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Spatial disparity and environmental issues of organic agriculture

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Abstract. Food systems are major drivers of such global environmental problems as a decrease in biodiversity, degradation and fragmentation of habitats, use of fertilizers and pesticides, and water pollution. To deal with the environmental issues caused by agriculture at the European level, agri-environmental measures, including organic agriculture, through Common Agricultural Policy (CAP) are introduced to alleviate the detrimental impacts of agriculture. As it is still not clear whether agri-environmental measures, including organic agriculture, contribute unambiguously to the goals set by the CAP and the impact of organic agriculture on water quality is of high uncertainty, this study aims to analyse the spatial disparity of organic land and its impact on the environment by probing into the connection between the location of organic lands and water quality. The paper is based on a study of spatial analyses of organically managed land, its structure, and its relation to water bodies with a significant load of dispersed pollution from agriculture as well as the statistical analysis of the relationship between organic agriculture and water quality. The research was carried out in Latvia and done on a national level. This paper highlights the necessity for a more goal-oriented approach to the implementation of specific CAP measures as well as gives a deeper understanding of a specific CAP measure - organic agriculture. The statistical analysis of the data confirms that the management of arable land with organic farming methods has the potential to contribute to improving and preserving surface water quality.

Key words: organic agriculture, spatial disparity, environment, water pollution, Latvia, Eastern Europe, common agricultural policy (CAP).

INTRODUCTION

Global food systems use natural resources intensively and are responsible for up to 50% of all anthropogenic environmental pressure (Willett et al., 2019). Food systems are significant drivers of such global environmental problems as a decrease in biodiversity (Maxwell et al., 2016; Benton et al., 2021), degradation and fragmentation of habitats, use of fertilizers and pesticides (Dalin & Outhwaite, 2019) and water pollution (Poore & Nemecek, 2019). The whole food system undoubtedly contributes to global environmental problems, but the agricultural stage is where the greatest environmental impacts occur (Garnett, 2014; Dalin & Outhwaite, 2019). One of the leading agricultural threats to the environment is excessive or unbalanced fertilization, thus, nutrients, especially nitrogen and phosphorus, still need to be fully used by plants. As a result, nutrient elements leak into waterways and through the soil into the groundwater (Piwowar et al., 2021).

To deal with the environmental problems caused by agriculture at the European level, in 1992 agri-environmental measures through Common Agricultural Policy (CAP) were introduced to alleviate the detrimental impacts of agriculture (Dedeurwaerdere et al., 2015). The agri-environmental measures provided payments to farmers who voluntarily committed to environmental measures (Boncinelli et al., 2016). Nowadays the member states of the European Union are given relatively large freedom to choose which specific environmental measures they will implement to achieve the goals set by the CAP. The number of agri-environmental programs and the share of agricultural land involved in them differs significantly among the EU member states (Zimmermann & Britz, 2016). Most agri-environmental measures are voluntary land management agreements, which provide compensation payments to farmers for income foregone by reducing the use of pollutants. Agri-environmental measures include such measures as, e.g., organic agriculture, intercrops and/or cover crops, catch crops, vegetation strips, more efficient management of livestock waste, extensive agriculture and others (Uthes & Matzdorf, 2013; Marconi et al., 2015).

In 2000 organic agriculture became one of the agri-environmental supported schemes (Cisilino et al., 2019). Nowadays, most Organizations for Economic Cooperation and Development countries support organic agriculture as a policy instrument to address environmental issues in agriculture (Vojtech, 2010). Today organic agriculture is admitted as a crucial instrument in reaching environmental goals set by the European Union (EU) as well - in May 2020, the European Commission introduced two strategies - Biodiversity Strategy to bring nature back into our lives (European Commission, 2020b) and a Farm to Fork Strategy for a fair, healthy and environmentally friendly food system (European Commission, 2020a), that both are mutually reinforcing, bringing together nature, farmers, business and consumers for jointly working towards a competitively sustainable future. Farm to Fork Strategy highlights the need of consumers to have access to safe, healthy, high quality and affordable food at the same time promoting environmental goals – increasing organic farming, reducing dependency on pesticides and antimicrobials, reducing excess fertilization, and others (European Commission, 2020a).

Although organic agriculture has been criticized for, e.g., lower yields (Connor, 2022), especially during the conversion period (Kuht et al., 2016), there is a list of benefits regarding the environment. Compared to conventional agriculture, organic agriculture is characterized by more nature and environment-friendly farming methods - it is forbidden to use pesticides and grow genetically modified crops and the use of antibiotics is limited. Research shows that areas cultivated with the methods of organic agriculture have a higher biodiversity (Rahmann, 2011; Tuck et al., 2014; Cisilino et al., 2019), reduced water pollution (Cambardella et al., 2015), have fewer pesticide residues in soils (Geissen et al., 2021; Parga et al., 2022), their natural soil fertility is preserved (Stubenrauch et al., 2021).

Nowadays, organic agriculture is one of the fastest-growing agricultural sectors of the world (Giampieri et al., 2022). It is present in 186 countries, covering an area of 71.5 million hectares (Ramakrishnan et al., 2021). The spatial distribution of organic agriculture in the EU is not equable, ranging from less than 1% of total agricultural land in Malta to more than 25% in Austria in 2019, but on average reaching 8.5% of utilized agricultural area (UAA) in the EU (Eurostat, 2021). The development of organic agriculture has been distinct in older and younger EU states as well. Over the last few years, younger EU member states from Central and Southeast Europe have experienced rapid growth in organic agriculture (Blaće et al., 2020). In Latvia, organically treated land started to increase rapidly just after Latvia acceded to the EU in 2004 (Pawlewicz et al., 2020), reaching 14,8% of the total utilized agricultural area in 2019 (Eurostat, 2021).

Even though the CAP is the EU's largest budget (Buckwell et al., 2017), it still needs to be clarified whether the funds used for agri-environmental measures contribute to the goals set by the CAP. It also refers to organic agriculture as despite there being a common EU-level legal framework, organic agriculture has developed differently in each Member State (Darnhofer et al., 2019) and the impacts of organic funds should be analysed taking into account different policy strategies regarding agriculture and rural development in each country that would allow comparing the efficacy of European fund implementation in other economic and political contexts (Casolani et al., 2021). Therefore, this study aims to analyse the spatial disparity of organic land and its impact on the environment by probing into the connection between the location of organic lands and water quality.

Researchers are revealing reduced water pollution in areas treated with organic methods (Cambardella et al., 2015), still the impact of organic agriculture on water quality is of high uncertainty. Although the variation of nitrogen runoff in organic systems is very high and depends on the specific management practices used, it is assumed to be lower than in conventional farming (Seufert & Ramankutty, 2017). Balanced nutrient management on the field, as well as keeping water within fields and capturing water runoffs may retain the nutrients on the farm and prevent their runoff into water bodies (Sivaranjani & Rakshit, 2019). Meanwhile, the application of compost is considered to decrease nitrogen and phosphorus runoff. Specifically, the active organic matter and living organisms in the soil can increase the storage capacity of soil and thus limit the runoff of nutrients and chemicals (Parizad & Bera, 2021). While the effect size of organic agriculture on water quality is still being determined, various positive impacts are evident. Thus, in this research, we expect that there would be a negative relation between the share of organic land in arable land and nitrogen concentration.

Thus this research addressed the knowledge gap resulting from the need for studies on the agri-environmental measure's contribution to the goals set by the CAP as well as to the ambiguity of the impact of organic agriculture on water quality. The research findings will improve our understanding of the spatial disparity of organic land and its impact on the environment, specifically, the potential improvement and preservation of surface water quality.

MATERIALS AND METHODS

The research was carried out in two stages. During the first stage (1) the analyses of the structure of organically managed areas, (2) the spatial analyses of organically managed land and (3) their relation to water bodies with a significant load of dispersed pollution from agriculture were done, while on the second stage analysis of the relationship between organic agriculture and water quality was carried out.

Analyses of the spatial disparity of organic land

In the study, the Geographical Information Systems (GIS) approach is used, performing spatial data analysis of organically managed areas and their relation to water bodies with a significant load of dispersed pollution from agriculture. In the study data from the Rural Support Service (RSS) was used, i.e., spatial data of all fields that were applied for the CAP support for organically managed areas since 2013. The data contained spatial information about each organically managed field as well as the linked database to it, containing information about the type of crops grown and farmland use in each specific field. To evaluate the location of organic farming areas, the trends of changes, and their connection with the environmental target areas, spatial data analysis was carried out in a 5×5 km grid for the entire territory of Latvia. In 2783 quadrants of the grid, data on indicators of organic agriculture were collected, calculations were made, and changes in organically managed areas in 2020 about 2013 were analysed.

The GIS approach was applied, computer program ArcMap 10.6.1 was used to collect, analyse and create images of spatial data. The data was linked to the Latvian geodetic coordinate system (LKS-92). As a result, choropleth maps of organically managed land in Latvia by 5×5 km grid in 2020 as well as changes in organically managed land areas in 2020 compared to the 2013 5×5 km grid were made applying the Jenks natural breaks classification in the case of organically managed land in 2020 and manual intervals classification in the case of organically managed land changes.

Analyses of water quality and organic lands

During the second research stage analysis of the relationship between organic agriculture and water quality was done based on the division of water bodies according to the current River Basin Management Plans (RBMP). In Latvian water management, 'surface water body is a discrete and significant element of the drainage system of surface water: a watercourse (river, stream, channel or part thereof), water body (lake, pond, water reservoir or part thereof), as well as other transitional waters or a stretch of coastal waters' (Water Management Law, 2002). The analysis included water bodies with a significant impact from agriculture on running water. According to the methodology for assessing agricultural loads in RBMP, it is generally assumed that the impact of agricultural pollution is present in water bodies with a 20% or higher share of arable land (LEGMC, 2022). However, other factors are considered as well. Water quality was expressed as the average total nitrogen concentration per water body according to the annual monitoring data of the Latvian Environment, Geology, and Meteorology Centre for the year 2020. Based on spatial data analysis created by authors the share of organic land was expressed as the proportion of the land area involved in the measure of Organic farming (OF) from the total arable land area in the water body. The initial analysis included data for 99 water bodies. The data load was limited by the organic land presence in water bodies and the availability of data on nitrogen concentrations.

First, to assess whether the presence of OF in arable lands might be related to lower nitrogen concentrations, we compared the average nitrogen concentration between two groups - water bodies with a significant share of OF in arable land (> 5%) (n = 55) and water bodies with a low share or absence of OF in arable lands (< 5%) (n = 44). The difference between the groups was measured with Student's t-test. The distribution of the average nitrogen concentrations in the two groups is presented in Fig. 1.

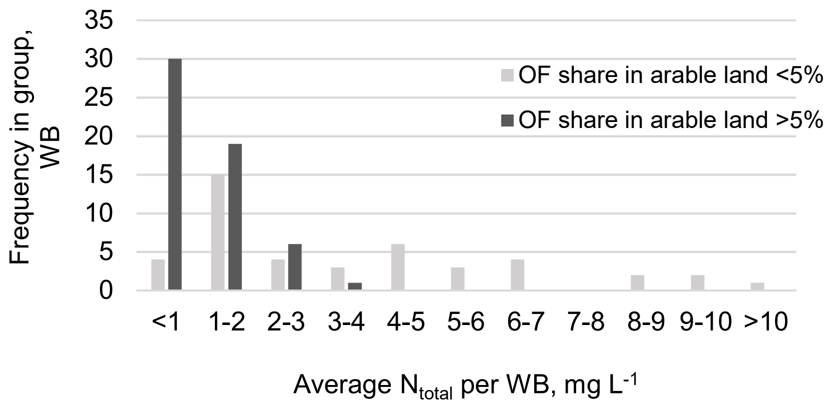

Figure 1. N_{total} distribution in groups of WBs with OF share < 5% and > 5% from arable land.

Further, a pairwise correlative analysis was performed to test the potential strength and direction of the association between two variables - the nitrogen concentration and the share of organic farming land in arable lands. Data for both variables are expressed per water body. Initially, the data were tested for normal distribution with the Shapiro-Wilk test. After excluding the extreme values, the data set for correlative analysis decreased to 89 water bodies. The distribution of the two variables is presented in Fig. 2.

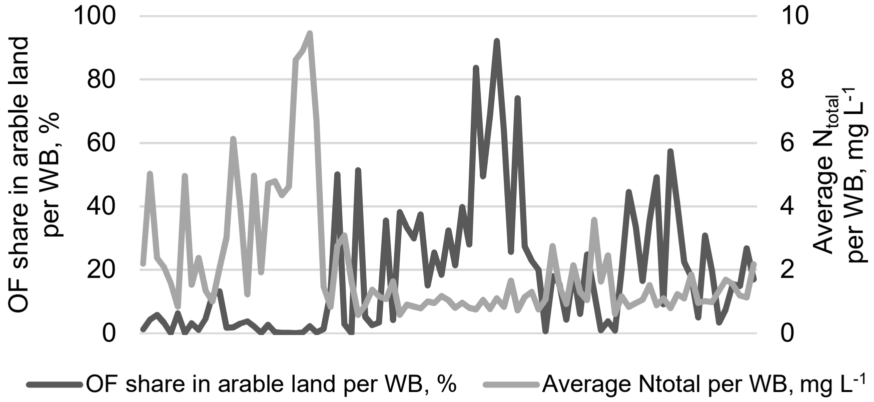

Figure 2. Distribution of OF share and N_{total} in the analyzed water bodies.

Considering the non-linear relationship between the share of organic land and nitrogen concentration, the relation between the two variables was assessed with Spearman's correlation coefficient, which allows testing the strength of a monotonic relationship between the two variables. The interpretation of Spearman's correlation coefficient was similar to that of Pearson's - values closer to ±1 indicate a stronger relationship between the two variables. Considering the impact of the share of arable land on nitrogen concentrations, the correlation between the two variables was conditioned on the share of arable land in the water body area. A one-tailed test was performed to determine the statistical significance of the correlation, which allows for testing a hypothesis for one-sided (positive or negative) distributions.

RESULTS

The development of organic agriculture in Latvia dates back to 1990 when the first organic farms appeared. More dynamic growth of organically treated land began after 2001 when in the Law on Agriculture, organic farming and state-assigned subsidies for this farming method were defined (Melece, 2010). After Latvia joined the EU in 2004, the rapid growth of organic agriculture started (Pawlewicz et al., 2020) and the number of organic farms increased more than four times (Melece et al., 2009). Although 14.8% of the total utilized agricultural area in Latvia was certified as an organic farming area in 2019 (Eurostat, 2021), the share of organic agriculture in the output of agriculture was only 6.8% in 2019 (Benga, 2020), indicating to the undeveloped economic potential of organic agriculture. One of the explanations is the fact that even nowadays, there is still an insufficiency of specific varieties suitable for organically managed areas (Zarina et al., 2021). The growth of organic agriculture is also indicated by the fact that in Latvia, similar to the EU, support for organic agriculture in the RDP 2014–2020 has significantly increased compared to the previous planning period. In Latvia, the total support for introducing and implementing organic farming practices has increased by 58% - from 122.4 million euros RDP in the 2007–2013 period to 194.3 million euros in the RDP 2014–2020 period (Benga, 2020).

Structure and spatial disparity of organic land in Latvia

In Latvia, mainly due to the interaction of physio-geographical conditions and the economical use of land resources, areas with different distributions of agricultural land, as well as management intensity, have been formed. The most significant proportion of OF areas is mainly concentrated in the eastern part of Latvia (Fig. 3.) in the regions of Vidzeme and Latgale. A smaller proportion of OF areas is typical in the central part of Latvia in Zemgale, where the most fertile soils are found, and already historically, the structure of agricultural land is dominated by arable land, as well as in Pierīga, where despite the much higher sales potential of organic products, there are few organically managed areas.

Figure 3. Organically managed land location and rate in Latvia 2020, in a 5×5 km grid.

The impact of agriculture on the environment is related to the intensity of use of agricultural land, which is often characterized by its structure of it, i.e., types of use - arable land, cultivated grasslands, permanent grasslands, and perennial plantations. As the maintenance activities of each type of land use differ, e.g., cultivated grasslands are ploughed no less than once in 5 years, fertilized and seeded, while semi-natural grasslands, that is, one type of permanent grasslands, are low-input agroecosystems dominated by natural species (Vinogradovs et al., 2020), different environmental impacts from agricultural activities can be observed in different places. The environmental impact is more significant in areas with a higher proportion of arable land associated with higher agricultural intensity, as opposed to areas where grasslands are more widespread and organically managed areas are more common. In Latvia, in general, the organically managed areas are increasing. Changes are also taking place in the structure of the arable land of organically acquired areas. If up till 2014 the dominant proportion of organically managed land was formed by grasslands (Fig. 4.) - both cultivated and permanent grasslands formed 79% of total organic land, then in 2020, the proportion of organically managed arable land has increased, reaching 36% of total organically managed land in Latvia.

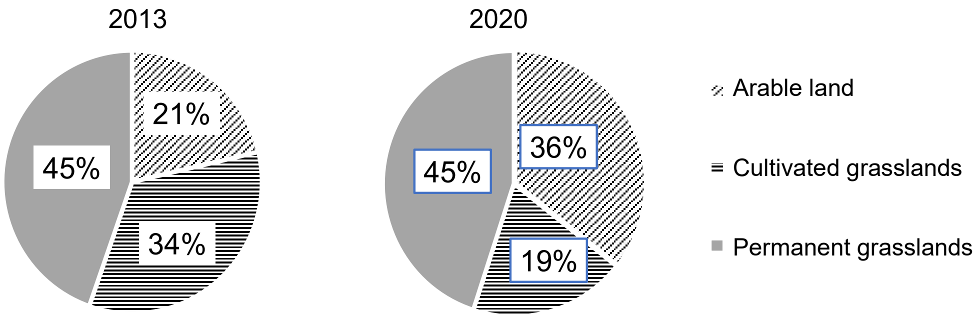

Figure 4. Structure of organically managed land in Latvia in 2013 and 2020.

From 2013 to 2020, the area of OF in Latvia has increased by a total of 82,641 ha (Fig. 5). The most significant increase in OF areas is primarily characteristic of territories with initially a relatively high share of OF areas. This indicates that the growth of OF is partially explained by the expansion of already existing territories on organic farms. In the meantime, it is essential to emphasize that in territories with a low proportion of OF areas, no significant changes have taken place in general, which indicates that the development of OF is not territorially uniform and that the tools promoting the development of OF mainly have a reinforcing effect only on the expansion of already existing OF areas, but are not practical about the territories, in which organic farming methods are used the least. In many places in Latvia, a decrease in the areas of OF is also observed, although such areas are not significantly large. In general, the reduction of organically managed areas has little territorial characteristics.

Agriculture is an essential source of diffuse pollution with nitrogen and phosphorus compounds in both inland waters and the Baltic Sea. In Latvia, no monitoring is carried out to assess the impact of organic farming on water quality indicators, but if we think about areas where water quality preservation, including reducing nitrogen runoff, would be most important and should be done as a priority, water bodies with a significant load of diffuse pollution from agriculture must be mentioned. These water objects are evaluated during the development of river basin management plans, determining the loads caused by agricultural pollution and mapping the surface water objects with a significant load of dispersed pollution from agriculture. There is a risk of failing to achieve a good ecological status in such water bodies. Since one of the environmental benefits of organically managed areas is improving water quality, the location of organically managed areas near water bodies with a significant load of dispersed pollution from agriculture would be critical. Therefore, we analysed the spatial disparity between organically managed arable land and the aforementioned water bodies (Fig. 6).

Figure 5. Changes in land areas managed with organic methods in a 5×5 km grid in Latvia. The situation in 2020 compared to 2013.

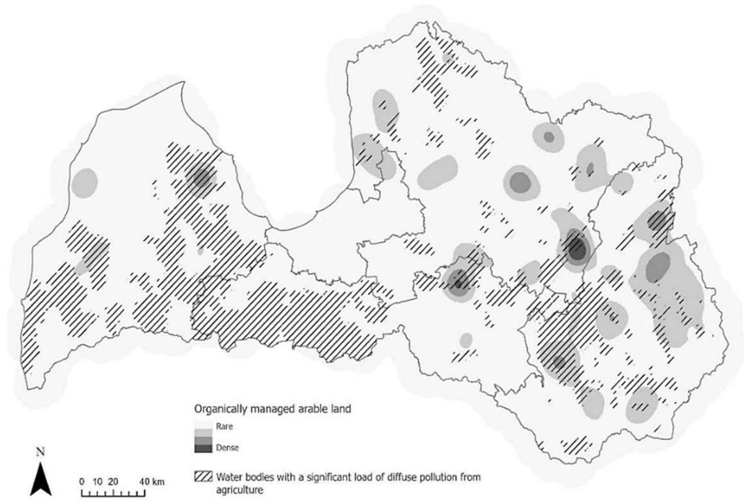

Figure 6. Organically managed arable land and water bodies with a significant load of diffuse pollution from agriculture in Latvia, 2020.

As can be seen in Fig. 6, currently, these territories overlap relatively minor, so the contribution of organic agriculture in improving water quality in Latvia can be assessed as preventive and minor. Most organically managed areas are located outside the risk water bodies, therefore, the spatial analysis of the data shows that the contribution of organic agriculture to the improvement of surface water quality is not significant. However, to validate this finding, we also performed a more detailed statistical analysis of the data.

Correlation: OF and water quality

As mentioned above, the share of organic agriculture in arable land was expected to be related to the average nitrogen concentrations in water bodies. Student's t-test indicates a significant difference in nitrogen concentrations between the two groups (Fig. 7). The average N concentration for the group with OF < 5% is 3.83 mg L^{-1}. In contrast, in the group with OF > 5%, it is significantly lower - 1.23 mg L^{-1}.

For the type of association between the two variables, we expected that the share of organic land in arable lands would be negatively associated with nitrogen concentration. Spearman's correlation indicates a significant weak negative association between the two variables ($\rho = -0.32$) at a 1% significance level when conditioned on the share of arable land in water bodies (Fig. 8).

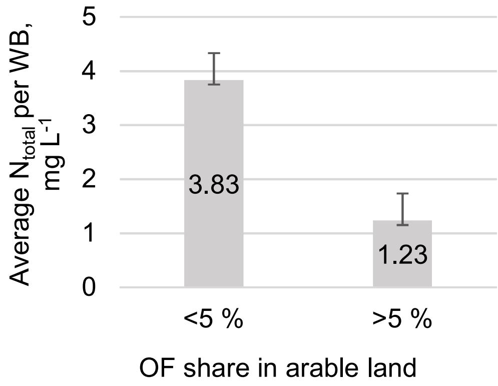

Figure 7. The comparison of N concentration in water bodies with and without OF.

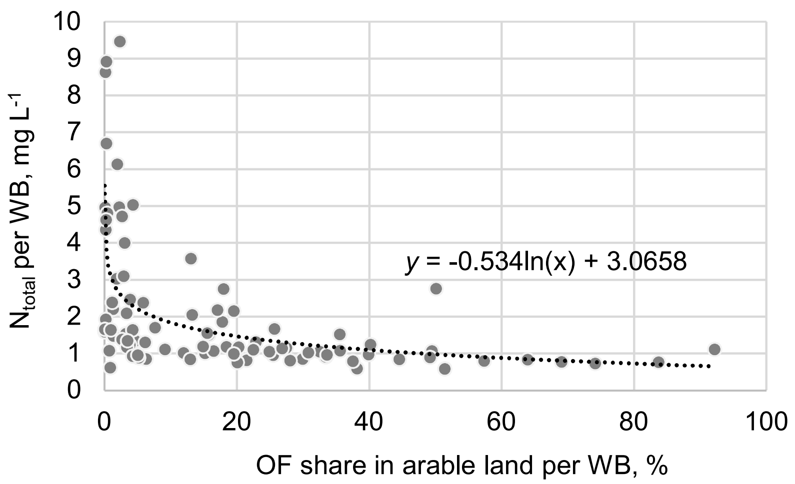

Figure 8. The relation between the share of OF in arable land and total nitrogen concentrations in water bodies (WB).

This confirms the expected assumption that a higher share of OF in arable lands is associated with lower concentrations of the total N in water bodies. The significant negative correlation between the share of OF and N concentrations points to a possible contribution of OF in increasing the quality of water bodies.

The correlation of our research analysis confirms that the average nitrogen concentration in water bodies decreases as the share of OF land increases, suggesting that OF measures might positively impact water quality. However, the association between the two variables could be stronger, indicating that the potential contribution of OF in improving water quality could be relatively higher. Various reasons may explain this. As seen in Fig.6., the overlap of OF lands and water bodies with a significant load of diffuse pollution from agriculture is low. Incredibly, only a tiny part of the areas with the highest share of arable land (e.g., Zemgale region) are organically managed, which points to the fact that in areas with the highest pollution risk, organic farming has little contribution. Simultaneously, in general, OF areas are primarily small and unevenly distributed, which most likely reduces their overall positive environmental effects.

DISCUSSION AND CONCLUSIONS

In this article, we have explored the spatial disparity of organic land and its impact on water quality. Although various measures are being introduced to improve water quality in the EU, their effect on improving water quality often needs to be clarified. Also, in Latvia, there is an insufficiency of research that would analyse water quality (Dumpis et al., 2021). Our research stresses the lack of monitoring that would allow us to assess the impact of organic agriculture on water quality. Previous researchers have admitted that problems in assessing the impact of implemented measures on changes in water quality indicators are caused by different aspects, such as (1) the implementation of measures at the national or even regional level, which can create significant mutual differences (Zimmermann & Britz, 2016); (2) lack of a common approach to describing the implemented measures (Nicholas et al., 2021); (3) lack of a common and transparent methodology for assessing the effectiveness of measures (Doehring et al., 2020); (4) lack of clear goals regarding the expected improvements in quality indicators or setting of non-quantifiable goals (Uthes & Matzdorf, 2013); (5) difficulties in tracking the flow of diffuse pollution and in simultaneously considering the many and spatially variable factors influencing it (Jansson et al., 2019) and (6) the high costs of monitoring water quality which can call into question the economic validity of the measures themselves (Bartkowski et al., 2021). Given the high monitoring costs and the complexity of measuring results, changes in water quality indicators are often assessed with a modelling approach (Reed et al., 2014; Jansson et al., 2019; Bartkowski et al., 2021). While in our research, we tested the data in real-life circumstances.

The obtained results of our research of the spatial and static analysis of the data confirm that the implementation of the organic farming measure needs a goal-oriented approach to improving surface water quality since the most significant areas are located outside the risk water bodies. But in particular, the statistical analysis of the data confirms that the average nitrogen concentration in water bodies decreases as the share of OF land increases. Thus, the management of arable land with organic farming methods has the potential to contribute to improving and preserving surface water quality. Our findings are especially important to keep in mind that EC has set a target of 'at least 25% of the EU's agricultural land under organic farming by 2030'. Therefore, it is necessary to introduce more targeted criteria in implementing OF in the future to increase the proportion of OF areas of water bodies with significant agricultural influence. Future research should also consider the agri-environmental measure's contribution to the goals set by the CAP by taking into account not only OF, but also other interventions and measures of new CAP Strategic Plans.

Until now, the impact of CAP measures on changes in water quality indicators is rarely evaluated separately. Primarily, the effectiveness of the measures is assessed for a combination of various environmental aspects and mainly at a local level. So far, attempts to assess the impact of agri-environmental measures on changes in water quality indicators have shown different results. Differences can be observed in agri-environmental measures, different studies, and various scales of water bodies (from local drainage systems to river basins). Also, our research has similar limitations regarding the territorial and scale context. Still, it gives a deeper understanding of a specific CAP intervention - organic agriculture - and its existing and potential contribution to the surface water quality and reveals the necessity for a more goal-oriented approach to implementing specific CAP measures.

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