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# Diversity of crop species in various types of farms

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**Abstract.** The paper presents the diversity of crop species that were grown in cattle and pig-raising farms, in mixed crop-livestock farms and in field-crop farms (with no livestock). The aim of the study was to access the effect of farm type on crop diversity. The data was collected in 2016–2018 in 48 farms located in the macroregion of Mazovia and Podlasie. Information on farms and crops on arable lands was obtained using a research questionnaire. It was found that the indicators of crop species diversity depended on the type of farm. The cattle farms had a large share of permanent grasslands in the structure of UAA and a large diversity of crop species. The crop structure of pig farms was dominated by cereals (80%), which significantly affected the species diversity of crops. Crop farms had low diversity of crop species on arable land. Species diversity in mixed farms reached intermediate values between those found in cattle and crop farms.

**Keywords:** types of farms, diversity indicators, crops on arable land

## INTRODUCTION

As commonly understood, biodiversity means diversity, abundance and changes in the composition of plant and animal species in a given area (Jaskulski, Jaskulska, 2006). According to Andrzejewski and Weigle (2003), biological diversity denotes the intraspecific variability (the richness of the gene pool) of all living populations, interspecific diversity (species diversity) and supra-specific diversity, i.e. that of ecosystems and landscapes. Biodiversity is a fairly complex concept and can be considered at various spatial scales and at various levels. Therefore, biodiversity in agriculture can be analysed and assessed at spatial scales: country, region, farm and arable field (Feledyn-Szewczyk, 2014). It is most often perceived at three levels: genetic, species and ecosystem level (Sienkiewicz, 2010; Feledyn-Szewczyk, 2016; Staniak, Feledyn-Szewczyk, 2016).

Biodiversity in a given area can be assessed on the basis of various indicators. The most commonly used measure of biodiversity in a given area is the number of plant species (Duelli, Obrist, 2003; Trzcińska-Tacik, 2003; Falińska, 2004; Piernik, 2012). A more objective measure includes the indicators taking into account the number of plant species and their richness in the community, i.e. the Shannon diversity index and Simpson dominance index (Shannon, 1948; Simpson, 1949) and the similarity index defined as the Sorensen index (Magurran, 1988; Zanin et al., 1997). Moreover, other indicators are used, such as: the share of permanent grassland, fallow and wasteland, as well as ecological space in the structure of agricultural land (Lankoski, Ollikainen, 2003; Pajewski, 2017).

Diversity plays an important role in maintaining a high level of agroecosystem productivity, soil fertility and soil protection by plants (Harasim, 2014). On the other hand, specialisation, concentration and intensification of agricultural production (crops and livestock) limits the number of crop plants on arable land, leading in many cases to single-crop farming and landscape monotony (Koc et al., 1994; Kęsik, 2008; Feledyn-Szewczyk, 2014; Matyka, 2017; Harasim, 2018).

Land use is of particular importance in the human-environment relationship. According to Gołębiewska et al. (2016) one of the most important factors affecting the agroecosystem biodiversity is the method of the agricultural management and land use. The structure of agricultural land may provide information on the biological diversity of areas used for farming (Matyka, 2017; Pajewski, 2017). Agricultural production space consists of agricultural land, which is made up of arable land (used and periodically not used for farming), permanent grassland and permanent plantations (orchards, fruit shrubs, hop plantations, etc.). An important element of the agricultural land structure is arable land, on which biodiversity is to a significant extent

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shaped by farmers, who decide on the structure of sown area adapted to the needs of livestock and commodity crop production. This biodiversity refers to the diversity of species and varietal structure of crops on arable land. It should be noted that important elements as far as agroecosystem biodiversity is concerned are crop plants, in particular the richness of crop species and varieties in sown area (Altieri, 1999; Jaskulski et al., 2006; Kęsik, 2008; Jaskulska et al., 2012).

The aim of the research was to assess the impact of farm type on the crop species diversity on arable land.

## MATERIALS AND METHODS

The research was carried out in the years 2016–2018 in 48 farms located in the macroregions of Mazovia and Podlasie, identified according to the FADN classification (Goraj et al., 2009), in three voivodeships – Lubelskie, Mazowieckie and Podlaskie. The sample selection was purposeful, taking into account commercial farms constituting the main source of income for the farming family, diverse in terms of specialisation. Four farm types have been identified:

– cattle farms that specialise in milk production;
– pig farms that specialise in pig fattening;
– mixed farms that specialise in crops and livestock production;
– crop farms, without livestock production.

The surveyed farms cooperate with the Agricultural Advisory Centres in Końskowola, Radom and Szepietów as well as with the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy. Information on farms and sown area of crops cultivated on arable land was obtained through the survey method, with the use of a research questionnaire. A comparative and descriptive method was used to interpret the obtained results.

The diversity of crops was assessed on the basis of three indicators: the number of crop species, the share of cereals in sown area and the dominance index of crop species. The dominance index of crop species (SI) was calculated according to the Simpson's index modified by Jaskulski et al. (2006):

$$SI = \sum \left(\frac{n}{N}\right)^2$$

where:
n – sown area of the crop species (ha),
N – total sown area of arable land (ha).

The value of this index ranges between 0 and 1. Values close to 1 indicate a clear dominance of one or several crop species and at the same time indicate a low diversity of crop species. Relations between the values of the dominance index of crop species on arable lands and the number of crop species and the share of cereals in sown area was assessed on the basis of correlation and regression. Relations were assessed at the significance level $\alpha = 0{,}05$, and statistically significant relationships between the variables were described with the use of regression equations. In the correlation assessment, the following scale of correlation between two variables ($r_{xy}$) was adopted, according to Komosa and Musiałkiewicz (1996):

| Correlation strenght | weak | average | substantial | high | very high |
|---|---|---|---|---|---|
| Correlation level | $0<r<0.3$ | $0.3\leq r<0.5$ | $0.5\leq r<0.7$ | $0.7\leq r<0.9$ | $0.9\leq r=1.0$ |

## RESULTS AND DISCUSSION

The surveyed farms which specialised in different production differed in terms of the size of agricultural land, arable land and permanent grassland (Table 1). Crop farms (with no livestock) and pig farms were characterised by a larger area of agricultural land and arable land than cattle farms and mixed farms. The group of farms that specialised in milk production was characterised by a large share of permanent grassland (26.9% of UAA). It should be noted that the large share of permanent grassland in farms limits the possibility of choosing the specialisation of agricultural production. Raising of ruminant animals, mainly dairy cattle, is naturally associated with meadows and permanent pastures (Harasim, Matyka, 2009).

Table 1. Characteristic of the studied agricultural farm (mean from 2016-2018).

| Farm type | Number of farms | Area [ha] | | | Share of grasslands in UAA [%] |
|---|---|---|---|---|---|
| | | UAA | AL | PG | |
| Cattle | 13 | 27.9 | 20.4 | 7.5 | 26.9 |
| Pigs | 11 | 43.6 | 41.9 | 1.7 | 3.9 |
| Mixed | 11 | 29.0 | 25.7 | 3.3 | 11.4 |
| Crops | 13 | 51.3 | 49.4 | 1.9 | 3.7 |

UAA – agricultural land, AL– arable land, PG – permanent grassland

The structure of sown area on arable land was considerably different in the compared farm types (Table 2). Cattle farms that specialised in milk production, with a 53% share of cereals in sown area, had a high percentage of cereal mixture and maize (22.0% each). Multi-annual forage crop mixtures (20.9%) had a similar share in sown area, and among them papilionaceous-grass mixtures (13.6%). Maize and multi-annual papilionaceous-grass mixtures supplemented the feed base, with permanent grassland as the main element. In particular, large share of these two groups of forage crops was present on farms located on weaker soils in the Podlaskie voivodeship. The research conducted by Harasim and Madej (2008) showed that in case of cattle farms the share of livestock production in commodity agri-

Table 2. Cropping system (%) in agricultural farm (mean from 2016–2018).

| Crops | Farm type | | | |
|---|---|---|---|---|
| | cattle | pigs | mixed | crops |
| Cereals* | 52.6 | 79.8 | 64.2 | 55.2 |
| – including the mixture of cereals | 22.0 | 8.2 | 5.2 | 2.4 |
| Maize | 22.0 | 6.9 | 5.2 | 4.2 |
| The other cereals (buckwheat, millet) | 0.3 | - | - | 6.4 |
| Sugar beet | - | 1.9 | 7.0 | 9.8 |
| Potato | 0.7 | 0.2 | 2.0 | 0.7 |
| Field-grown vegetables | 0.1 | - | 0.5 | 1.7 |
| Winter oilseed rape | 0.7 | 6.3 | 7.0 | 12.4 |
| Pulses for seeds | 1.3 | 4.7 | 2.9 | 7.6 |
| Pulse-cereal mixtures | 1.4 | - | 1.2 | 0.2 |
| Perennial legumes (clover, alfalfa) | 0.8 | - | 1.1 | 0.4 |
| Legume-cereal mixtures | 13.6 | - | 3.2 | - |
| Grass mixtures and grasses | 6.5 | 0.2 | 5.3 | 1.4 |

* together with mixture of cereals

cultural production increased along with the percentage of permanent grassland. Moreover, it was found that a large share of permanent grassland in the structure of agricultural land contributed to an increased share of forage crops in sown area in arable lands (Harasim, Matyka, 2009).

The basic cereals (79.8%) dominated in the structure of sown area of the surveyed pig farms; (Table 2). In the remaining part of arable land, maize grown for seeds and winter oilseed rape had a significant share. Cereal mixtures and maize were grown mainly in the Podlasie region, and oilseed rape in the Lublin voivodeship. On farms with a mixed crop-livestock production, cereal crops prevailed (64.2%), and they were complemented by the cultivation of many other plants. Worth mentioning is the significant share of sugar beet and winter oilseed rape in sown area (7.0% each), especially in case of farms located in the Lublin region. In the structure of sown area of crop farms (with no livestock), cereals covered slightly over 55% of the arable land (Table 2). Among the remaining crops, the following had a significant share in sown area: winter oilseed rape (12.4%), sugar beet (9.8%), leguminous crops grown for seeds (7.6%) and other cereals (6.4%). Sown area of the above-mentioned crops varied regionally; oilseed rape and sugar beet were most often cultivated in the Lublin region, buckwheat and leguminous crops were cultivated in Podlasie, while leguminous crops, millet and ground vegetables were cultivated in Mazovia region. Among leguminous crops, field beans, peas, soybean, lupins and serradella were most often grown for seeds. In case of ground vegetables, beetroot, cauliflower, cabbage, carrot and cucumber were quite commonly cultivated.

From the point of view of crop biodiversity, mixed sowing plays an important role. In case of cattle farms, as well as of mixed farms (but to a lesser extent) annual mixtures had a significant share in sown area (cereal, legume-cereal mixtures) and multi-annual (legume-grass mixtures, grass mixtures) (Table 2). According to Jaskulski and Jaskulska (2006), as a result of mixed sowing, a greater genetic diversity of croplands was obtained. Hence, intergeneric and interspecific mixtures, as well as inter-variety mixtures, are important elements of biodiversity of crops on arable land. Diversified crop rotation, the use of mixed sowing and the cultivation of catch crops are among agricultural practices with a beneficial effect on the diversity of flora on arable land (Stalenga et al., 2016).

Indicators of crop species diversity in relation to farm types and years in which research was conducted are presented in Table 3. The number of crop species cultivated on arable land clearly depended on the type of farm, i.e. its specialisation. On average, most of crop species were cultivated on cattle farms (7–8 species), less on mixed and pig farms, and the smallest number of crop species (4–5 species) was cultivated on crop farms. Cattle, pig and mixed farms make their crops on arable land dependent to a large extent on the needs of livestock production (feed production), the remaining area is intended for the cultivation of commodity crops. Therefore, a greater number of crop species was found on these farms than on crop farms (with no livestock). Other research also indicates a large diversity of crops cultivated on cattle farms (Harasim, 2018). Farms that specialise only in crop production strive to limit the number of crop species to the most profitable crops. The diversity of the number of crop species through the years turned out to be relatively low, because in 2016 this diversity index amounted to slightly over 6 species on average, and in the next two years it reached the level of 6 crop species.

The share of basic cereals in sown area showed a greater dependence on the farm type than on the years when the research was conducted (Table 3). Most cereals (approx. 80% of sown area), with low diversity through the years, were cultivated on pig farms. Smaller share of cereals in sown area (on average approx. 64%), with higher diversity (58–69%) through the years was cultivated on mixed farms. In case of cattle and crop farms the share of cereal cultivation was the lowest, with a diversity of 49–60% through the years. The highest share of cereal production was in 2018 (approx. 66%), and the lowest in 2017 (60%); (Table 3). The diversity of cereal cultivation area through the years, in some cases, was associated with resowing of arable land when (due to freezing or drought) other crops species were damaged. The share of cereals in sown area structure determines the correctness of crop rotation and the degree of agrocenose biodiversity. According to Jaskulska et al. (2012) a large share of cereals in sown area structure limits biodiversity in agroecosystems, so the introduction of different varieties can be one of the ways to reduce the negative effects of cereal monocultures.

Changes concerning sown area for crops assessed in a farm over a longer period of time may be associated with production reprofiling. Research conducted by Harasim (2012) showed that on a farm with diverse crop and livestock production, crops on arable land of good quality were characterised by a large diversity (7–11 species), while after the elimination of livestock production (due to its unprofitability) there was a reduction of crops to 3–4 species with a large share of cereals. It should be added that, according to the Code of Good Agricultural Practice (Duer et al., 2002), rational crop rotation should include 3–4 species on light soils and 4-5 species on heavier soils.

Table 3. Indexes of species diversity of crops on arable lands.

| Farm type | Year | | | |
|---|---|---|---|---|
| | 2016 | 2017 | 2018 | mean |
| Number of crop species | | | | |
| Cattle | 7.2 | 7.3 | 8.0 | 7.5 |
| Pigs | 6.2 | 5.3 | 5.4 | 5.6 |
| Mixed | 7.2 | 6.7 | 6.6 | 6.8 |
| Crops | 4.9 | 4.6 | 4.1 | 4.5 |
| Mean | 6.4 | 6.0 | 6.0 | - |
| Share of cereals in sown area [% AL] | | | | |
| Cattle | 49.1 | 52.8 | 55.9 | 52.6 |
| Pigs | 79.5 | 80.4 | 79.4 | 79.8 |
| Mixed | 66.2 | 57.8 | 68.6 | 64.2 |
| Crops | 56.8 | 49.5 | 59.2 | 55.2 |
| Mean | 62.9 | 60.1 | 65.8 | - |
| Dominance index (SI) | | | | |
| Cattle | 0.250 | 0.268 | 0.234 | 0.251 |
| Pigs | 0.280 | 0.282 | 0.280 | 0.281 |
| Mixed | 0.238 | 0.283 | 0.290 | 0.270 |
| Crops | 0.334 | 0.338 | 0.363 | 0.345 |
| Mean | 0.276 | 0.293 | 0.292 | - |

The share of cereals on crop farms depends to a large extent on the scale of their production, specialised machinery and labour resources. In case of larger farms with small labour resources, cereal cultivation is rather concentrated, while in case of small farms with significant labour resources more labour-intensive and at the same time profitable plants are cultivated, e.g. ground vegetables, fruit shrubs, and berries. Some farms mainly engaged in the cultivation of vegetables also carry out their processing and preservation (pickled cabbage and cucumbers). In the first case, the number of crop species (mainly cereals) cultivated on the farm is small, and in the second, much higher. In the group of surveyed crop farms there were also a few cases with a small or large number of crop species.

The diversified structure of sown area occurs both in case of farms and voivodeships equated with regions of the country (NUTS-2 level). Research conducted by Matyka (2017) indicated that the following three voivodeships were characterised by the least diverse and even crop structure: Opolskie, Dolnośląskie and Podlaskie. On the other hand, beneficial structure of sown area, both in terms of biodiversity and environment, occurs in the following five voivodeships: Lubelskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie and Lubuskie.

Diversity of crops is more fully characterised by the species dominance index, calculated on the basis of the number of crop species and their share in sown area. Its scope depended more on the farm type than the year in which the research was conducted (Table 3). The highest dominance index of crop species (0.345) was found in the group of crop farms (with no livestock), and the lowest (0.251) was found in case of cattle farms that specialised in dairy production. Intermediate values (0.281 and 0.270) were achieved by the index referring to pig and mixed farms. Diversity of the dominance index of crop species through the years was low.

Research has shown that the dominance index of crop species was significantly negatively correlated with the number of crop species cultivated on arable land (Table 4). The level of this correlation was high in case of cattle and crop farms ($r = -0.81$ and $-0.80$), while the correlation for groups of pigs and mixed farms was substantial ($r = -0.51$). Thus, the increase in the number of crop species cultivated on arable land significantly reduced the level of dominance index of crop species. In the group of pig farms, the dominance index was considered moderately correlated (but positively) with the share of cereals in sown area ($r = 0,49$), and there was also a significant negative correlation between the number of crop species and the share of cereals in sown area ($r = -0.38$). According to the research conducted by Harasim (2012), the dominance index of crop species in

Table 4. Relationship between indices of dominance of crop species (Y), number of species on arable land ($x_1$) and the share of cereals in sown area ($x_2$).

| | Cattle farms (n = 39) | | Piges farms (n = 33) | |
|---|---|---|---|---|
| variable | $x_1$ | $x_2$ | $x_1$ | $x_2$ |
| Y | -0.81* | 0.14 | -0.51* | 0.49* |
| $x_1$ | | -0.04 | | -0.38* |
| | Mixed farms (n = 33) | | Crops farms (n = 39) | |
| variable | $x_1$ | $x_2$ | $x_1$ | $x_2$ |
| Y | -0.51* | 0.17 | -0.80* | 0.16 |
| $x_1$ | | -0.16 | | -0.11 |

* correlation significant at $\alpha = 0.05$

Table 5. Equations of regression of dependence of species dominance of crops (Y) on number of crops species ($x_1$) and the share of cereals in crop structure ($x_2$).

| Farm type | Regression equation | Coefficient | |
|---|---|---|---|
| | | correlation (r) | determination ($R^2$) |
| Cattle | $Y = 0.486 – 0.031\ x_1$ | 0.81 | 0.66 |
| Piges | $Y = 0.254 – 0.021\ x_1 + 0.001\ x_2$ | 0.60 | 0.36 |
| Mixed | $Y = 0.398 – 0.019\ x_1$ | 0.51 | 0.26 |
| Crops | $Y = 0.557 – 0.047\ x_1$ | 0.80 | 0.64 |

farms was also highly negatively correlated with the number of crop species cultivated on arable land (r = - 0.84).

Analysis of multiple regression shows that the dominance index of crop species in the examined farm types was significantly negative affected by the number of crops cultivated on arable land. In case of pig farms it was positively related to the share of cereals in sown area (Table 4). Variability of index was determinated by that traits to a greater extent in case of cattle and crop farms (66 and 64%, respectively), and to a much smaller extent in case of pig and mixed farms (36 and 26%) (Table 5). The results of analysis of correlation and regression indicated that on farms that specialised in pig fattening the share of cereals in sown area was bigger.

Based on the regression equation (Table 5), it can be estimated how the number of plant species cultivated on arable land affects the change in the crop dominance index. An increased number of plant species resulted in a decreased value of dominance index. The value of the dominance index (Table 3) in crop farms corresponded to the dominance of 4–5 species of cultivated crops while in other types of farms it corresponded to 5–8 species of crops.

## CONCLUSIONS

1. Indicators of crop species diversity depended more on the farm type than the years when the research was conducted. Each farm type was distinguished by specific features.

2. Pig and crop farms were characterised by a larger area of agricultural land and arable land than cattle farms and mixed farms.

3. Cattle farms were distinguished by a large share of permanent grassland in the structure of agricultural land and a fairly large diversity of crop species, which is confirmed by a large number of plant species cultivated on arable land and a low value of dominance index of crop species.

4. The structure of sown area for pig farms was dominated by cereals (80%), which significantly influenced the diversity of crop species.

5. Crop farms (with no livestock) were characterised by a low diversity of crop species, which is associated with a small number of crop species and a fairly high value of the dominance index of crop species on arable land.

6. Indicators of crop species diversity on mixed farms reached intermediate values between those found in case of cattle and crop farms.

7. The set of indicators used can be considered as useful to assess the diversity of crop species on farms.

## REFERENCES

**Altieri M.A., 1999.** The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment, 74: 19-31, doi: 10.1016/S0167-8809(99)00028-6.

**Andrzejewski R., Weigle A., 2003.** Różnorodność biologiczna Polski. Narodowa Fundacja Ochrony Środowiska, Warszawa, 284 ss.

**Duelli P., Obrist M.K., 2003.** Biodiversity indicators: the choice of values and measures. Agriculture, Ecosystems and Environment, 98(1-3): 87-98, doi: 10.1016/S0167-8809(03)00072-0.

**Duer I., Fotyma M., Madej A.** (red.)**, 2002.** Kodeks dobrej praktyki rolniczej. MRiRW – MŚ, Warszawa, 93 ss.

**Falińska K., 2004**. Ekologia roślin. Wyd. PWN Warszawa, 453 pp.

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

**Feledyn-Szewczyk B., 2014.** Bioróżnorodność roślin jako element zrównoważonego rozwoju rolnictwa. Studia i Raporty IUNG-PIB, 40(14): 163-177.

**Gołębiewska B., Chlebicka A., Maciejczak M., 2016.** Rolnictwo a środowisko. Bioróżnorodność i innowacje środowiskowe w rozwoju rolnictwa. SGGW Warszawa, 123 ss.

**Goraj L., Malanowska B., Osuch D., Sierański W., 2009.** Opis realizacji planu wyboru próby gospodarstw rolnych dla Polskiego FADN w 2009 roku. IERiGŻ-PIB Warszawa, 18 ss.

**Harasim A., 2012.** Crop production on arable lands: a long term single-farm case study. Monografie i Rozprawy Naukowe, IUNG-PIB Puławy, 34, 63 pp. (in Polish)

**Harasim A., 2018.** Environmental Consequences of Specialization of Farms. Roczniki Naukowe SERiA, 20(2): 65-71. (in Polish)

**Harasim A., 2014.** Przewodnik do oceny zrównoważenia rolnictwa na różnych poziomach zarządzania. IUNG-PIB Puławy, 91 ss.

**Harasim A.**, **Madej A., 2008.** Evaluation of sustainable development of cattle farms with varied percentage of grasslands. Roczniki Nauk Rolniczych, Seria G, 95(2): 28-38. (in Polish)

**Harasim A., Matyka M., 2009.** Regionalne zróżnicowanie trwałych użytków zielonych a wybrane wskaźniki rolnictwa w Polsce. Studia i Raporty IUNG-PIB, 15: 59-69.

**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)

**Jaskulski D., Jaskulska I., 2006**. Bioróżnorodność agroekosystemów i krajobrazu rolniczego a polowa produkcja roślinna. Postępy Nauk Rolniczych, 4: 43-53.

**Jaskulski D., Jaskulska I., Rudnicki F., 2006.** Cultivar diversity of cereals seed and production plantations. Fragmenta Agronomica, 4(92): 94-102. (in Polish)

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

**Koc J., Brodziński Z., Gotkiewicz W., 1994.** Wpływ agrotechnologii na bioróżnorodność. pp. 141-150. In: Doradztwo w ekorozwoju obszarów wiejskich (red. A. Mickiewicz i A. Lewczuk), Wyd. AR Szczecin.

**Komosa A., Musiałkiewicz J., 1996.** Statystyka. Wyd. Ekonomik, Warszawa, 184 pp.

**Lankoski J., Ollikainen M., 2003.** Agri-environmental externalities: a framework for designing targeted policies. European Review of Agricultural Economics, 30(1): 51-75, doi: 10.1093/erae/30.1.51.

**Magurran A.E., 1988**. Ecological diversity and its measurement. Princeton University Press, New Jersey, 179 pp.

**Matyka M., 2017.** Evaluation of regional diversification in sown area structure in the context of impact on the natural environment. Roczniki Naukowe SERiA, 19(3): 88-192. (in Polish)

**Pajewski T., 2017.** Structure of agricultural land as an agricultural component of biodiversity. Roczniki Naukowe SERiA, 19(2): 182-187. (in Polish)

**Piernik A., 2012.** Zastosowanie metod numerycznych w ekologii. UMK Toruń, 113 pp.

**Shannon C.E., 1948.** A mathematical theory of communication. Bell System Technical Journal, 27(3): 379-423.

**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)

**Simpson E.H., 1949.** Measurement of diversity. Nature, 163(4148), 688, doi.org/10.1038/163688a0.

**Stalenga J., Brzezińska K., Stańska M., Błaszkowska B., Czekała W. et al., 2016.** Kodeks dobrych praktyk rolniczych sprzyjających bioróżnorodności. Monografia. Wyd. II popr., IUNG-PIB Puławy, 292 pp.

**Staniak M., Feledyn-Szewczyk B., 2016.** Bioróżnorodność obszarów wiejskich – znaczenie i zagrożenia. Fundacja „Ziemia i ludzie", Warszawa, 112 pp.

**Trzcińska-Tacik H., 2003.** Importance of field weeds species diversity. Pamiętnik Puławski, 134: 253-262. (in Polish)

**Zanin G., Otto S., Riello L., Borin M., 1997.** Ecological interpretation of weed flora dynamics under different tillage systems. Agriculture, Ecosystems and Environment, 66: 177-188, doi: 10.1016/S0167-8809(97)00081-9.

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