Polish Journal of Agronomy
2019, 38, 46–51

doi: 10.26114/pja.iung.397.2019.38.06

Biodiversity of the cropping system in Poland's family farms with various production strategies in terms of the requirements of the Common Agricultural Policy

Andrzej Madej

Department of Systems and Economics of Crop Production
Institute of Soil Science and Plant Cultivation – State Research Institute
ul. Czartoryskich 8, 24-100 Puławy, POLAND

Abstract. The structure of cropland adjusted to the specialization of farm production, apart from production and economic functions, may also be an element influencing the maintenance of biodiversity of rural areas.

The paper presents research on the diversity and uniformity of biological cropping patterns in family farms with different production strategies. The three indicators: the number of plant species grown on the farm, Shannon-Wiener index (*H'*) and the Pielou evenness index (*J'*) were used.

The study showed the differences of analyzed indexes. Mixed-production farms with the highest number of cultivated species in the cropping pattern (*H'*=1.80) were the most beneficial in terms of the diversity of crops (8.0). However, together with cattle and dairy farms, they were characterized by the most homogeneous cropping pattern (*J'*=0.89 and *J'*=0.88). On the other hand, the group of grain farms that produced the lowest average number of cultivated crops (4.5) was characterized by the lowest diversity of crop structure (*H'*=1.16) and its lowest uniformity (*J'*=0.83).

Taking into account the assumptions concerning crop diversification, obligatory under the framework of greening, limit values of diversity and uniformity of cropping structure indicators were determined. The comparison of the cropping structure indicators obtained in the study with their limit values showed that the cropping structure in all groups of farms was characterized by much greater diversity and evenness, which resulted in its more beneficial environmental impact.

Key words: cropping system, crop diversity, natural environment, family farms

INTRODUCTION

Depending on the level of farming intensity, agricultural activity may contribute to the maintenance of the biodiversity of the organisms present in the fields (Feledyn-Szewczyk et al., 2016). According to the author, conventional farming with its simplified crop rotation and intensive production leads to the reduction in the biodiversity of organisms. On the other hand, Tyburski (2013) points out that biodiversity in agriculture can be seen on two levels: relating to the diversity of species and varieties of cultivated plants and species and breeds of farm animals; and as the biodiversity of plants and wild animals accompanying agricultural production. Therefore, a structure of cropland adjusted to the specialization of farm production, apart from its production and economic functions, can also be an element affecting the maintenance of biodiversity in rural areas. According to the data of the Central Statistical Office (GUS) (2018), in 1016, these areas occupied more than 93% of the country's area, and thus had a significant impact on the preservation of landscape biodiversity.

The cropping pattern, occurring in the farm, is closely related to the crop rotation applied in the rural holding, considered as one of the methods increasing arable land biodiversity (AL) (Feledyn-Szewczyk et al., 2016). The Common Agricultural Policy (CAP) also introduces measures to enhance biodiversity. One of them is linking direct payments to farmers with compliance with requirements and standards aimed at protecting the rural environment. Initially, this concerned the maintenance of agricultural land in good farming level, by meeting "the cross-compliance" requirements, and from 2015 in the form of the implementation of the so-called "greening" by means of, inter alia, diversification of crops in holdings with more than 10 hectares of arable lands (MRiRW, 2019).

The aim of the study is to determine the degree of diversification of cropping pattern in farms with various production directions and its compliance with the Common Agricultural Policy requirements.

MATERIALS AND METHODS

The material for the study consisted of data from 27 family farms cooperating with IUNG-PIB from the years

Corresponding author:
Andrzej Madej
e-mail: amjan@iung.pulawy.pl
phone: +48 81 4786 809

2015–2017. The farms were located in the following provinces: Lubelskie, Podlaskie and Wielkopolskie. The holdings were characterized by diverse production directions (multidirectional – 2 farms, cattle and dairy – 7 farms, pigs – 4 farms, plants – 14 farms) according to the structure of commercial production. In order to eliminate the variability of results in particular years, the analysis of cropping pattern covering particular plant species was based on the three-year average. To assess its environmental impact, indicators commonly used in agroecological studies were used (Falińska, 2004; Feledyn-Szewczyk, 2016; Jaskulska et al., 2012; Sienkiewicz, 2010). The diversity of cropping system was assessed by means of the Shannon-Wiener index (*H'*) according to the formula below:

$$H' = -\sum_{i=1}^{S}(p_i)(\ln p_i)$$

where p_i is the relation of cultivation area of i-th species to the sum of cultivation area of all species in the cropping system (the sowing area of particular plant species was not given in the paper).

The evenness of the contribution of cultivated area for individual species in the cropping pattern of farms, by means of the Pielou index (*J'*) also was analyzed in the paper. The index reflects the ratio of actual (*H'*) to maximum (H'_{max}) diversity.

$$J' = \frac{H'}{H'_{max}}$$

where $H'_{max} = ln\ S$

S – total number of cultivated species

The value of the *J'* indicator ranges from 0 to 1, where 1 represents the total evenness of the area under cultivation of the respective species.

Furthermore, for the organizational description of the farms purposes, the average data from 3 years (2015–2017) concerning the structure of cropland and land use for groups of holdings with various production orientation were used.

RESULTS AND DISCUSSION

Among the analyzed groups of rural farms, the largest average area of agricultural land (UAA) was recorded in farms with plant production (58.2 ha); (Table 1), which demonstrates that they were more than five times larger than an average farm in Poland, whose area amounted to 10.3 ha UAA in 2018 (GUS, 2019). The smallest average UAA area was characteristic for farms with cattle and dairy cows (26.4 ha). In turn, multidirectional farms were characterized by the largest share of permanent grassland (39.1%) and thus the smallest contribution of arable land (AL). The share of permanent grassland was marginal and the contribution of arable lands slightly exceeded 90% in pig and plant growing farms. Plant production farms were also distinguished by the largest share of permanent plantations (5.2%). It is significant that all types of farms were characterized by a very small share of fallows, amounting to a maximum of 0.9% in plant growing farms. On the other hand, in multidirectional and pig farms their share was not recorded.

The soil quality assessment, applying the conversion hectare index (Harasim, 2006), indicated that multidirectional farms were characterized by poor arable land soils (Table 1). On the other hand, the farms, dealing with cattle and dairy cows as well as pigs and plants farms, managed on medium-heavy soils. However, farms breeding cattle and dairy farms had soils whose quality only slightly exceeded the lower limit of the range for medium soils of 0.8.

Cereals dominated in the cropping system of all groups of farms (Table 2). The lowest contribution of grains was observed in multidirectional farms (53.0%) and in cattle-breeding farms and dairy farm (54.4%). While in the first group of farms, apart from fodder plants (25.6%), potato cultivation (9.9%) and leguminous plants (6.1%) played a significant role in the sowings, in the second group, in addition to cereals, only fodder plants (39.4%) played a considerable and also major role among all farm groups. Rudnicki (2014) in his research on the cropping system in Polish agriculture in the years 2002–2010 indicated on important, multidirectional shifts which, in the national

Table 1. Land use structure and their quality in farms with various specialization (2015-2017).

Farms by production direction	UAA area on the farm [ha]	Share [%]				Soil valuation index of arable land
		arable land	permanent crops	permanent grassland	fallow land	
A – multidirectional	30.41	59.4	1.5	39.1	-	0.76
B – cattle and dairy	26.41	71.4	-	28.3	0.3	0.82
C – pigs	38.03	90.3	-	9.7	-	0.93
D – crop	58.21	91.7	5.2	2.2	0.9	0.95
#Total	44.92	86.9	3.6	9.0	0.6	0.93

weighted averages for total farms

Source: author's calculations

Table 2. The cropping system in farms with various specialization (2015–2017).

Farms by production direction	Cereals [%]	Pulses [%]	Oilseeds [%]	Potatoe [%]	Sugar beets [%]	Feed [%]	Other [%]
A – multidirectional	53.0	6.1	0.9	9.9	0.0	25.6	4.5
B – cattle and dairy	54.4	4.3	1.1	0.6	0.0	39.4	0.2
C – pigs	83.4	2.3	3.8	0.1	0.0	10.4	0.0
D – crop	62.0	6.2	15.7	0.0	10.4	5.6	0.1
#Total	63.5	5.4	11.8	0.5	7.4	11.1	0.3

weighted averages for total farms
Source: author's calculations

perspective, were characterized by decrease in the area of cereals, potatoes and edible legumes stands and by increase in the area of industrial and fodder crops. According to the author, these changes indicate that specialization processes are taking place. In turn, Kęsik (2008) points out that the share of cereals in the sowing structure exceeding 70% in Poland forces the implementation of crop rotations and cereal monocultures having an adverse environmental impact. However, the author considers the decrease in the share of structure-forming plants (perennial papilionaceous plants), as well as leguminous crops grown for seeds or potatoes and other root crops as worrying. The highest share of cereals in the cropping system was characteristic for pig farms (83.4%), where fodder plants also played a greater role (10.4%). On the other hand, in farms specializing in crop production, the share of cereals amounted to 62.0% and was similar to the average contribution for the whole collection of farms. The group of rural holdings focused on commercial plant production was also distinguished by a higher than average share of industrial oilseed crops (15.7%), sugar beet (10.4%), as well as leguminous crops (6.2%) in the cropping system, on a level similar to multi-directional agricultural farms. Wasilewska (2008) conducting an analysis of the cropping pattern in the years 1996–2007 indicates for an over twofold decrease in the area under sugar beet cultivation resulting mainly from a clearly limited demand for sugar in the studied period. The phenomenon mentioned above is unfavourable from the point of view of the correct application of crop rotation, because the field after sugar beet is a very good position for the cultivation of cereals, especially spring wheat. Simultaneously, the author indicates for a gradually increasing area of industrial plant cultivation in the following years, which she considers to be a beneficial process, contributing to greater marketability of farms and diversifying crop rotation.

The value for the indicator of the cropping system diversity including particular groups of farms varied in the years. Its average value ranged from 1.16 in plant production farms to 1.80 in multidirectional farms (Table 3). Likewise, in the study of Matyka (2017) on the diversity of cropping system in terms of voivodships (2017), the highest diversity and evenness index was observed in voivodships where multidirectional plant production dominated.

The average value of the diversity index in own research showed a close relationship with the amount of cultivated plants. In multidirectional farms, where 8 species were grown on average, the diversity index value was the highest. In livestock farms (cattle farms, dairy farms and pig farms), the number of plant species grown on average per year was lower (about 6), which also resulted in a lower value of the cropping system diversity index. In turn, in the farms focused mainly on plant production, the lowest value of the cropping system diversity index was observed, which corresponded to the lowest on average per year number of cultivated plants (4.5). In the survey by Korsak-Adamowicz et al. (2012) conducted in central-eastern Poland, more than 40% of conventional farm owners stated that they were involved in crop rotation farming, few of

Table 3. The cropping system diversity index (*H'*) in family farms with various specialization.

Farms by production direction	Year			Average	Average number of species per farm
	2015	2016	2017		
A – multidirectional	1.71	1.75	1.94	1.80	8.0
B – cattle and dairy	1.48	1.49	1.50	1.49	5.9
C – pigs	1.55	1.70	1.38	1.54	6.3
D – crop	1.15	1.12	1.22	1.16	4.5
#Total	1.34	1.35	1.37	1.35	5.4

weighted averages for total farms
Source: own calculations

which with papilionaceous plants. However, most of them (over 60%) introduce other plants improving soil fertility, e.g. root crops and maize on manure and rape. In turn, some farmers who take into account only cereal plants in the crop rotation, declare the introduction of catch crops.

The limit indicators calculated for farms with an area of more than 10 ha of AL, which meet the requirements of greening, inter alia, through crop diversification were decided to be reference value for the index of cropping system diversity for family farms with various specialization achieved in the study. It is worth mentioning that this is one of the new CAP instruments for obtaining part of area payments in the years 2014–2020 (Ministry of Agriculture and Rural Development, 2019). In the group of farms with an area of 10–30 ha of AL, it requires that at least 2 different crops are grown, with the main crop not occupying more than 75% of AL. The limit value for the cropping system diversity index calculated for such assumptions amounts to 0.56. On the other hand, in the case of farms with an area exceeding 30 ha AL, obliged to run at least 3 (three) different crops, where the main crop cannot occupy more than 75% of the arable land, and 2 (two) crops together cannot occupy more than 95% of the arable land, the cropping system diversity index is 0.69. The implementation of the type of crop rotation system with three different plants, according to the research conducted by Korsak-Adamowicz et al. (2012), is an essential action in the integrated system. The surveyed farmers carry out mentioned above type of crop rotation in the vast majority (90%). Moreover, they declare the cultivation of papilionaceous plants and other plants improving soil fertility while meeting the obligation of species diversity. Whereas Rudnicki (2014) pointed to another CAP tool shaping the cropping pattern, the current in earlier years, which was complementary area payments. However, the author stated that the set of crops covered by payments was very wide, which limited the territorial diversity of this factor.

In the curried out research, the average size of farm was 45 ha UAA in total, including 39 ha AL. Therefore, the limit value for the cropping system diversity index can be assumed to be 0.69, which is almost twice as low as that calculated for total farms participating in the study (1.35). Above proves that the biodiversity of cropping pattern on these farms is higher than that required to meet the conditions for greening through crop diversification. On the other hand, multidirectional farms, cattle-breeding farms and dairy farms had an arable land area in the range from 10 to 30 ha (Table 1), for which the limit diversity index calculated for the cropping system is 0.56. Multidirectional farms, in connection with the production direction, were characterized by the largest number of plant species grown among the examined groups of farms. As a result, they had an index of the biodiversity of the cropping system almost three times higher than the assumed limit value. In multidirectional farms as many as 8 species were cultivated on average, almost twice as many as in plant farms, whereas in cattle-breeding farms and dairy farms the average number of cultivated species was almost 6. In both groups of farms this increased number of cultivated species was significantly influenced by the cultivation of fodder plants on arable land, whose share in the sowing structure was 25.6 and 39.4% respectively. Additionally, in multidirectional farms, potato cultivation played a significant role in the cropping pattern (9.9%).

In pig farms, the average area occupied by the AL exceeded 30 ha, and the index of the diversity of the cropping system was similar to cattle-breeding farms (1.54). Also the number of cultivated plant species was similar (6.3), however, in the sowing structure dominated mainly cereals (83.4%), pulses (10.4%) and oilseeds (3.8%). This quite diverse sowing structure caused that the diversity index was more than twice as high as that resulting from the realization of greening requirements (0.69). In addition, these farms made use of their own fodder resulting from livestock production, which enriched their biological diversity of the sowing structure. In Majewski's study (2010), using the Herfindahl-Hirshman concentration index (HHI), Poland with HHI equal to 0.66 belongs to the group of countries with the highest sowing structure concentration index (characterized by plant groups), mainly due to the high share of cereals. At the same time, according to the author, Polish agriculture is characterized by one of the lowest HHI indices (0.28) for the structure of cereal crops, which is related to the differentiation of soil conditions and a common practice of cereal cultivation (including cereal mixtures specific for Poland) for the production of own concentrated feed in livestock farms. Moreover, the author specifies that farmers most often grow 2–3 different cereal species, appropriately selected for soil conditions.

In turn, the last group of farms (crop farms) was characterized by the lowest value of the cropping system diversity index (1.16). At the same time, these were the largest farms in terms of area, with an average AL area of 53.4 ha. This is understandable in view of the nature of production carried out, involving the sale of agricultural raw materials for further processing. In relation to the adopted limit value of this indicator (0.69), the biodiversity index of the cropping system exceeded it only 1.7 times. Cereals dominated in the structure of sowing, however, their share was similar for the average for the entire population of the farms under study. Moreover, the contribution of oilseeds (15.7%) and industrial plants – sugar beets (10.4%) was significant. Crop farms were also distinguished by the largest share of leguminous plants for seeds (6.2%). While, the average number of plant species grown here was the smallest and amounted to 4.5. Majewski (2010) on the basis of the research indicates that strong simplification of sowing structure, especially cultivation in monoculture, leads to a decrease in soil productivity and causes an increase in yield fluctuations. The author also points out that progres-

Table 4. Cropping system evenness index (*J'*) in family farms with various production.

Farms by production direction	Year			Average
	2015	2016	2017	
A – multidirectional	0.92	0.84	0.90	0.89
B – cattle and dairy	0.86	0.88	0.89	0.88
C – pigs	0.85	0.90	0.84	0.86
D – crop	0.81	0.80	0.87	0.83
#Total	0.84	0.84	0.87	0.85

weighted averages for total farms
Source: author's calculations

sing organizational and economic changes in farms with a simplified cropping pattern irreversibly affect the process of moving away from classic crop rotation management. However, according to the author, negative effects of this process should be limited by avoiding excessive simplifications and using correct rotations of crops, including cultivation of catch crops, promoted by instruments available within the CAP.

Average values of the evenness index ranged from 0.83 to 0.89 – 0.85 on average (Table 4). Their differentiation depending on the direction of commodity production was small. The most uniform was the structure of sowing in multidirectional farms (*J'*=0.89), where the calculated limit value of the evenness index for farms meeting the greening conditions was 0.81 (for farms with 10 to 30 ha of AL), i.e. by 8 percentage points less. Although the number of cultivated plant species was the highest in this group of farms, their cropping pattern was characterized by the highest evenness. This was directly influenced by the share of cultivated species in the sowing structure within a relatively narrow range – from oilseeds (0.9%) to cereals (53.0%).

The degree of evenness of the cropping pattern in crops farms looked different. It took the lowest value (0.83), which in relation to the determined limit value of this index (*J'*=0.63) calculated for farms with more than 30 ha of AL, gave a difference of 20 percentage points. Despite the lowest number of cultivated plants in this group of farms, their uniformity was the lowest. It was influenced by the range of their share in the sowing structure, ranging from 62.0% (cereals) to 0.1% (others).

CONCLUSIONS

1. The research carried out in family farms with various production directions has shown a diversity, both in terms of the biodiversity index of the cropping system and its uniformity. In terms of sowing diversity (*H'*=1.80), multidirectional farms with the highest number of cultivated plants in the structure of sowing (8.0) were the most advantageous. At the same time, together with cattle-breeding and dairy farms, they were characterized by the most uniform sowing structure (*J'*=0.89 and *J'*=0.88 respectively). On the other hand, quite different results were recorded in the group of farms with crop production, with the lowest diversity of sowing structure (*H'*=1.16) and the lowest average number of cultivated plants (4.5). It is also the group of farms with the least evenness of sowing structure (*J'*=0.83).

2. Taking into account the assumptions concerning crop diversification, obligatory under the framework of greening, limit values of diversity and uniformity of cropping structure indicators for farms with 10–30 and more than 30 ha of AL were determined. The comparison of the cropping structure indicators obtained in the study with their limit values showed that the cropping system in all groups of farms was characterized by much greater diversity and uniformity.

REFERENCES

Falińska K., 2004. Ekologia roślin. PWN Warszawa, 512 pp., ISBN 83-01142-22-7.

Feledyn-Szewczyk B., 2016. Bioróżnorodność jako wskaźnik monitorowania stanu środowiska. Studia i Raporty IUNG-PIB, 47 (1): 105-124.

Feledyn-Szewczyk B., Kazimierczak R., Rembiałkowska E., Staniak M., 2016. Bioróżnorodność obszarów wiejskich. Dobre praktyki rolnicze. Fundacja „Ziemia i ludzie", Warszawa, 111 pp., ISBN 978-83-943202-2-5.

GUS, 2018. Obszary wiejskie w Polsce w 2016 r. Warszawa, 199 pp. ISSN 978-83-63285-54-8.

GUS, 2019. Użytkowanie gruntów i powierzchnia zasiewów w 2018 r. Warszawa, 92 pp., ISSN 2353-5180.

Harasim A., 2006. Przewodnik ekonomiczno-rolniczy w zarysie. IUNG-PIB Puławy, 171 pp., ISBN 83-89576-36-8.

Jaskulska I., Osiński G., Jaskulski D., Mądry A., 2012. Diversity of crop cultivars in the farm group covered by the survey in the Kujawy and Pomorze region. Fragmenta Agronomica, 29 (1): 41-48. (in Polish + summary in English)

Kęsik T., 2008. Cropping pattern and its influence on agricultural ecosystem. Zeszyty Problemowe Postępów Nauk Rolniczych, 527: 39-50. (in Polish + summary in English)

Korsak-Adamowicz M., Dobka D., Płotczyk B., 2012. Running farms in different systems and its effect on the environment. Fragmenta Agronomica, 29(2): 77-86. (in Polish + summary in English)

Majewski E., 2010. Selected production, economic and environmental aspects of crop rotations. Roczniki Nauk Rolniczych, G, 97, 3: 159-169. (in Polish + summary in English)

Matyka M., 2017. Evaluation of regional diversification in sown area structure in the context of impact on the natural environment. Roczniki Naukowe SERiA, Warszawa-Poznań-Bydgoszcz, XIX, 3: 188-192. doi: 10.5604/01.3001.0010.3245. (in Polish + summary in English)

MRiRW, 2019. Materiał informacyjny dotyczący płatności z tytułu praktyk rolniczych korzystnych dla klimatu i środowiska (zazielenienie). Warszawa, 47 pp.

Rudnicki R., 2014. Crop structure transformations in Polish agriculture in conditions imposed by Common Agricultural Poli-

cy instruments (2002-2010). pp. 98-128. In: Polityka spójności UE a rozwój obszarów wiejskich: stare problemy i nowe wyzwania; Kamińska W., Heffner K., Studia KPZK PAN, t. CLVI, Warszawa.

Sienkiewicz J., 2010. Concepts of biodiversity – their dimensions and measures in the light of literature. Ochrona Środowiska i Zasobów Naturalnych, 45: 7-29. (in Polish + summary in English)

Tyburski J., 2013. Dzika bioróżnorodność ekosystemów rolnych i metody jej ochrony. pp. 279-291. In: Biologiczna różnorodność ekosystemów rolnych oraz możliwości jej ochrony w gospodarstwach ekologicznych; Tyburski J., Kostrzewska M.K., UWM Olsztyn.

Wasilewska E., 2008. Changes in the structure of sown area in Poland in the years 1996-2007. Zeszyty Naukowe SGGW – Ekonomika i Organizacja Gospodarki Żywnościowej, Warszawa, 71: 123-135. (in Polish + summary in English)

Author	ORCID
Andrzej Madej	0000-0002-3369-1077

received – 13 September 2019
revised – 5 November 2019
accepted – 7 November 2019