ADAPTATION TO CLIMATE CHANGE IN AGRICULTURE: ECOSYSTEM BASED OPTIONS

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Abstract. Climate change induced great challenges for agriculture, particularly implementation of new farming practices. Adaptation to climate change requires sustainable and environmentally friendly farm-level management practices and methods, and most promising of them are offered by an ecosystem approach and agroecological principles. The paper presents the results of the research, which has twofold aim: 1) to determine the most promising ecosystem based adaptation measures to climate change for Latvia's crop farms via evaluating recommendations; 2) to evaluate the implementation and possibilities of adaptation measures via assessing trends in Latvia, as well as comparing status among the countries in the Baltic Sea region. The data was obtained from the EU and national statistical database. The mixed research, combining suitable qualitative and quantitative research methods, was used. Most promising adaptation measures to climate change for implementation in the Latvia's crop farms could be combination of conservation agriculture practices (i.e. minimum soil disturbance, crop diversification, and permanent soil cover) with agroecological farm management practices. The results show that in Latvia, with the exception in the organic agriculture sector, in particular in the organic farming, the above mentioned climate adaptation measures at farm level have not yet been introduced and implemented sufficiently and effectively, especially compared to other EU countries in the Baltic Sea region.

Keywords: agriculture, climate change, adaptation, ecosystem.

Introduction

Agriculture is a source and a cause of the problem, agricultural ecosystems can be a sink of atmospheric carbon dioxide (CO_2) and reduce greenhouse gas (GHGs) emissions through the adoption of sustainable land management options. Climate change induced great challenges are related with actual and projected warmer and wetter conditions, as well as extreme weather events in Europe, in particular in Northern Europe [1]. These challenges require the implementation of adaptation measures that would change current farming practices and make agriculture more resilient to the adverse effects and risks posed by climate change.

Current practices of crop farms oriented to the intensification of agricultural production have caused: (i) increasing cropping of monocultures and application of agrochemicals (i.e. pesticides, mineral fertilizers); (ii) reduction of biodiversity (i.e. agricultural, wild and soil); (iii) decline of soil quality and fertility; etc. [2-4]. These practices have induced several undesirable consequences and contribute to further climate change.

Controversially intensive monoculture farming systems, which are recognised as unsustainable farming, agroecological diversification of farms aims to optimise nutrient cycling and soil organic matter turnover, soil biological activation, water and soil conservation and balanced pest-natural enemy populations [5]. Furthermore, one of sustainable climate change prerequisite is soil quality and fertility (i.e. soil organic matter and soil organic carbon), which are affected by crop rotation and plant diversity.

Adaptation to climate change may be achieved in many different ways. One widely recognised way is ecosystem-based approaches, which integrate biodiversity and sustainable land management, and, due to the restoring ecosystem functions, allow better mitigate and adapt to climate change [3; 6-7]. Moreover, this approach, which is defined as 'sustainable management', has been recognised as an important strategy via restoration of ecosystems for disaster risk reduction that is aimed to achieve sustainable and resilient development, particularly of agricultural production [7].

Ecosystem-based approaches are strongly linked with agroecological practices or farming, which include: integrated pest management, organic farming, conservation agriculture (i.e. crop rotations, composting, cover cropping, etc.), regenerative agriculture, sustainable intensification, etc. [5; 8-10]. These farming practices enhance and create various benefits among others as: sequestering of organic carbon in soils, soil restoration, conservation, promotion and conservation of below and above-ground biodiversity [3; 11].

On global and European level it is recognised that most effective are farm-based adaptation measures [1; 11-12]. Therefore, encouragement should be given to farmers who reconsider their management practices with the ecosystem functions and services, reducing chemical inputs, introducing more varieties and crops into rotation, implementing conservation agriculture and preservation of biodiversity, etc., and are oriented to agroecological transformation [12].

The aim of presenting the research was twofold: : 1) to determine the most promising ecosystem based adaptation measures to climate change for Latvia's crop farms via evaluating recommendations; 2) to evaluate the implementation and possibilities of adaptation measures via assessing trends in Latvia, as well as comparing status among the countries in the Baltic Sea region.

Materials and methods

The principal **materials** used during studies are as follows: various sources of literature, e.g. scholars' articles, the reports of institutions (esp. EU), etc. The data were obtained from the Eurostat database [13] and the database of the Central Statistical Bureau – CSB [14].

As the Baltic Sea region countries are also non-EU countries, only EU member states— Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, and Sweden—are included for state and trends' evaluation; and are indicated as the Baltic Sea countries.

The mixed research **methods** [15], combining suitable qualitative (monographic; analysis and synthesis, etc.) and quantitative (correlation-regression analysis) research methods have been used during studies.

Results and discussion

The EU Thematic Strategy for Soil Protection identified soil degradation caused by erosion as one of the major threats to European soils [17-18]. Soil erosion and runoff are affected by climate change, such as changes in temperature and precipitation patterns [19].

The main factors affecting the rates of soil erosion by water are precipitation [17]. Soil erosion by water is one of the major threats to soils in the EU, with a negative impact on ecosystem services, crop production, drinking water and carbon stocks [17]. Erosion leads to loss of soil fertility, loss of soil organic matter (SOM), and loss of the topsoil that provides the water and nutrient holding capacity [20].

Latvia has the fourth largest soil loss rate of arable land among the Baltic Sea countries (Fig. 1).

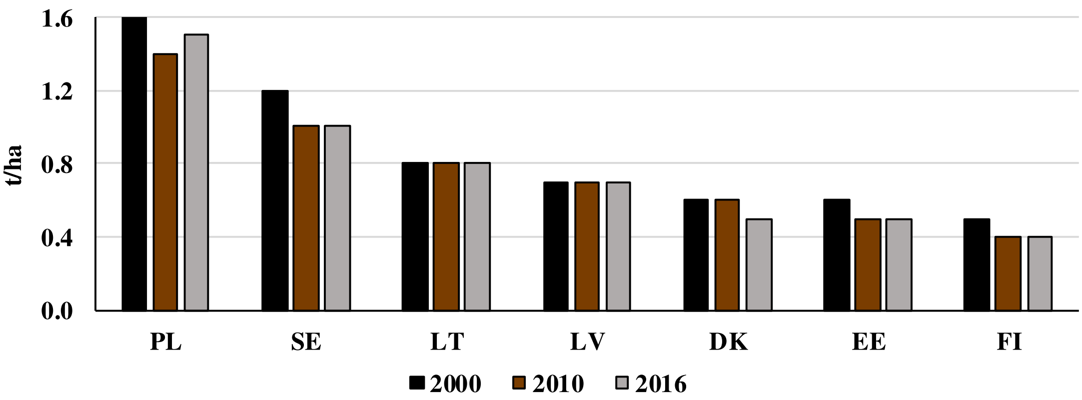


Fig. 1. S**oil water erosion rate in agricultural areas of Baltic Sea countries, 2000-2016** [13]

The North region (i.e. areas surrounding the North Sea and the Baltic Sea) is mostly dominated by the highest wind-erodible fraction (EF) values in Europe [18]. Among other Baltic Sea region countries in Latvia the EF value is the third highest (Table 1).

Farm level adaptation measures

Adaptation measures at farm level with positive effects on mitigation and biodiversity are as follows: no tillage and minimum tillage; use of cover crops and artificial soil covers; crop diversification and rotation; adapted crops; adapted timing of sowing and harvesting; precision farming; improved pasture management; organic farming; farm production and income diversification and opportunities for climate change adaptation: adaptation measures at farm level [1; 5; 8-9; 16].

Table 1

Estimated descriptive statistics of wind-erodible fraction of soil for Baltic Sea countries, aggregated data from 2009 to 2013 [18]

Country	Mean, %	Maximum	Standard deviation
Poland	45.2	68.8	8.4
Denmark	41.1	61.4	5.7
Latvia	40.1	62.4	5.2
Lithuania	39.3	62.5	5.5
Finland	38.6	67.0	8.0
Estonia	38.3	61.6	5.8
Germany	35.0	69.0	10.2
Sweden	34.5	63.8	6.2

Adaptation and mitigation synergies involve, e.g. measures to improve the soil water holding capacity by adding crop residues or manure, measures that reduce soil erosion, or measures that reduce leaching of nitrogen and phosphorus [1; 21]. The various farming practices can be used in order to reduce soil degradation. Good management of soil is an ecosystem-based approach that aims to water regulation, via reduction of soil compaction, which affects runoff and nutrient leaching. At the same time, it can help reduce soil carbon losses through soil disturbance, thus contributing to climate change mitigation [9; 22]. Soil management practices, such as tillage, induce physical, chemical, and biota changes in the soil and, consequently, affect nutrient cycling, water transfer, and the quality and growth of crop and non-crop plants [9]. Ecosystem approach based farm-level management practices, which have provided via agroecosystem different beneficial ecosystem services and have affected climate change, and are the bases of adaptation measures, are presented in Figure 2.

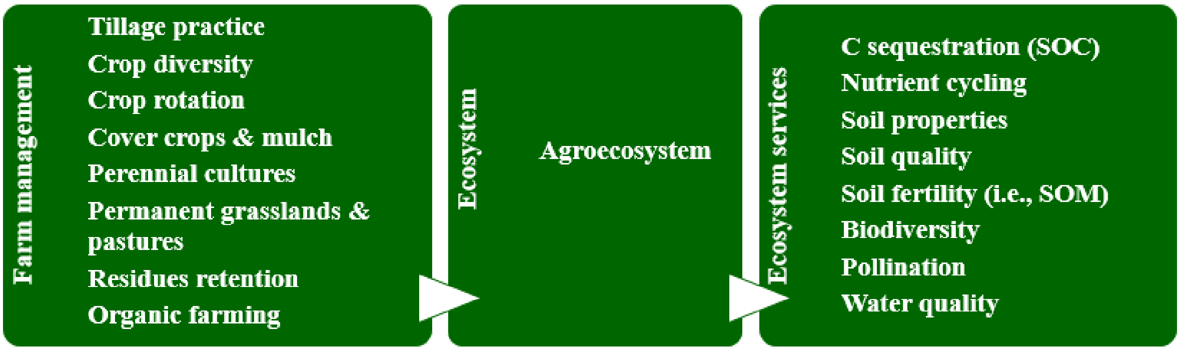


Fig. 2. **Farm management practices affecting climate change and induced ecosystem services**

Adaptation and mitigation synergies involve, e.g. measures to improve the soil water holding capacity by adding crop residues or manure, measures that reduce soil erosion [1; 8]. A recommended way to reduce emissions from the soil is to reduce tillage and plant catch crops [1].

Soil cultivation practices

The soil protection measures against erosion propose limitation of bare soils, promotion of reduced tillage and a minimum soil cover, contour farming in sloping areas, maintenance of terraces and stone walls, and increased use of grass margins [17]. Soil tillage promotes well-drained soils and simultaneously prevents pest and weed establishment, but on the other hand, it causes nutrient loss and CO_2 emissions from the soil, which are mainly emitted during soil management, particularly due to ploughing [1].

Deep ploughing and other intensive soil tillage techniques have destroyed the soil structure and, together with intense use of mineral or inorganic nitrogen fertilizers, have reduced soil quality and fertility via oxidation of soil organic matter, at the same time releasing huge amounts of CO_2 [11]. Moreover, tillage erosion is recognised as an important process of soil degradation affecting soil productivity [23; 24].

Conservation tillage – tillage practice or a system of practices that leaves plant residues (at least 30 %) on the soil surface for erosion control and moisture conservation, normally by not inverting the soil. Zero tillage or direct seeding – a soil cultivation method within which sowing is performed after harvesting the fore-crop without additional soil treatment for the after-crop. Comparison of a share of arable land cultivated with various tillage methods in various economic size holdings in Latvia in 2016 (Table 2) shows that conservation and zero tillage or no tillage practices have been implemented only on 8.8 % of total arable land.

As agricultural machinery, which is necessary for implementation of gentle or sustainable soil cultivation – reduced or no-tillage method, is expensive and needs additional investment, these practices presently in Latvia are implemented by farms with higher economic size.

Table 2

Share of arable land cultivated with various tillage methods in farms of various economic size in Latvia, 2016 [14]

Tillage method	Total	Economic size class of farms, thou EUR						
		≤ 3.9	4.0-14.9	15.0-24.9	25.0-49.9	50.0-99.9	100.0-499.9	≥ 500.0
Conventional	91.2 %	3.0 %	6.9 %	4.1 %	8.0 %	11.0 %	33.7 %	24.5 %
Conservation	7.4 %	0.0 %	0.1 %	0.0 %	0.1 %	0.5 %	2.8 %	3.8 %
Zero or no tillage	1.4 %	0.0 %	0.0 %	0.0 %	0.0 %	0.1 %	0.4 %	0.8 %

Cover crops and soil covers

Several studies have described the benefits (i.e. fixing nitrogen, reduction of soil erosion, mitigation the effects of drought in the long term, as mulch conserves soil moisture, etc.) of cover crop (i.e. catch crops) introduction in crop rotation [25]. Agroecological farming practices are focusing also on cover cropping [5]. Permanent soil organic cover with crop residues and/or cover crops facilitates climate change adaptation by reducing soil erosion and degradation [25]. Moreover, cover crops improve the soil properties, prevent soil erosion, preserve soil moisture, avoid compaction of the soil, contain pests and diseases, and increase biodiversity in the agroecosystem [26].

The results presented in Table 3 show that in Latvia economically strongest and more intensive farms are less sustainable (i.e. less agri-environmental or agroecologically oriented), comparing with less economically developed farms. For instance, farms of the economic size from 100 to 500 and more thou EUR leave in winter as bare soil 57.5 % of total arable land, but farms of the economic size from 3.9 to 24.9 thou EUR only – 19.8 %.

Table 3

Share of soil cover in winter in farms of various economic size in Latvia, 2016 [14]

Soil cover	Total	Share from total UAA, %						
		Economic size class of holding, thou EUR						
		≤ 3.9	4.0-14.9	15.0-24.9	25.0-49.9	50.0-99.9	100.0-499.9	≥ 500.0
Share of total UAA	100.0 %	4.3 %	8.0 %	4.7 %	8.9 %	11.6 %	35.0 %	27.5 %
Normal winter crop	35.2 %	0.4 %	1.3 %	0.8 %	1.8 %	3.1 %	13.8 %	14.0 %
Cover crop	4.4 %	0.2 %	0.4 %	0.3 %	0.4 %	0.6 %	1.3 %	1.2 %
Plant residues	8.5 %	0.2 %	0.6 %	0.4 %	0.8 %	1.1 %	3.6 %	1.8 %
Bare soil	30.0 %	1.5 %	2.8 %	1.6 %	3.0 %	3.8 %	10.1 %	7.2 %
Perennial grass	21.9 %	2.1 %	2.9 %	1.7 %	2.9 %	2.9 %	6.2 %	3.3 %

Crop diversification and rotation

Climate change creates a need to change the species and varieties to reduce vulnerability in the future and to exploit new crop production potential [1]. On farms vegetation diversity can be realised by increasing the number of cultivars or varieties (e.g. increasing genetic diversity), increasing the species diversity of crops in intercropped or polyculture systems, adding crop rotations, increasing the spatial diversity of the crops, and planting or leaving non-crop plants [9; 25]. The share of the agricultural land – utilised agricultural area (UAA) under diverse crops is decreased in Latvia, and noticeably increased the production of several crops (i.e. winter wheat and rape), mainly grown as monocultures [4].

However, the share of UAA under cereals, which characterises monoculture, in some Baltic Sea countries is high (Table 4), in all Baltic Sea countries, except the Baltic States, the measures have been implemented to decrease the cereal area proportion (Fig. 3). For example, the share of cereals from UAA in the period from 2005 to 2013 has decreased by 10.4 % in Poland, less than per one per cent in other Baltic Sea countries, except the Baltic States. In these countries the share of UAA under cereal cultivation increases by 6.3 % in Estonia, 14.0 % in Latvia and 21.4 % in Lithuania.

Table 4

Share of main crops from total UAA in Baltic Sea countries, 2016

Countries	Cereals	Dry pulses protein crops	Root crops	Industrial crops	Plants harvested green	Other crops	Fallow land
Poland	68 %	3 %	5 %	9 %	10 %	3 %	2 %
Lithuania	63 %	11 %	2 %	8 %	12 %	1 %	3 %
Denmark	62 %	1 %	4 %	7 %	22 %	4 %	1 %
Latvia	56 %	3 %	2 %	8 %	26 %	1 %	4 %
Germany	54 %	1 %	5 %	12 %	24 %	1 %	3 %
Estonia	51 %	8 %	1 %	11 %	26 %	1 %	2 %
Finland	50 %	2 %	2 %	4 %	32 %	1 %	8 %
Sweden	40 %	2 %	2 %	4 %	44 %	2 %	7 %

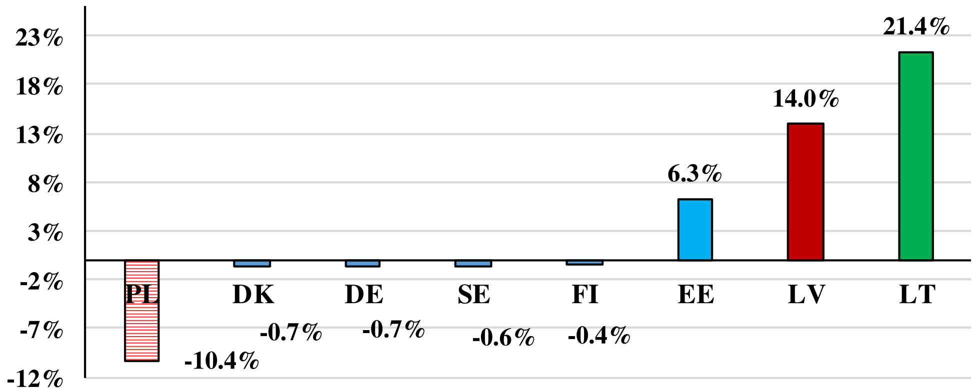


Fig. 3. **Changes of share of UUA under cereals (2013/2005) in Baltic Sea countries**

It is recognised that the dominant current monocroping systems will have to adapt to meet these variable pressures associated with the frequency and intensity of extreme weather conditions [25].

Organic farming

It is argued that sustainable agriculture: ‘ecological intensification’, ‘sustainable intensification’ and ‘agroecological intensification’, also includes sustainable farming practice or a system, such as organic agriculture (farming) [10]. Organic farming plays a significant role to support environmental friendly agriculture and contributes to solving of various challenges, such as sustainability issues, climate change mitigation and adaptation, biodiversity loss and soil degradation, and land-use changes, as well as supports resilience of rural areas [23; 27]. Furthermore, it is argued that organic agriculture besides resilient to climate change is more resilient against extreme weather conditions [28].

A rapid increase of both the numbers of organic farmers and organic agricultural land area in the world and the EU, including Latvia, was observed. The share of organic UAA from total UAA is high (14 %) and is the third highest among the Baltic Sea countries (Fig. 4).

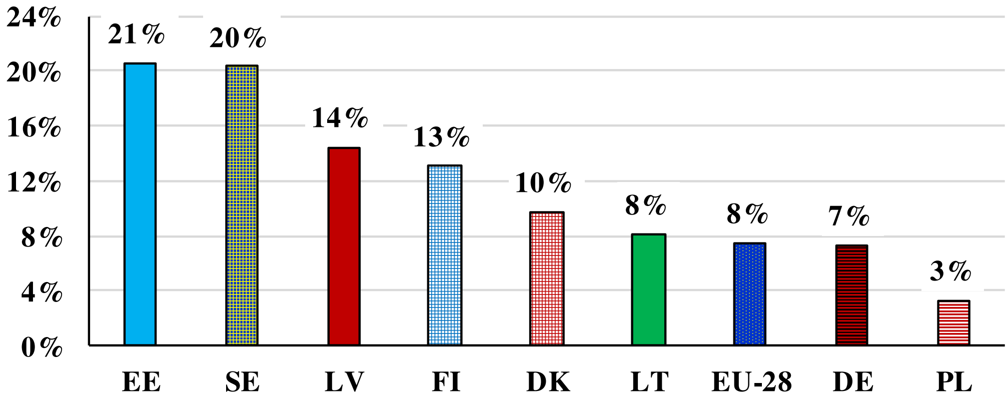


Fig. 4. **Share of organic area from total UAA in Baltic Sea countries, 2018**

Agricultural land is divided into three main types of use: arable land (cropping), permanent grassland (pastures and meadows), and permanent crops [27]. Considering that permanent cultures and crops mitigate soil degradation processes, as well as carbon loss, the latest tendencies of permanent cultures decreasing, particularly in organic areas, is alarming. Comparing among the Baltic Sea countries, the results show that Latvia has the second best result, because in Latvia arable land crops accounted for 51 % of the organic area, but permanent pastures and meadows covered 48 % (Fig. 5).

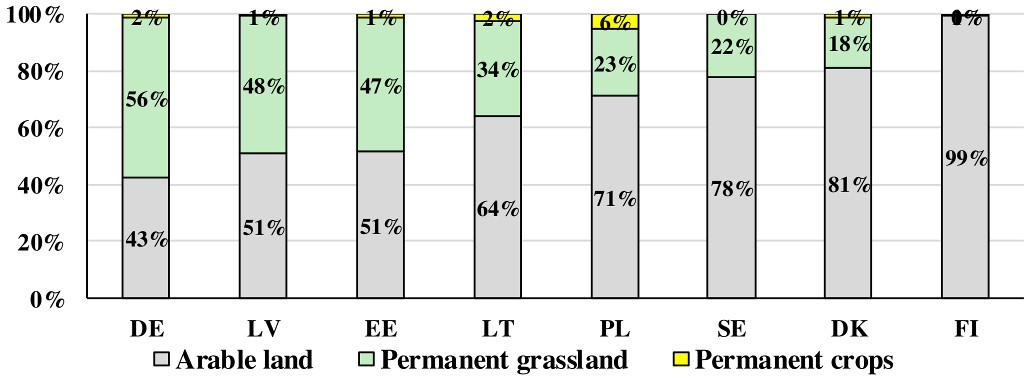


Fig. 5. **Share of organic UAA by use type in Baltic Sea countries, 2017**

Diverse farming systems

The diversification of agroecosytems in the form of polycultures, agroforestry systems, and crop-livestock mixed systems is accompanied by crop diversification, maintaining local genetic diversity, animal or livestock integration, organic soil management, water conservation and harvesting, and general enhancement of agrobiodiversity [25]. Diversified farming systems also enhance the regulation of weeds, diseases, and insect pests, while increasing pollination services [5]. Besides, diversified agroecosystems maintain soil fertility, crop production, and pest regulation [9; 25]. The results of comparison of the share of agricultural land under diverse farming systems in Latvia show that farming systems are simplified (Table 5).

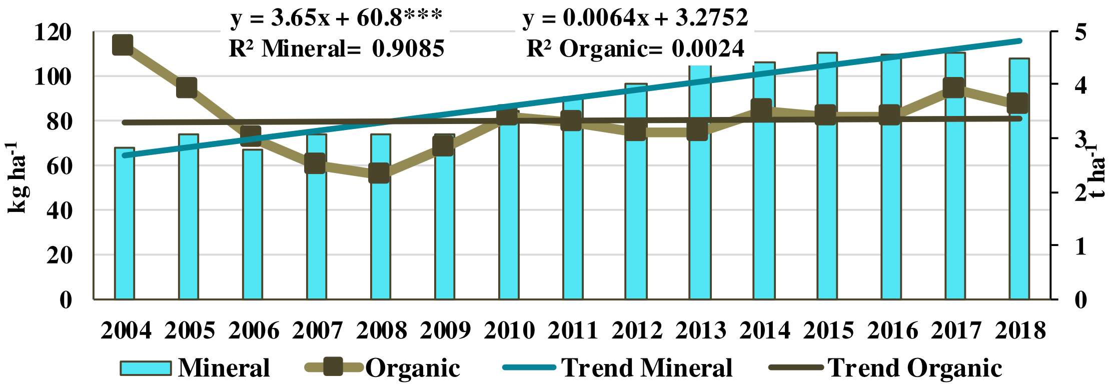
Only two farming systems, which are based mainly on usage of intensive production technologies, occupy about 70 % of total agricultural land. For example: (i) 51.9 % of land are used as arable land for field crop production; (ii) 17.7 % – for dairy farms. Moreover, economically stronger farms – in the higher economic size class (i.e. also larger ones) – occupy the largest share of UAA of both farming systems.

The high share – 51.9 % (Table 5) cultivation share of field crops, mainly as monocultures, leads to a decrease in soil fertility and statistically significant increasing application of mineral or inorganic nitrogen fertilizers (Figure 6). Moreover, the high share of cropping, in particular cereals' cultivated farms, reduces the availability of organic fertilizers (livestock manure) in farms and their application.

Table 5

Share of UAA by type of farming in farms of various economic size in Latvia, 2016

Type of farming	Share from total UAA, %						
	Total	Economic size class of holding, thou EUR					
		≤ 3.9	4.0-14.9	15.0-49.9	50.0-99.9	100.0-499.9	≥ 500.0
Total	100 %	17 %	12 %	6 %	9 %	11 %	26 %
Field crops	51.9 %	18.4 %	7.2 %	3.1 %	6.2 %	9.4 %	32.2 %
Vegetables	0.6 %	15.7 %	10.7 %	9.1 %	19.8 %	10.7 %	24.0 %
Permanent crops	0.3 %	69.0 %	8.6 %	3.4 %	6.9 %	3.4 %	6.9 %
Mixed cropping	2.0 %	38.4 %	18.6 %	7.1 %	8.7 %	7.9 %	10.7 %
Dairying	17.7 %	7.4 %	12.6 %	8.1 %	13.9 %	13.9 %	27.4 %
Grazing livestock	9.2 %	18.4 %	20.7 %	13.4 %	18.4 %	16.5 %	12.7 %
Granivores	1.4 %	71.0 %	5.9 %	1.5 %	1.8 %	0.7 %	2.6 %
Mixed livestock	1.9 %	22.3 %	39.9 %	12.2 %	13.8 %	7.7 %	4.8 %
Mixed cropping and livestock	15.0 %	10.9 %	19.9 %	7.7 %	10.0 %	9.2 %	20.2 %



*** - $p < 0.001$

Fig. 6. **Trend of mineral nitrogen fertilizers and organic manure usage in Latvia, 2004-2018**

Conclusions

1. In Latvia, the share of the agricultural land area, in which conservation tillage methods are implemented, is only 8.8 %. Moreover, as agricultural machinery, which is necessary for implementation of gentle or sustainable soil cultivation - reduced or no-tillage method, is expensive and needs additional investment, these practices are implemented by farms with higher economic size.
2. As Latvia's farms of the economic size from 100 to 500 and more thousand EUR leave in winter time as bare soil 57.5 % of total arable land, but farms of the economic size from 3.9 to 24.9 thousand EUR only - 19.8 %, the conclusion could be made that economically strongest and more intensive crop farms are less sustainable (i.e. less agri-environmental or agroecologically oriented), comparing with less economically developed farms.
3. The share of agricultural land under cereals, which characterises monoculture and unsustainable crop farming, in some Baltic Sea region countries is relatively high (Poland, Lithuania, Denmark, etc.). It varies from 40 % in Sweden to 68 % in Poland. In the period from 2005 to 2013 measures were implemented to increase the diversity of crops in all countries, which were successful, except in the Baltic States. For instance, in Poland— the cereal share decreases by 11.4 %, but controversially, the share of cereals increases by 6.3 % in Estonia, 14.0 % in Latvia and 21.4 % in Lithuania.
4. Only two farming systems, which are based mainly on usage of intensive production technologies, occupy about 70 % of total agricultural land in Latvia, from which 51.9 % of land are used as arable land for field crop production; and 17.7 % - for dairy farms. Moreover, economically

stronger farms – in the higher economic size class (i.e. also larger ones) – occupy the largest share of agricultural land of both farming systems.

5. Considering that permanent cultures and crops mitigate soil degradation processes, as well as carbon loss, the latest tendencies of permanent culture decreasing, particularly in organic areas, is alarming. Comparing among the Baltic Sea region countries, the results show that Latvia has the second best result, because in Latvia arable land crops accounted for 51 % of the organic area, but permanent pastures and meadows covered 48 %.

Acknowledgements

This research was partially supported by both the project "INTERFRAME-LV" (No VPP-IZM-2018/1-0005) within the National Research Program "Challenges and Solutions of the Latvian State and Public in the International Context" and the Collaborative Project "Advanced farming systems for environmentally friendly and efficient crop production in Latvia" (No 19-00-A01612-000011) funded by EAFRD, supported by the Ministry of Agriculture and Rural Development Service.

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