moreover, in the years 2005-2010 I coordinated Task 2.3 "Improvement of farm and crop management in organic farming" implemented within the framework of the IUNG-PIB Long-term Programme **[II.I.46]**. Scientific research within this Task included, among others, the identification of the problems of management of selected organic farms in the Kuyavian-Pomeranian Voivodeship and farms in conversion to organic system on the basis of Experimental Station case study in Grabów. The results confirmed the previously presented conclusions that the **economic situation of organic farms was significantly influenced by direct payments and area payments for organic farming**. **Moreover, an increasing role of non-agricultural incomes in maintaining the financial viability of farms was confirmed.** The key problems identified included the **increasing number of stockless farms** resulting from the specialisation of agricultural production, as well as the **poor condition of farm buildings**

and other farm facilities (manure slabs, slurry tanks, etc.) in the part of organic farms with livestock production and in mixed farms **[II.D.36]**.

Task 2.3 and other activities in this area have become the basis for developing one scientific publication from category A **[II.A.1]** and two publications from category B **[II.D.10; II.D.12]**. I was also a co-author of three chapters in monographs in Polish **[II.D.28; II.D.33; II.D.36]**, four chapters in monographs in English **[II.D.40-II.D.43]**, three conference publications in Polish **[II.D.52; II.D.57; II.D.59]**, five in English **[II.D.67; II.D.69; II.D.70; II.D.72; II.D.73]**, two popular publications **[III.I.9; III.I.10]** and one expert opinion **[III.M.3]**. I also presented two posters at international conferences **[III.B.3; III.B.12]** and two at national conferences **[III.B.9; III.B.20]** and gave eight lectures at scientific conferences **[II.K.3; II.K.5-II.I.7; II.K.10; II.K.12 II.K.16; II.K.25]** and six at seminars and workshops **[II.K.33; II.K.37; II.K.46; II.K.51; II.K.57; II.K.59]**. The most important research results were discussed in detail in five reports **[II.E.5; II.E.14; II.E.15; II.E.22; II.E.39]**.

As a member of the team realizing the above mentioned issue I received in 2018 the **Award and Diploma of recognition of the Director General of the National Centre for Agricultural Support** for scientific activity in the field of organic farming and its impact on the environment and active support for the development of the national organic farming **[II.J.4]**.

4. Evaluation of the development of organic farming in Poland and in the world

My research in this area has focused mainly on the assessment of stimulating factors and the identification of barriers to the development of organic farming. As a result of analyses and evaluations, it was found that in Poland there are good potential opportunities for the development of organic farming. **The main factors supporting its development include: a significant number of family farms with large labour force resources, low level of chemical intensity of agricultural production in many regions, as well as low pollution of the environment and soils.** Using a synthetic indicator of the suitability of agricultural areas of gminas for organic production, developed in the IUNG-PIB, two regions characterized by the generally best environmental conditions for the development of this system were distinguished. These are: northern region with Warmian-Masurian, Pomeranian and Kuyavian-Pomeranian Voivodships, and south-eastern region with Lublin and Podkarpackie Voivodships. However the actual distribution of organic farms differs from the results of this assessment and in practice depends primarily on economic and organisational factors.

The dynamic development of organic farming in Poland, stimulated mainly by attractive subsidies for organic land, lasted until 2013. In this year the area of organic land amounted to ca. 670 thousand ha, which constituted ca. 4.5% of the total area of agricultural land. In the years 2014-2018 a decrease in the number of producers was observed, as well as a decrease in the area under organic farming, in total by about 175 thousand ha. Despite this decrease, **a clear increase in the value of the organic food market, as well as the number of processing plants and importers of raw materials and organic products was observed in this period**. In recent years, **an advancing specialization of agricultural production in large**

organic farms has been observed. However, there are still no good mechanisms encouraging small and medium farms to produce organic food for the market.

The analysis of the development of organic farming in Poland, but also in other European countries indicates **a high share of meadows and pastures in the structure of agricultural land use, and in the case of arable land - the dominance of weak and very weak soils. Large differences in the crop productivity between organic and conventional farming on better, more fertile soils** cause that the **attractiveness of the organic system in relation to intensive farming is no longer so high**, which results in a small number of organic farms in such areas.

Analysing the perspectives for the development of organic farming in the world, it is worth noting the hypothesis put forward in recent years of the conventionalization of this agricultural system, i.e. the convergence of organic farming with conventional farming. The authors of this hypothesis emphasize that market mechanisms are universal and act equally on every farm, regardless of the system in which it is run. Partial confirmation of this hypothesis is the advancing land concentration (increasing the area of farms) observed in organic farming, and also mechanization and specialization of agricultural production. Some authors stress, however, that conventionalization is right in the context of organisational and structural changes in organic farming, but to a lesser extent it concerns organic farmers themselves and their motivations.

The results obtained in this area became the basis for one scientific publication from category A **[II.A.4]** and three publications from category B **[II.D.5; II.D.9; II.D.14]**. I was also a co-author of two chapters in a monograph in Polish **[II.D.31; II.D.35;]**, two conference publications in Polish **[II.D.54; II.D.58]**, one popular publication **[III.I.8]**, one expert opinion **[III.M.4]**, as well as an expert report commissioned by the Ministry of Agriculture and Rural Development **[III.M.1]**. I also presented one poster at a national conference **[III.B.15]**, and gave five lectures at scientific conferences **[II.K.1; II.K.2; II.K.4; II.K.9; II.K.13]** and seven at seminars and workshops **[II.K.29; II.K.35; II.K.42; II.K.48; II.K.52; II.K.56; II.K.63]**.

Presentation of training and popularizing achievements, international cooperation and other indicators of scientific achievements

My training and popularizing achievements include **10 publications in popular science journals [III.I.1.1-III.I.10]**, training material, as well as **270 hours of training lectures** for farmers and agricultural advisors, as well as Open Door Days at IUNG-PIB and Science Festivals **[III.I.12-III.I.39]**. My achievements also include the development of one expert report commissioned by the Ministry of Agriculture and Rural Development **[III.M.1]** and nine expert opinions **[III.M.2-III.M.10]**. I also performed six reviews of scientific publications **[III.P.1-III.P.6]** and one review of the report from the national project **[III.O.7]**.

During my scientific activity I gave 25 lectures **[II.K.1-II.K.25]** and presented 25 posters **[III.B.1-III.B.25]** at national and international scientific conferences. I participated in the organization of six international scientific conferences **[III.C.1-III.C.5; III.C.8]** and in the work of scientific committees of four national conferences **[III.C.6; III.C.7; III.C.9; III.C.10]** and one international conference **[III.C.8]**. In addition, in the years 2002-2011, I worked in the Editorial Committee of the *Pamiętnik Puławski* **[III.G.1]**.

From 2012 to 2016, I supervised **two PhD students as assistant promotor [III.K.1; III.K.2].**

For my scientific activity I received **four awards and one distinction [II.J.1-II.J.4; III.D.1]**.

During my scientific activity I completed a total of four scientific internships **[III.L.1-III.L.4]** and participated in three study trips abroad **[III.L.5-III.L.7]**.

My **international cooperation** activity included participation in **three European research programmes (EU FP7, Horizon 2020, ERA-NET)**, in the BSR programme 2007-2013 and in **two bilateral programmes (Polish-Norwegian and Swiss-Polish) [III.A.1-III.A.6]**. Within their framework **I participated or participate <u>in seven projects</u>, <u>in all of them as a project coordinator</u> [II.I.2; II.I.3; II.I.5-II.I.7; III.F.1, III.F.2].**

Within the framework of international cooperation in the years 2003-2019, I actively participated in the **development of 29 international projects [III.Q.1-III.Q.29]** or their parts, including **11 projects under the Horizon 2020 Programme [III.Q.12; III.Q.14; III.Q.15; III.Q.18; III.Q.19; III.Q.21; III.Q.22; III.Q.25; III.Q.27-III.Q.29]**.

Since 2004, I participate or have participated in the work of four expert teams **[III.N.1; III.N.2; III.N.4; III.N.5]**, as well as two project evaluation teams **[III.N.3; III.N.6]** appointed by the European Commission. **Works in the latter two ones allowed me to perform 10 reviews of international projects submitted under the calls of EU FP7 and EU Programme Horizon 2020 [III.O.1-III.O.6; III.O.8-III.O.11].**

Summary of all scientific achievements (including publications listed as the main scientific achievement)

My all scientific achievements, together with publications listed as the main scientific achievement, include **149 publications**, of which **38 are original scientific publications**, of which **7 papers were published in journals with IF**.

I also published **4 monographs in Polish**, **7 chapters in monographs in English, 13 chapters in monographs in Polish**, 14 communications from international conferences and 15 from national conferences. My achievements also include **editing of 5 multi-author monographs**.

Summary Impact Factor for all my original scientific publications: <u>17,433</u>

Number of scores according to the lists of the Ministry of Science and Higher Education for all my original scientific publications: <u>564</u>

Total number of citations:

- according to the Web of Science database: **<u>100</u>**
- according to Scopus database: **<u>109</u>**

Hirsch index:

- according to the Web of Science database: **<u>3</u>**
- according to Scopus database: **<u>4</u>**

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