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AN ANALYSIS OF BIODIVERSITY OF LITHUANIAN FAMILY FARMS

Vida DABKIENĖ

Lithuanian Institute of Agrarian Economics, LAEI, V. Kudirkos st. 18–2, 03105, Vilnius, Lithuania, Phone: +370 5 262 2429, Email: vida@laei.lt

Corresponding author: vida@laei.lt

Abstract

The paper aimed to measure the biodiversity of Lithuanian family farms using readily available FADN data. The research draws on a sample of 1304 family farms. Farms diversity is expressed by diversity in land use and cropping based on Shannon's equitability and Simpson's diversity indices. The effects of farms' management to biodiversity between farms in terms of specialization, economic size, farming intensity and land area are examined. The biodiversity indices ranged from 0 to 1 (scaled into three intervals), assuming that the closer to 1 were the values of the index the higher was biodiversity of the farm. Lithuanian case analysis suggested that certain measures for strengthening farms biodiversity were necessary as the average values of the biodiversity based on Shannon's equitability (land use and cropping) and Simpson's diversity (land use and cropping) indices fell within the medium biodiversity interval. Lower diversity values of Simpson's diversity in comparison to Shannon's indices values were obtained across analysed farming types and farm classes. This is likely related to Simpson's index sensitivity to the number of land use and cropping elements of farms. Though, the Shannon's equitability index has greater importance to rarer land use or cropping elements. Therefore, for policy purposes both indicators provide valuable insights to enhance and maintain the biodiversity on farms.

Key words**:** *biodiversity, FADN, Shannon equitability index, Simpson diversity index*

INTRODUCTION

Maintaining biodiversity is one of the key issues of sustainable development [1] and agricultural intensification is one of the main drivers of worldwide biodiversity decline [1, 3, 12]. The biodiversity is important issue in the EU since the Rio de Janeiro summit in 1992. The protection of biodiversity is legislated in the Birds and the Habitats Directives and the EU Biodiversity Strategy, entitled "Our life insurance, our natural capital: an EU biodiversity strategy in 2020". Also the environmental objectives have become increasingly integrated into the EU's Common Agricultural Policy [15]. The European agricultural policy stimulates organic farming, projects associated with environmentally friendly investment and innovation measures through rural development programmes. For the period of 2014–2020, the CAP recommends that 30% of direct payments to be linked to environmentally-friendly farming practices as, crop diversification, maintaining permanent grassland and conserving 5%, and later 7%, of areas of ecological interest [2, 15]. To determine the extent to which such policy objectives are being fulfilled and to enhance biodiversity in arable land the operational assessment tools for stakeholders are required [6, 9]. However, the complexity of all the aspects of the term biodiversity presented by Kaennel [11] demonstrated that no single tool to evaluate biodiversity can be devised. Bockstaller et al. [1], Clergue et al. [3] provided an overview of biodiversity assessment tools in agricultural areas. Herzog et al. [9] emphasised the importance of farm-scale measurement. Large number of studies has been done to evaluate and compare biodiversity results at a farm level [9, 10, 13, 23, et al.]. The biodiversity is a central element of sustainable agricultural development. Therefore, usually the biodiversity is analysed as one of the component of environmental sustainability in farm sustainability research [7, 8, 20, 22, 24, et al.]. As pointed out by Clergue et al. [3], assessment tools must be easily usable in order to be generalised for other case studies and to help decision-makers involved with land-use management. Besides, tools must be

useful to communicate with farmers and encourage them to adopt practices maintaining biodiversity at farms. In response to these issues, the biodiversity assessment mostly relied on simple indicators (e. g percentage of area cropped in organic farming, average number of crops per farm, percentage of area cropped intensively) and composite indices (Shannon's index, Simpson's index) in farms sustainability scientific research.

As stressed Diazabakana et al. [5], data gathering for the calculation of indicators can be time-consuming and expensive. Therefore, readily available data sources such as Farm Accountancy Data Network (FADN) have been employed [22, 7, 14, 10, 23, et al.]

European Union, aiming at halting biodiversity loss, has adopted the Farmland Bird Index as an indicator of structural changes in biodiversity [16]. According to this indicator the biodiversity has declined in Lithuania. In 2014, the Shannon equitability index value was 0.54, compared to 0.59 in 2010. As stated by Czyżewski and Brelik [4], from the perspective of sustainable land management, the resignation of many farmers from livestock has many negative consequences for the health of soil. Moreover WAS et al. [21] indicated that in Lithuania the share of cereals is too high and must be reduced due to biodiversity requirements. According to Eurostat data, in 2015 the share of crop production, cereal and rapeseed comprised the larger portion of the gross agricultural output value as compared to livestock output, if calculated at the basic prices, and as compared to 2010, increased by 9.9 percentage points in Lithuania. Analysis of the scientific literature has suggested that biodiversity assessment of Lithuanian family farms has been little studied. Therefore, an aim of the current paper was to measure the Lithuanian family farms biodiversity using FADN data. Farms diversity is expressed by diversity in land use and cropping based on Shannon's and Simpson's indices. To account for the effects of farms' management strategies to biodiversity the comparison analysis between farms groups is presented.

MATERIALS AND METHODS

The family farms' farming data were obtained from Lithuanian FADN. The sample size comprised of 1304 family farms in 2014. These farms are aggregated into farm types based on specialization and into farm classes based on economic size (related to the total Standard Output), intensity (total output per ha UAA) and land area (utilized agricultural area (UAA)) (Table 1).

Table 1. Farms sample distribution according to specialization, economic size, intensity and land area

Farm types, classes	Number of farms	Average farm size (ha UAA)
Specialization		
Specialist cereals, oilseeds and protein crops	453	87.5
General field cropping, mixed cropping	125	34.5
Horticulture and permanent crops	64	10.6
Specialist dairying	303	27.2
Grazing livestock	92	35.0
Specialist granivores	8	30.7
Field crops-grazing livestock, combined	209	42.1
Various crops and livestock combined	50	14.7
Economic size classes (thou EUR)		
Small scale (less than 16)	255	25.9
Medium scale (from 16 to 40 ESU)	303	57.8
Large scale (40 ESU or over)	746	249.0
Intensity classes		
Low intensity (total output per ha less than 500 EUR)	23	89.5
Medium intensity (total output per ha from 500 to 3000 EUR)	822	138.8
High intensity (total output per ha 3000 or over EUR)	459	204.6
Land area (farm size classes of UAA)		
Less than 5 ha	22	2.7
From 5 to 10 ha	47	7.2
From 10 to 20 ha	83	14.9
From 20 to 30 ha	85	25.0
From 30 to 50 ha	170	40.2
From 50 to200 ha	571	103.0
From 200 to 500 ha	246	306.0
500 ha or over	80	795.6

Note: the distribution of land area and specialization is based on Lithuanian FADN farm typology (http://laei.lt/index.php?mt=leidiniai&straipsnis=955&metai=2015); the distribution of economic size and intensity classes is based on typology proposed by Reidsma and Ewert [17].

After literature review on biodiversity assessment most commonly employed are the Shannon's and Simpson's indices. The Shannon index of diversity (H_{Sh}, see Shannon and Weaver [18]) is calculated using the following formula:

$$H_{Sh} = -\sum_{i=1}^{S} pi \times \ln pi \; ;$$

where H_{Sh} is Shannon diversity index, S is the number of land use elements (or cultivated crops) in a certain farm, pi denotes the proportion of the area covered by a specific land use element (or crop) in a certain farm.

The Shannon equitability index E_{HSh} (or Shannon evenness index) shows the Shannon index in proportion to the maximum diversity index possible for the farm:

$$E_{H_{Sh}} = \frac{H_{Sh}}{H_{Sh}max} = \frac{H_{Sh}}{\ln S}.$$

The Shannon equitability index evaluates farm's biodiversity and takes into consideration the number of different land use elements (or crops) observed and their relative abundance. The index is based on values within the range of 0–1, with zero representing a farm with no diversity (only one land use element or crop) and a value of one representing the maximum diversity.

The second measure of species diversity is Simpson index (D_{Si}, see Simpson [19]):

$$D_{Si} = 1 - \sum_{i=1}^{S} pi^2 .$$

The Simpson diversity index is a measure of diversity which takes into account richness and evenness. With this index, zero represents no diversity (only one land use element or crop) and a value of one represents infinite diversity.

In this paper the Shannon equitability and the Simpson diversity indices were employed. The indices of biodiversity ranged from 0 to 1 scaled into three intervals: 1) low biodiversity score which fell within the interval [0; 0.33]; 2) medium biodiversity score which fell within the interval [0.34; 0.66]; 3) high biodiversity score which fell within the interval [0.67; 1].

The indices of land use diversity on farms calculation was based on Lithuanian detailed FADN data of 27 crops. Eurostat categorization of crops into 14 different categories to estimate the indices of crop diversity was employed.

ANOVA test was used to measure statistical significance of the difference in the indicator values between the farm size classes. A p value of less than 0.05 ($p<0.05$) was considered to indicate a statistically significant difference across types of farming and the farms classes. The statistical package for social science (SPSS 22) was employed for processing and analysis of the collected data.

RESULTS AND DISCUSSIONS

The analysis on the biodiversity in Lithuanian family farms revealed that average values of the biodiversity Shannon equitability (land use and cropping) and Simpson diversity (land use and cropping) indices fell within the medium biodiversity interval. Calculated average values of biodiversity indices across different types of farming based on Shannon's equitability (land use and cropping) and Simpson's diversity (land use and cropping) are presented in Table 2.

Table 2. Values of biodiversity indices on family farms by farming type

Farming type	Land use elements on farms	Cropping elements on farms	Land use diversity		Crop diversity	
			Shannon equitability index	Simpson diversity index	Shannon equitability index	Simpson diversity index
Specialist cereals, oilseeds and protein crops	4.7	3.0	0.69	0.56	0.52	0.34
Horticulture and permanent crops	3.0	2.0	0.52	0.37	0.55	0.32
Specialist dairying	4.2	2.7	0.59	0.45	0.55	0.34
Specialist granivores	3.0	2.2	0.56	0.39	0.41	0.25
General field cropping, mixed cropping	4.9	3.5	0.70	0.57	0.64	0.44
Grazing livestock	3.4	2.3	0.49	0.35	0.46	0.26
Field crops-grazing livestock, combined	5.6	3.4	0.76	0.64	0.65	0.46
Various crops and livestock combined	4.3	2.5	0.63	0.51	0.50	0.31
Total	4.6	2.92	0.65	0.52	0.56	0.36
$F_{(7,1296)}$	23.3	23.9	20.5	32.0	7.4	13.8
Significance	***	***	***	***	***	***
Standard deviation	0.94	0.56	0.09	0.11	0.08	0.08
Coefficient of variation	22.7	20.7	15.3	22.1	15.4	22.3

Note: *p<0.05; **p<0.01; ***p<0.001; ****p>0.05.

The highest level of biodiversity was achieved on farms combined field crops with grazing livestock. The value of land use Shannon equitability index on farms combined field crops with grazing livestock fell within the high biodiversity interval, whereas, values of land use diversity Simpson index and crop diversity Shannon and Simpson indices fell within medium biodiversity interval. The lowest land use diversity was found on grazing livestock farms, whereas, the lowest crop diversity indices values were determined on specialist granivores (poultry, pigs) farms. The lowest average values of the biodiversity indices fell within the interval of medium biodiversity, except for the Simpson's crop

diversity index, the average value of which fell within the low biodiversity interval and concentrated at the upper boundary of the low biodiversity interval.

Results from the use of Shannon's and Simpson's biodiversity indices of land use and crop diversity across analysed farming types indicated higher diversity values of land use diversity. This is likely related to obtained higher number of land use elements which were grouped to lower number of cropping elements on farms.

Moderate variation of Shannon's equitability (land use and cropping) indices across farm types was determined, and made 15.3 % for land use diversity and 15.4% for crop diversity. High variation of Simpson's diversity (land use and cropping) indices across the analysed farm types was established (22.1% and 22.3 % in land use and cropping, respectively). This explains that biodiversity state is rather different in considered farms types.

Calculated average values of biodiversity indices across economic size classes based on Shannon's equitability (land use and cropping) and Simpson's diversity (land use and cropping) are presented in Table 3.

Table 3. Values of biodiversity indices on family farms by economic size classes

Economic size classes	Land use elements on farms	Cropping elements on farms	Land use diversity		Crop diversity	
			Shannon equitability index	Simpson diversity index	Shannon equitability index	Simpson diversity index
Small scale	3.7	2.4	0.64	0.48	0.51	0.31
Medium scale	4.2	2.6	0.63	0.48	0.53	0.32
Large scale	5.0	3.2	0.67	0.55	0.58	0.39
Total	4,6	2.9	0.65	0.52	0.56	0.36
$F_{(2,1301)}$	44.8	65.9	3.1	15.3	7.0	22.9
Significance	***	***	*	***	***	***
Standard deviation	0.61	0.43	0.02	0.04	0.04	0.04
Coefficient of variation	14.3	15.8	3.2	8.0	6.7	12.8

Note: *p<0.05; **p<0.01; ***p<0.001; ****p>0.05.

The highest level of biodiversity was achieved on large scale farms. The values of land use Simpson diversity index and crop diversity Shannon equitability index fell within the medium biodiversity interval, whereas, the crop diversity Simpson index value concentrated closer to the bottom boundary of the medium biodiversity interval. By contrast, the value of land use diversity Shannon equitability index fell within the high biodiversity interval and concentrated at its bottom boundary. The lowest land use diversity based on Shannon's equitability index was found on medium scale farms and based on Simpson's diversity index the lowest value was observed on small scale and medium scale farms classes. The lowest crop diversity based on Shannon's and Simpson's indices was found on small scale farms. The lowest average values of the biodiversity indices across the analysed farm economic size classes fell within the interval of medium biodiversity, except for the Simpson's crop diversity index, the average value of which fell within the low biodiversity interval and concentrated at the upper boundary of the low biodiversity interval.

Low variation of Shannon's equitability (land use and cropping) indices and Simpson's crop diversity indices was observed, except for Simpson's crop diversity indices, which value indicates the moderate variation. This explains that biodiversity state is rather similar in considered farms economic size classes.

Table 4 provides average values of Shannon's equitability (land use and cropping) and Simpson's diversity (land use and cropping) indices according to the farm intensity classes.

Table 4. Values of biodiversity indices on family farms by intensity classes

Intensity classes	Land use elements on farms	Cropping elements on farms	Land use diversity		Crop diversity	
			Shannon equitability index	Simpson diversity index	Shannon equitability index	Simpson diversity index
Low intensity	3.0	2.0	0.60	0.40	0.55	0.30
Medium intensity	4.8	2.9	0.68	0.55	0.55	0.35
High intensity	4.3	3.0	0.61	0.48	0.57	0.38
Total	4.6	2.9	0.65	0.52	0.56	0.36
$F_{(2,1301)}$	16.9	7.9	10.3	18.4	1.3	2.8
Significance	***	***	***	***	****	****
Standard deviation	0.93	0.55	0.04	0.08	0.01	0.04
Coefficient of variation	23.0	20.9	6.9	15.7	2.1	11.8

Note: *p<0.05; **p<0.01; ***p<0.001; ****p>0.05.

The highest level of land use biodiversity was achieved on medium intensity farms based on Shannon's and Simpson's diversity indices. Whereas, the highest level of crop diversity in terms of Shannon's and Simpson's indices was observed on high intensity farms. The lowest land use diversity was found on low intensity farms. The lowest crop diversity based on Shannon's equitability index was indicated in low and medium intensity classes.

The lowest Simpson's crop diversity was determined on low intensity farms. Low variation of Shannon's equitability (land use and cropping) indices across farm intensity classes was determined, and made 6.9 % for land use diversity and 2.1% for crop diversity. Moderate variation of Simpson's diversity (land use and cropping) indices across the analysed farm intensity classes was established (15.7% and 11.8 % in land use and cropping, respectively). Medium and high intensity farms were found to have more beneficial effect on conservation of agricultural biodiversity.

The calculated values of biodiversity indices on family farms by farm size classes of UAA are presented in Table 5.

Table 5. Values of biodiversity indices on family farms by farm size classes of UAA

Land area (farm size classes of UAA (ha))	Land use elements on farms	Cropping elements on farms	Land use diversity		Crop diversity	
			Shannon equitability index	Simpson diversity index	Shannon equitability index	Simpson diversity index
Less than 5 ha	2.8	1.9	0.54	0.40	0.47	0.27
From 5 to 10 ha	3.3	2.4	0.69	0.48	0.58	0.34
From 10 to 20 ha	3.6	2.3	0.63	0.46	0.54	0.33
From 20 to 30 ha	3.9	2.5	0.64	0.47	0.52	0.32
From 30 to 50 ha	4.0	2.6	0.62	0.47	0.55	0.34
From 50 to200 ha	4.6	2.8	0.66	0.52	0.54	0.35
From 200 to 500 ha	5.4	3.5	0.69	0.58	0.61	0.42
500 ha or over	5.6	4.0	0.65	0.57	0.55	0.42
Total	4.6	2.9	0.65	0.52	0.56	0.36
$F_{(7,1296)}$	22.9	30.1	2.10	7.10	1.70	6.20
Significance	***	***	*	***	****	***
Standard deviation	1.0	0.7	0.05	0.06	0.04	0.05
Coefficient of variation	23.7	24.8	7.5	12.1	7.5	14.4

Note: *p<0.05; **p<0.01; ***p<0.001; ****p>0.05.

The highest level of land use diversity based on Simpson's diversity index was achieved on the large-sized farms (from 200 ha UAA or over). According to Shannon's equitability index the highest level was observed on farms at two considered farm size classes, i.e. from 5 to 10 ha UAA and from 200 to 500 ha UAA. Calculated crop diversity indices (Shannon and Simpson diversity indices) has showed that more efforts were made by large-sized farms (from 200 ha UAA and over).

The highest values of land use and crop diversity fell within the medium biodiversity interval, whereas, the value of land use Shannon's equitability index fell within the high biodiversity interval and concentrated at its bottom boundary. The lowest biodiversity indices values across analysed farms size classes were found on the smallest-sized farms class and fell within the medium biodiversity interval, except for the crop Simpson's diversity index the average value of which concentrated closer to the upper boundary of the low biodiversity interval.

The analysis of calculated Shannon's equitability indices values suggested slightly difference between the farm size classes. This is evidenced by low variation of Shannon's equitability (land use and cropping) indices across farm size classes (7.5 % for both considered diversity indices). Moderate variation of Simpson's diversity (land use and cropping) indices across the analysed farm intensity classes was established (12.1% and 14.4 % in land use and cropping, respectively).

CONCLUSIONS

Lithuanian case analysis suggested that certain measures for strengthening farms biodiversity were necessary as the average values of the biodiversity based on Shannon's equitability (land use and cropping) and Simpson's diversity (land use and cropping) indices fell within the medium biodiversity interval.

Analysis on family farms biodiversity across considered farm types and classes revealed that the highest level of biodiversity was achieved by farms combined field crops with grazing livestock, large scale farms and by medium and high intensity farms. The best average biodiversity situation across observed farm size classes of UAA was found on the large-sized farms class (from 200 to 500 ha UAA) and small-sized class (from 5 to 10 ha UAA).

Lower diversity values of Simpson's diversity in comparison to Shannon's equitability indices values were obtained across analysed farm types and farm classes. This is likely related to Simpson's index sensitivity to the number of land use and cropping elements of farms. Though, the Shannon's equitability index has greater importance to rarer land use

or cropping elements. Therefore, for policy purposes both indicators provide valuable insights to enhance and maintain the biodiversity on farms.

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