CROP DIVERSITY AND PRODUCTIVITY UNDER ORGANIC FARMING IN LITHUANIA

Aušra ARLAUSKIENĖ[1], Žydrė KADŽIULIENĖ[2], Irena DEVEIKYTĖ[2],
Lina ŠARŪNAITĖ[2], Roma SEMAŠKIENĖ[2], Edita KARBAUSKIENĖ[3],
Laura MASILIONYTĖ[1], Danutė JABLONSKYTĖ-RAŠČĖ[1]
[1]Joniškėlis Experimental Station, Lithuanian Research Centre for Agriculture and Forestry,
Joniškėlis LT-39301, Pasvalys distr., Lithuania
[2]Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry,
Instituto av. 1, Akademija LT-58344, Kėdainiai distr. Lithuania
[3] Chamber of Agriculture of the Republic of Lithuania,
K. Donelaitis st.. 2, LT-44213, Kaunas, Lithuania
Email: joniskelio_lzi@post.omnitel.net

Abstract. *In Lithuania, the land area under organic management has been steadily increasing over the recent years. A research and development project was implemented in Lithuania with the aim of ascertaining crop strukcure, plant diversity and crops productivity in organically-managed farms under different soil conditions. In mixed farms, involved both in crop and animal production, perennial forage grasses prevailed in the crop structure, while cereals predominated in crop production farms. Crop production farms grew more grain legumes and their mixtures with cereals compared with mixed farms. Of grain legumes, field pea (semi-leafless) occupied the largest area. Lithuania's natural conditions are suitable for the cultivation of cereals, which are the main crops in the organic farm. Central Lithuania's soils are best suited for winter wheat cultivation. The total production area of spring cereals is slightly bigger than that of winter cereals. The greatest crop species diversity (on average 8 species) was recorded in the farms present in Central Lithuania, characterised by fertile soils, where conditions for both crop production and animal production are favourable. The productivity of organically - managed crops was unstable and varied within a very wide range. This was influenced not only by natural and soil conditions but also by the different agronomic practices applied.Winter cereal was slightly more productive than spring cereal.*

Key words: *organic farming, crop structure, yield, plant diversity.*

INTRODUCTION

Organic agriculture is generally perceived as an environment-safe or at least friendly farming method [1], and this is one of the reasons why the current consumption of organic products is on the increase [2]. Researchers from many countries and advocates of organic farming agree that organic agriculture has to be developed in the concept of sustainability, and its application proceeds using certain control measures pre-established and defined by international and national documents [3]. Organic farming system encompasses various aspects that are of interest both to researchers and agricultural producers. In many counties, attempts are being made to search for scenarios for the development of future sustainable agriculture by estimating the consequences of economic and environmental impacts on a farm level and by looking for means affecting production environment but facilitating mitigation or neutralization of undesirable effects [4]-[6].

Farms involved in organic production are being expanded in Lithuania. However, the larger part of organic farms have abandoned animal production (in 2012, the latter farms accounted for 35.1% of the total farms) and have been specializing in marketable crop production.

The relief of Lithuania's terrain was formed by the last glaciers that resulted in the formation of very diverse soils. According to climate and soil peculiarities, the country's territory is divided into three regions – western, central and eastern. Intensive soil erosion processes are taking place in West Lithuania's relief, where the soils are characterised by unequal texture, lower fertility as well as crop productivity, and higher production costs and where crop cultivation technologies are aimed at erosion reduction. Plains account for 95% of Central Lithuania's Lowland where the most fertile soils – *Cambisols* and *Calcaric Luvisols* prevail. East Lithuania has the highest proportion of low productivity soils. Natural and soil conditions of all Lithuania's regions are favourable for animal production (agroclimatic conditions determine the choice

of the most suitable animal production branch: dairy and beef cattle production, pig production, sheep production, livestock breeding, etc.); however, due to economic and social reasons, farmers lack interest in developing these activities. As a result, commercial crop production farms prevail.
Aim of the studies was to evaluate the crop structure, plant diversity and crops productivity in organically-managed farms under different soil (region of Lithuania) conditions.

MATERIALS AND METHODS

In 2012-2013, a research and development project "Assessment of agricultural load on agrocenoses of organic farming and phytosanitary state of crops grown" was implemented jointly by the Lithuanian Research Centre for Agriculture and Forestry and Chamber of Agriculture of the Republic of Lithuania. Monitoring of organic production farms was carried out. It involved periodical and systematic survey of the selected organic farms, collection and analysis of information, and provision of forecasts. The farms for monitoring were selected having analysed the data on certified organic production obtained from the Lithuanian Institute of Agricultural Economics and Public Institution "Ekoagros". Organic farms were divided into groups according to regions – West, Central and East Lithuania; according to specialization – crop production and mixed farms; according to size: < 30 ha, 31-100 ha and > 100 ha. Monitoring was performed in three stages: i) in spring – analysis of crop structure and plant diversity; ii) before harvesting – establishment and assessment of crop productivity. During the period of monitoring, samples were taken and stands of cereals (wheat, rye, triticale, barley, oats) and grain legumes (pea) were assessed. Plant samples for the determination of biometric indicators and biological yield were collected before harvesting. Before harvesting, 8 samples were taken from each crop stand, all stems including productive ones, grain number and weight per ear, 1000 grain/seed weight were calculated. Biological productivity was calculated according to the formula (1):

$$((PD*GrE)*TGw)/1000, \quad (1)$$

where PD – productive cereal density, unit m^{-2}; Gs – grain number per ear, unit m^{-2}; TGm – thousand grain weight, g. The productivity was recalculated into kg ha^{-1}.

RESULTS AND DISCUSSION

Crop structure and plant diversity

The size (ha) of Lithuania's organic farms is highly variable. Monitoring was performed in farms whose area ranged from 5.4 to 781.7 ha. In West and East Lithuania, farms with an area ranging from 30 to 100 ha are predominant, while in Central Lithuania those with an area of over 100 ha. Crop production farms were smaller in size compared with mixed farms. When estimating farming possibilities and quality, farm size is an important factor to consider, since unequal farming conditions form in differently sized farms and different crop cultivations are used. In West Lithuania prevailed mixed organic farms (crop and animal production), in Central and East Lithuania – crop production farms.
Farmers choose those crops for cultivation for which the climate and soil conditions are suitable and which can produce the highest yield at the lowest possible production costs and inputs. However, the choice of crops is also considerably influenced by the level of direct payments and market. The crop structure of organic farms was unstable and varied between years, especially in crop production farms. Perennial forage grasses predominated in the crop structure of mixed farms, while in crop production farms the prevalent crops were cereals and grain legumes (Table 1).
Practically no perennial grasses were grown by organic crop production farms (Table 2). Some farms grew them to sell as forage as well as seed or for soil restoration. In Central and East Lithuania's large crop production and animal production mixed farms, cereals accounted for a large portion in the crop structure (up to 58.2 and 48.6%, respectively). The highest concentration of cereals (up to 80.1%) was in the crop production farms of Central Lithuania (31-100 ha). Grain legumes occupied the largest areas there also.
Black fallow and green manure fallow account for a very small portion of arable land and are commonly used for the control of perennial weeds or for the restoration of soil fertility. As a result, fallows occupy the largest area in crop production farms where no perennial grasses are grown and there is no manure. Smaller farms (especially those specialising in crop production) are involved in horticulture, gardening and or cultivation of medicinal herbs.

Table 1

Crop structure in organic mixed crop production and animal production farms (2010-2013, averaged data)

Region	Farm size ha	Crop share in the crop structure (variation range from to), %					
		Total crops	Cereals	Grain legumes	Perennial grasses	Other plant species *	Various fallows
West Lithuania	<30	-**	-	-	-	-	-
	31-100	0-26.3	0-26.3	0	68.9-100	0-2.8	0-1.1
	>100	24.8-38.6	12.3-27.2	11.5-12.5	61.3-76.8	0.1-0.7	0
Central Lithuania	<30	37.7	26.2	11.5	58.6	3.8	0
	31-100	-	-	-	-	-	-
	>100	44.0-92.7	17.3-58.2	17.1-41.6	3.8-54.2	0-9.9	0-0.6
East Lithuania	<30	25.8-51.8	16.9-37.7	8.9-23.9	36.0-69.22	5.4-28.7	0-6.7
	31-100	6.4-76.2	0-48.0	0-28.2	9.9-91.0	9.0-13.9	0
	>100	34.1-74.6	19.9-48.6	14.0-26.0	24.4-64.0	0.3-2.1	0-0.7

* horticultural, garden plants, medicinal herbs, ** data not available

Table 2

Crop structure of organic crop production farms (2010-2013, averaged data)

Region	Farm size ha	Crop share in the crop structure (variation range from to), %					
		Total crops	Cereals	Grain legumes	Perennial grasses	Other plant species *	Various fallows
West Lithuania	<30	21.8	15.7	6.1	49.4	28.7	0.1
	31-100	69.6-100	33.5-53.0	36.0-47.0	0	0–30.4	0
	>100	50.3	27.0	16.0	0.7	56.2	0.1
Central Lithuania	<30	69.7-78.5	20.7-73.5	5.1-49.2	0-24.7	7.7-28.3	1.8-3.7
	31-100	96.4-100	62.5-80.1	19.9-33.8	0-0.5	0-3.2	0
	>100	90.1-98.1	53.5-70.2	15.4-44.6	0	1.9-14.4	0-0.1
East Lithuania	<30	78.8	63.5	10.8	10.3	12.7	4.5
	31-100	52.1-73.6	18.0-69.5	0-55.6	0	22.9-26.4	0
	>100	27.8-73.6	27.8-78.2	0-30.3	3.6-35.9	3.0-23.5	0-12.9

* horticultural, garden plants, medicinal herbs,

Crop species analysis showed that four and fewer crop species (most of which are cereals) and seven and more crop species were grown by 41.2% of the organic farms surveyed. Comparison of the data from years 2013 and 2010 indicated that the number of crops grown tended to increase, especially in larger farms. The greatest crop species diversity (on average 8 species) was recorded in the farms present in Central Lithuania, characterised by fertile soils, where conditions for both crop production and animal production are favourable. Some farmers diversified their crop structure by including maize, millet, linseed flax, oilseed rape. The greater the plant diversity, the more organic matter and more varied nutrients are accumulated in the soil, which results in a better phytosanitary state of the farm.

Productivity of crops.

Lithuania's natural conditions are suitable for the cultivation of cereals, which are the main crops in the country. Cereal cultivation has been encouraged by increased grain exports and grain purchasing prices. East and Central Lithuania's crop production farms grew the largest area of winter cereals (up to 49.2%), in West Lithuania the area under winter cereals was smaller. The data of the survey indicated that the largest winter wheat production areas were in Central Lithuania's organic production farms,

because Central Lithuania's soils are best suited for winter wheat cultivation [7] and because these farms are the largest. In West and East Lithuania's regions the production area of winter cereals is much smaller. They are chosen more by crop production farms than by mixed farms. On less productive soils farmers grow less demanding crops such as winter rye (in East Lithuania) and triticale (in West Lithuania).
The analysis of biological yield of the most common cereal species grown in organic farms showed that the productivity of winter cereals was unstable and varied within a very wide range (Table 3).

Table 3

The biological yield (t ha^{-1}) of most common winter cereals grown in organic farms

Region	Yield	Winter wheat		Winter triticale		Winter rye	
		2012	2013	2012	2013	2012	2013
West Lithuania	from–to	-*	-	-	2.1-4.7	-	2.9-4.3
	average	-	4.2	4.2	3.5	-	3.6
Central Lithuania	from–to	2.7-6.6	2.2-4.4	-	-	1.9-2.7	-
	average	4.2	2.3	-	4.0	2.3	4.9
East Lithuania	from–to	2.7-4.7	2.4-2.9	3.8-4.9	-	1.7-3.3	1.6-4.4
	average	3.7	2.7	4.3	2.8	2.5	2.0
Total Lithuania 2012-2013	from–to	2.2-6.6		2.1-4.9		1.6-4.4	
	average	3.4		3.7		3.1	

* data not available

This was influenced not only by natural and soil conditions but also by the different agronomic practices applied: pre-crops, fertilization and other management practices. Winter wheat was slightly more productive than winter triticale, and the latter was more productive than winter rye. The greatest grain yield variation range was established for winter wheat, which is more demanding in terms of soil and management. Wheat and rye grains in 2012 were larger (1000 grain weight – 39.5, 37.3 g, respectively) than in 2013 (35.4, 35.2 g, respectively). The differences in triticale grain size between the two years were inappreciable.

Table 4

The biological yield (t ha^{-1}) of most common spring cereals and grain legumes grown in organic farms

Region	Yield	Spring barley		Oats		Pea	
		2012	2013	2012	2013	2012	2013
West Lithuania	from-to	1.1-2.9	2.8-3.3	1.2-1.7	3.3-5.0	-	-
	average	1.8	3.0	1.5	4.1	-	2.0
Central Lithuania	from -to	2.4-3.6	-*	1.6-4.6	-	1.3-5.4	-
	average	3.2	2.4	2.9	4.0	3.6	3.5
East Lithuania	from -to	1.2-2.7	-	-	1.5-1.8	2.2-4.2	1.5-4.1
	average	2.1	3.7	-	1.7	3.2	2.8
Total Lithuania 2012-2013	from -to	1.1-3.6		1.2-5.0		1.3-5.4	
	average	2.7		2.8		3.0	

* data not available

The total production area of spring cereals is slightly bigger than that of winter cereals. In crop production farms, especially in those of Central Lithuania, they account for nearly half of the total crop structure. With increasing farm area, more spring cereals are grown in mixed farms. Barley, which has been a dominant spring cereal crop in crop production farms for a long time, is being replaced by wheat, triticale and other spring cereals. The largest areas of barley or its mixtures with grain legumes were cultivated in mixed farms. So far, oats have been grown on least productive soils (in West and East Lithuania). However, due to their phytosanitary and agronomic properties and grain demand in the market of organic products, oats

production area has increased. Currently oats are grown all over Lithuania, especially in crop production farms. In West Lithuania, because of adverse wintering or poor autumn conditions, farmers tend to choose spring cereals instead of winter cereals. The average productivity of spring cereals (spring barley, oats) was 2.8 t ha^{-1} or 17.6 % lower than that of winter cereals (Table 5).

Spring cereals were most often grown after winter cereals and got into the worst place in the crop rotation. The situation has been changing recently. Our data showed that spring barley was mostly grown by mixed farms, which grew perennial grasses and applied farmyard manure to restore soil fertility, therefore spring barley productivity was relatively stable. Crop production farms grew other spring cereals, characterised by a good weed suppressive ability and greater demand on the market.

Oats were grown all over Lithuania on various soils using different management practices. Oat yield varied from 1.2 to 5.0 t ha^{-1}. However, on less fertile soils the yield of properly cultivated oats was similar to that of other cereals. Barley grains were large (1000 grain weight – 41.1 g), oat grains were small (1000 grain weight – 31.7 g).

Legume plants are valued because they enrich the soil with symbiotically fixed atmospheric nitrogen and are a source of nitrogen in the crop rotation. Crop production farms grew more grain legumes and their mixtures with cereals compared with mixed farms. The largest area cultivated with these crops was in Central and East Lithuania's farms. Of grain legumes, semi-leafless pea occupied the largest area. Some farmers chose other grain legumes: beans, soy, lupine and vetch. Mixed farms (crop and animal production) cultivated mainly legume/cereal mixtures. However, few farmers pay attention to effective use of nitrogen accumulated by legumes. Pinder et al. (2012) suggest that nitrogen from legumes when their biomass is used as green manure can have negative effects on soil and water quality and climate change (due to N_2O, NH_3 losses) [8]. Development and introduction of innovative elements and technologies in organic crop production farms can serve as an alternative for organic animal production [9].

Biological grain yield of semi-leafless pea was unstable and ranged from 1.3 to 5.4 t ha^{-1}. There is a greater likelihood to produce higher and more stable pea yields in Central Lithuania and regions close to it. In the survey, the farmers indicated the reasons for such low pea grain yield: high weed infestation, disease and pest incidence, losses during harvesting, yield handling and storage. Most of the farmers grew peas according to conventional technology but without the use of synthetic fertilizers and pesticides. Unlike in conventional agriculture much attention has to be devoted to weed control, i.e. choice of pre-crops, mechanical weed control, alternative pea cultivation methods (intercrops, wide inter-row spacing and others).

Crop yield reduction in organic farming depended on plant species and the soil conditions (region) (Figure 1).

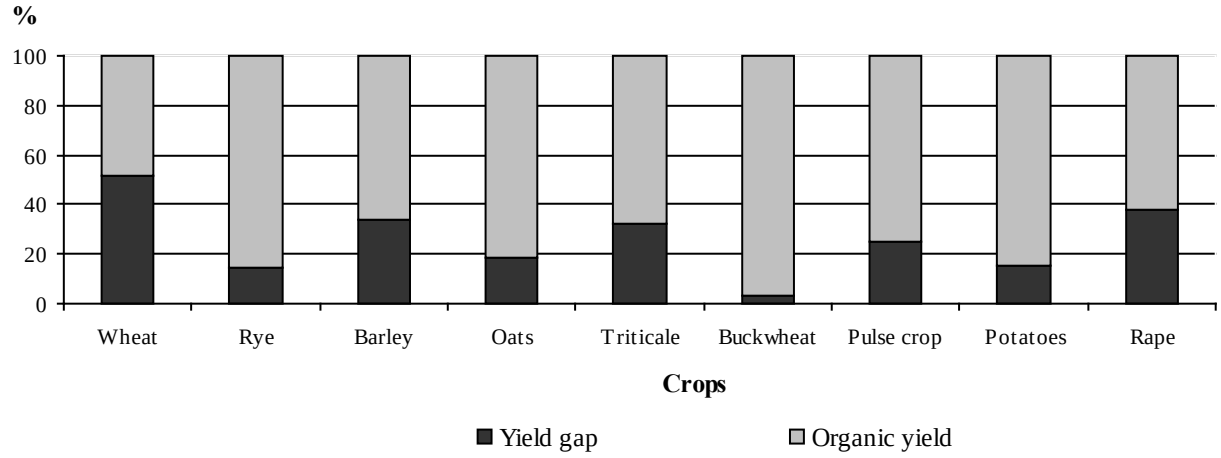

Figure 1. **Crop yield gap (%) between organic and conventional agriculture in Lithuania (2010-2013)**

Organically-managed winter wheat, triticale, spring barley, oilseed rape reduced grain/seed productivity by 51.4%, 32.0%, 34.2% and 38.0% respectively, compared with managed in intensive agriculture. Buckweat was less sensitive to the organic management.

CONCLUSIONS

1. When choosing production specialization, farmers often disregard regional differences, which are largely determined by soil and climate. The crop structure of organic farms was unstable and varied between years, especially in crop production farms. Perennial forage grasses predominated in the crop structure of mixed farms, while in crop production farms the prevalent crops were cereals and grain legumes. The highest concentration of cereals (up to 80.1%) was in the crop production farms of Central Lithuania (31-100 ha).

2. The greatest crop species diversity (on average 8 species) was recorded in the farms present in Central Lithuania, characterised by fertile soils, where conditions for both crop production and animal production are favourable.

3. The grain yield of organically grown winter wheat, triticale and rye was 3.4, 3.8 and 3.1 t ha^{-1}, respectively. The grain yield of spring barley and oats was lower and amounted to 2.7 and 2.8 t ha^{-1}. The yields of organically grown crops were optimal but unstable.

ACKNOWLEDGEMENTS

The research was part of the long-term Lithuanian Research Centre for Agriculture and Forestry programme „Biopotential and Quality of Plants for Multifunctional Use“.

REFERENCES

1. Goldberger J. R. (2011) Conventionalization, civic engagement, and the sustainability of organic agriculture. *Journal of Rural Studies*, 27, pp. 288-296.
2. Lamine C. (2011) Transition pathways towards a robust ecologization of agriculture and the need for system redesign. Cases from organic farming and IPM. *Journal of Rural Studies*, 27, pp. 209-219.
3. European Organic Regulations, 2012.
4. Acosta-Alba I., Lopéz-Ridaura S., van der Werf H.M., Leterme P. and Corson M.S. (2012) Exploring sustainable farming scenarios at a regional scale: an application to dairy farms in Brittany. *Journal of Cleaner Production*, 28, pp. 160-167.
5. Fumagalli M., Acutis M., Mazzetto F., Vidotto F., Sali G. and Bechini L. (2012) A methodology for designing and evaluating alternative cropping systems: Application on dairy and arable farms. *Ecological Indicators*, 23, pp. 189-201.
6. Oudshoorn F. W., Sörensen C.A.G. and de Boer I.J.M. (2011) Economic and environmental evaluation of three goal-vision based scenarios for organic dairy farming in Denmark. *Agricultural Systems*, 104, pp. 315-325.
7. Jablonskytė-Raščė D., Maikštėnienė S. and Mankevičienė A. (2013) Evaluation of productivity and quality of common wheat (*Triticum aestivum* L.) and spelt (*Triticum spelta* L.) in relation to nutrition conditions. *Žemdirbystė=Agriculture*, 100(1), pp. 45-56.
8. Pinder R.W., Bettez N.D., Bonan G.B., Greaver T.L., Wieder W.R., Schlesinger W.H. and Davidson E.A. (2012) Impacts of human alteration of the nitrogen cycle in the US on radiative forcing. *Biogeochemistry*, 114, pp. 1-16.
9. Wall D.H., Bardgett R.D., Behan-Pelletier J., Herrick J.E., Jones T.H., Ritz K., Six J., Strong D.R. and van der Putten W.H. (2013). *Soil Ecology and Ecosystem Services*, Oxford University Press, Oxford, UK, 397 p.