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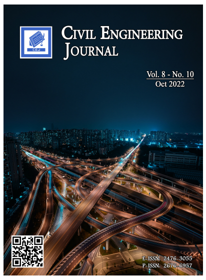

Nutrient-Rich Organic Soil Management Patterns in Light of Climate Change Policy

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Abstract

Nutrient-rich organic soil management in agriculture is among the critical sources of greenhouse gas (GHG) emissions globally and at the European level, where the most significant effects are observed in Northern, Eastern, and Central Europe. Growing climate change mitigation targets urge the need to assess and analyze current organic soil management patterns and policy planning and look for appropriate future management strategies. The objectives of this research were to assess the nutrient-rich organic soil management patterns in Latvia during the last decade and to conclude whether organic soil management in agriculture has been climate change mitigation targeted and driven by agriculture support policy. We analyzed the complex, two state-level databases based organic soil data set by using the multidimensional approach of the research methods, including graphical, spatial, correlation, factor, and cluster analysis. Our results revealed the lack of purposeful organic soil management planning in light of the climate change policy in Latvia during the research period and the inexpediency of the agriculture support policy in this regard. The research introduced an innovative methodological approach for the analysis of organic soil management patterns and policy impacts, as well as opened the necessity for a revision of the nutrient-rich organic soil management perspective in light of climate change mitigation targets.

Keywords: Organic Soil; Agriculture; Climate Change; Factor and Cluster Analysis; Latvia.

1. Introduction

Global observations confirm the impact of anthropogenic carbon dioxide emissions on the climate system, and it is recognized that this impact is growing and affecting all continents [1]. Part of anthropogenic GHG emissions is associated with land use and, specifically, soil management. Globally, cropland covers about 12-14% of the non-freezing land area, while managed grassland has about 37% [2], and part of this area is agricultural land with organic soil. Global peat soil coverage is approximately 4 000 000 km^2, or 3% of the Earth's land area [3], and is mainly localized in the boreal climate regions [4]. Different management practices for organic soil determine the decomposition of the previously accumulated carbon, resulting in the release of increased levels of carbon dioxide and nitrous oxide [5]. Historically, peatland ecosystems have often been drained for peat extraction and later subjected to various land management scenarios, including conversion to cropland and grassland with organic soil. Currently, one of the typical organic soil management methods is agriculture management (arable land) [6].

The spread of organic soil in Europe is geographically uneven, with a more significant proportion found in Northern, Eastern, and Central Europe. Organic soil occupies approximately 7.7% of the total area of the European Union (EU)

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countries. In some countries, like Latvia, Lithuania, Ireland, the United Kingdom, and Finland, GHG emissions from managed organic soil make up more than a fifth of the total national emissions [7]. The evaluation of organic soil distribution in Latvia is burdened by the lack of actual cartographic information and differences in national versus international definitions. The data set used for the National greenhouse gas inventory is based on digitalized historical soil mapping information and results of national research to detect the current organic soil distribution in cropland and grassland [8, 9]. According to the National greenhouse gas inventory submission for 2021, in 2019, organic soil covered 6.4% of total agricultural land (cropland and grassland) in Latvia, but GHG emissions associated with the management of this land made up more than 30% of emissions from agriculture activities [10]. The socio-economic importance of organic soils in Latvia is determined by the fact that organic soil in greater or smaller proportions can be found in around 48% of all agricultural holdings [11].

Growing international (UNFCCC) and EU-level (European Green Deal) climate change mitigation targets are attributed to all sectors included in a GHG inventory. Organic soil-related GHG emissions are part of two sectors: the sector of agriculture and the sector of land use, land use change, and forestry. By signing the UN Framework Convention on Climate Change and becoming a member state of the EU, Latvia has committed to fulfilling its climate policy obligations. Considering the high organic soil proportion, GHG emissions associated with this soil are highly relevant in Latvia's movement toward climate change target achievement. Organic soil relevance is also mentioned in national sectorial and climate policy planning documents. The draft document of the Common Agriculture Policy 2021–2027 Strategic Plan of Latvia highlights the lack of organic soil data, including for more precise estimates of GHG emissions, and includes remarks on research and more targeted support needs to minimize GHG emissions [12]. The strategy of Latvia for the Achievement of Climate Neutrality 2050 captures Latvia's climate policy goals, including the national climate neutrality target for 2050 and the GHG emission neutrality target for land use, land use change, and the forestry sector by 2040. The strategy highlights the high amount of GHG emissions from organic soils in Latvia's arable land and grassland, the necessity to develop an understanding of organic soils related processes and their impact on and relation to the surrounding environment as well as a need to investigate the actual organic soil area and do the regular soil information updates [13].

Although the relevance of organic soil-related GHG emissions is currently recognized in national policy planning documents, the high prominence of the issue has emerged only in recent years (in general, since 2019). Organic soils have been mentioned in the policy planning documents of the previous periods, but the significant GHG reduction potential has not been reflected so far. Several national climate change and agriculture policy-related documents, such as the informative report on LULUCF actions in Latvia [14]; reports to the European Commission and UNFCCC on policies, measures, and GHG projections [15, 16]; Latvia's National Energy and Climate Plan (NECP) [17]; and Latvia's Rural Development Programme 2014–2020 [18], include climate change mitigation measures attributed to agriculture land management but with only an indirect effect on agriculture land with organic soils. Among these measures, the development and adaptation of drainage systems in cropland, the support of the introduction and promotion of integrated horticulture, the introduction of legumes, and the maintenance of biodiversity in grassland can be mentioned, but none of the actions has been directly targeted at organic soil management, thus any impact, if any, will be only indirect.

A somewhat similar situation can be observed at the EU level. However, at this level, some range of specifically organic soil targeted climate change mitigation measures can be found - conversion of arable land on organic soils to nature (natural habitat) or grassland and pasture, converting cropland from annual tillage crops to perennial crops, use of submerged drains and raising water levels for grassland areas with deep drainage, afforestation of organic soil and rewetting of organic soil [19]. Looking at the Baltic States` level, Latvia's situation, in general, mimics the regional one. When examining Estonian and Lithuanian policy planning documents by 2020 (Estonia's Rural Development Programme 2014 – 2020 and Common Agricultural Policy, Estonian Nature Conservation Development Plan until 2020, Estonian Earth's Crust Act, Lithuanian Inter-institutional action plan on the implementation of the Goals and Objectives of the Strategy for the National Climate Change Management Policy, Lithuania's Rural Development Programme 2014 – 2020), no particularly organic soil management targeted measures can be found, all mentioned measures are attributed to the overall agriculture land management thus effect on organic soil can be only indirect [20].

To assess the historical organic soil management patterns in Latvia and evaluate possible interrelations among different variables (including policy planning through the EU's support) characterizing management patterns, we analyzed Latvia's organic soil data set using graphical, spatial, correlation, factor, and cluster analysis. Thus, this research aims to assess nutrient-rich organic soil management patterns in Latvia in light of climate change policy and to conclude the drivers of the management changes and whether organic soil management for agriculture purposes in Latvia is targeted with regards to climate change policy. The hypothesis set for this research is that the current management of the nutrient-rich organic soils in agriculture in Latvia is not purposefully targeted toward climate change mitigation challenges.

2. Data and Methods

The study area of the research is the territory of Latvia (Figure 1). The researched plots are evenly distributed across the whole country.

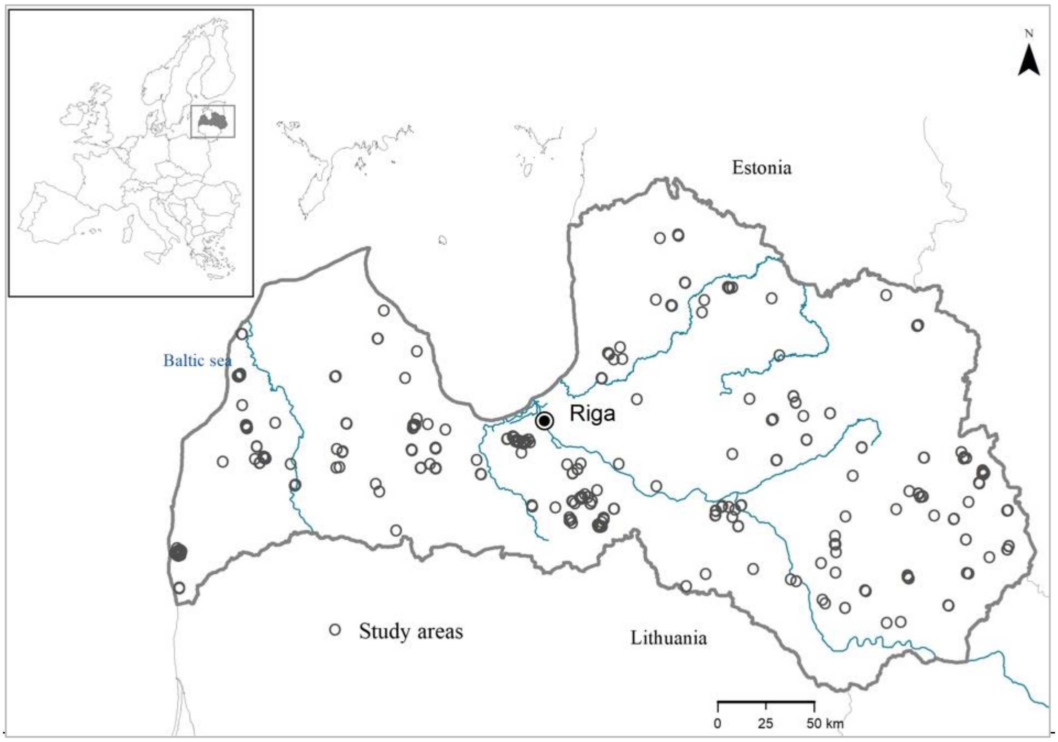


Figure 1. Map of studied areas in Latvia

Latvia is a North-Easter Europe country in the Baltic Sea region with a total area of 64,594 km^2, and the coverage of agricultural land in 2021 was 1.97 ml ha [21]. Climatic conditions, where precipitation dominates over evapotranspiration poor natural drainage, among other aspects, have determined historical preconditions of peat formation and accumulation [22] and led to the organic soil distribution in Latvia. Lack of up-to-date soil cartographic information (the newest geospatial information is based on soil mapping materials prepared from 1960 to 1991) [23] and inconsistencies between national and internationally used soil classifications hinder the precise assessment of the actual organic soil distribution. Most agricultural land, including nutrient-rich organic soil, was ameliorated in the period 1966 to 1985 [24]. Thus mineralization processes could have negatively impacted soil organic carbon content and organic soil distribution [25], which is an additional obstacle hampering the availability of precise, georeferenced data set covering the whole territory of Latvia. To analyse the management impacts within this research, we looked for the highest available accuracy data on organic soil area, policy and implemented practices. Thus we decided on the data set merging organic soil information based on recent measurements (laboratory analysis) and information about provided EU's support and applied farming practices. Since the genesis of organic soil in agricultural land is of minerotrophic origin and the best practice suggested by IPCC guidelines for temperate climatic regions in case of the lack of detailed soil information is to assume that all of the organic soil is nutrient-rich, we used this assumption also for this research.

An overview of the methodological approach is summarized in Figure 2. Firstly, we identified the relevant literature and EU and national policy for the assessment of the current organic soil management in the light of climate change (Step 1), then assessed and selected the national databases (Step 2 and Step 3), merged the selected databases and technically prepared the data set for statistical analysis (Step 4). The justification for the selection and description of data sources and databases is provided in the following paragraphs. Then we ranked organic soil management patterns according to their climate impact, did a retrospective graphical analysis and generated maps of the management patterns for the analysed years (Step 5). Finally, to understand the interrelationships of organic soil variables and conclude the impacts (Step 8), we used two steps of statistical data analysis using factor and clustering approaches (Steps 6 and 7).

State Plant Protection Service of Latvia is an institution that carries out regular soil surveys based on farmers` and state` needs (*https://www.vaad.gov.lv/lv*). Although surveys do not cover the whole agricultural land area, the obtained data basis can be considered the best available data set precisely (laboratory analysis) identifying organic soil distribution in agricultural land. The EU's Common Agriculture Policy support data, including information about organic soil area, is gathered and stored by the Rural Support Service of Latvia (*http://www.lad.gov.lv/lv*). The Rural Support Service data set was considered the best available data source for support-based agronomical activities data regarding Latvia organic soil management. The methodological approach chosen for this research included merging these two data sets from 2012 to 2020, thus representing nine years of dynamics. 2012 was the first year rural support data were available in digital format in Latvia. The cadastral number was used as unique identification in merging the Rural Support Service and the State Plant Protection Service data.

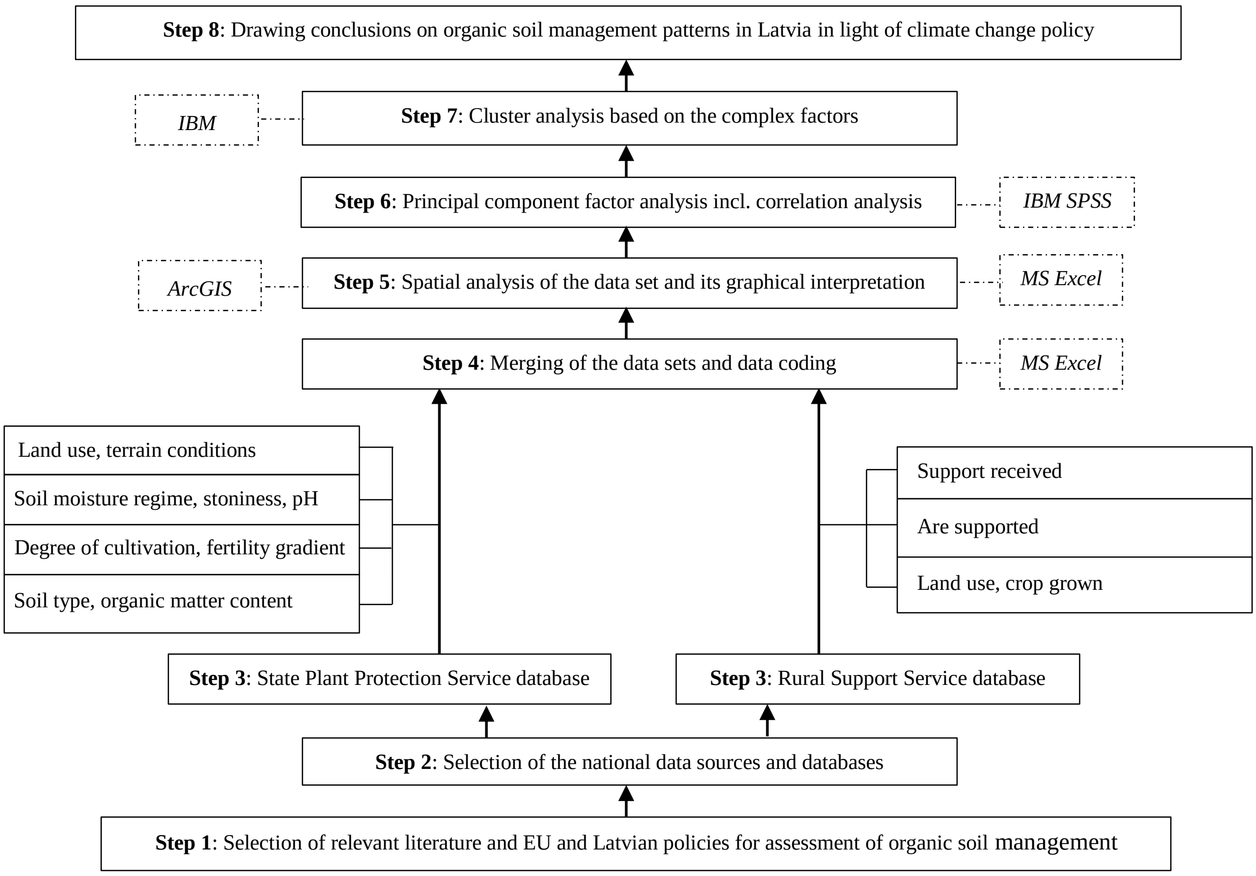


Figure 2. Flowchart of the structure of the study and the methodological steps followed to assess the nutrient-rich organic soil management patterns

Initially, all the surveyed areas were listed, but then the research limitation was imposed to exclude the areas with marginal soil carbon content and areas for whom some variables were missing or resulted in 0. The final data set of the organic soil area analysed in this research contained 2547 georeferenced records. The analysed data set covers approximately 30% (48 901 ha) of the total organic soil area of Latvia if calculated against the organic soil area in agricultural land used in the National Greenhouse Gas Inventory calculations in 2022 (166 800 ha) [26]. However, the actual proportion of the research coverage could be higher because the organic soil area reported in the National Greenhouse Gas Inventory has not been tested in the field and could include areas where mineralization processes have already taken place. The data set was used for graphical, spatial, factor and cluster analysis.

Simple spatial analysis was done by using ArcGIS tools and included a grouping of the spatial data on agronomical activities by the impact on climate change. Based on international guidelines for national GHG inventories [27] four most common crop groups were identified, moving from the crop type with the most negligible impact on climate changes to the crop type with the highest impact in the following order: (1) perennial plantings; (2) grassland; (3) legumes; (4) vegetables; (5) cereals, oilseeds and corn. The spatial analysis aimed to look for geographically identifiable EU support policy-based changes in cropping patterns for the whole data set and the period (2012 - 2020). To better characterize the results of spatial analysis, it was accompanied by a graphic interpretation of the data matrix.

We used factor analysis, namely principal component factor analysis, as a multidimensional method for researching interrelationships of different variables and determining complex factors underlying these relationships to analyse various selected variables associated with organic soil management. Factor analysis allowed us organize and structure the data set. The relationships among the 12 selected variables (Table 1) and factors were measured by using correlation analysis. Factor analysis explains the detected correlation relationships by identifying the factors that determine the correlation [28]. We used factor analysis to determine the interrelationships among different variables associated with organic soil management in the research area and find complex factors explaining these relationships, including support measures.

Using the complex factors obtained by factor analysis, a cluster analysis was performed to identify the groups of agricultural land with organic soil receiving support, depending on the complex factors. As a set of tools and algorithms cluster analysis is useful and thus was used in this study to group different elements n into k (k>1) groups or clusters, based on their properties p (p>0) so that the clusters are homogeneous within the cluster (with maximally similar features), but are mutually heterogeneous at the same time [28, 29]. The number of clusters was determined by using the Elbow method. IBM SPSS Statistics 26 (Statistical Package for Social Sciences) was used to perform factor and cluster analysis for the entire set of observations of agricultural land with organic soil receiving support from 2012 to 2020.

Table 1. Variables used for factor and cluster analysis

No.	Variable	Description of the variable
1	Land use	Arable land, grassland, perennial plantings (0-20 years), perennial plantings (20-40 years), horticulture, set-aside area, overgrown agricultural land
2	Soil moisture regime	Regular moisture regime, periodically wet, wet, dry
3	Terrain conditions	Flat area, undulate plane, gentle slope – weak erosion, steep slope – medium to strong erosion, very steep slope
4	Soil stoniness	No stones, rare stones, pebbly areas, piles - individual large stones, many stones in different sizes
5	Soil organic matter content	Value in %
6	Soil pH_{KCl}	Value in a range from <4.6 to >6.5
7	Degree of cultivation	Low, medium, high
8	Soil type	Peat and peaty soil types according to the national soil classification
9	Soil fertility gradient	Fertility gradient in relative value units (<10 to >60)
10	Support received	Various EU support measures
11	Crop grown	Various crop cultures (e.g. perennial crops, grassland, horticulture crops, cereal crops, overgrown area)
12	Area supported	hectares

3. Results

3.1. Spatial analysis

In Latvia, several types of organic soil management systems can be identified – perennial plantings; grassland; legumes; cereals, oil crops, corn, and vegetables. From the perspective of climate change, some of them can be considered more climate-friendly soil management systems, like perennial plantings, grassland and growing of legumes, but others – GHG emissions intensive soil management systems, like growing of cereals, oil crop, corn, growing of vegetables. In this study, we analysed how these organic soil management systems have changed during the last decade and tried to identify the shifts in soil management systems. Graphical and spatial analysis of the data matrix from 2012 to 2020 indicated moderate shifts in organic soil management systems (Figure 3).

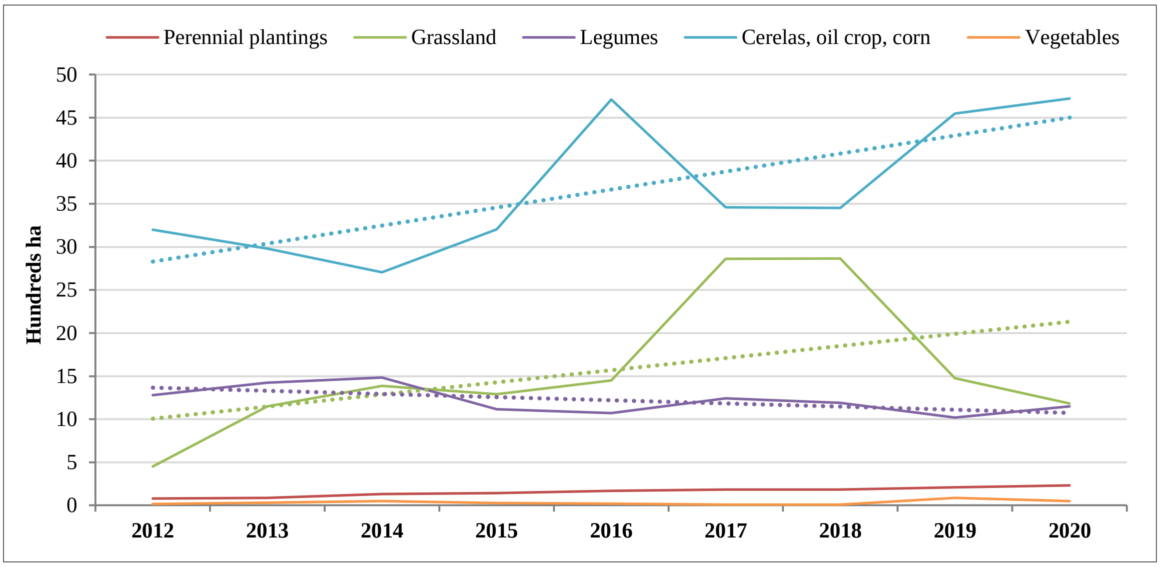
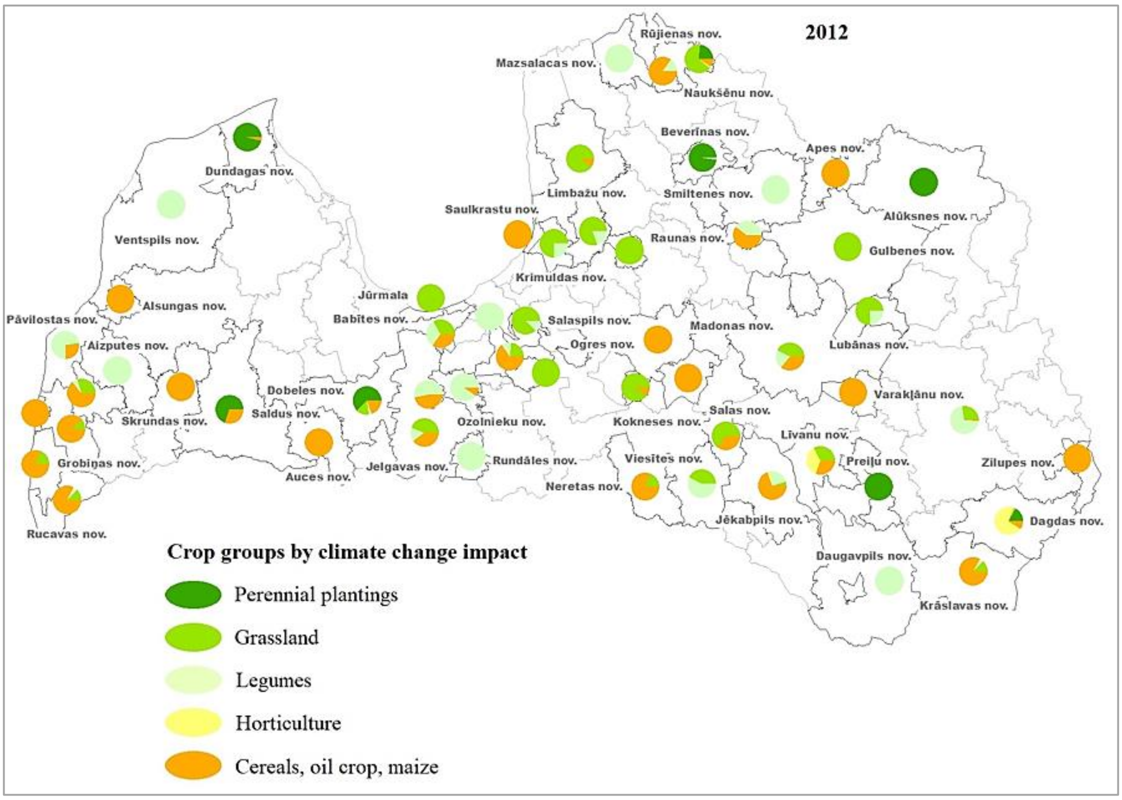


Figure 3. Organic soil management changes by crop groups in the research area (2012 - 2020)

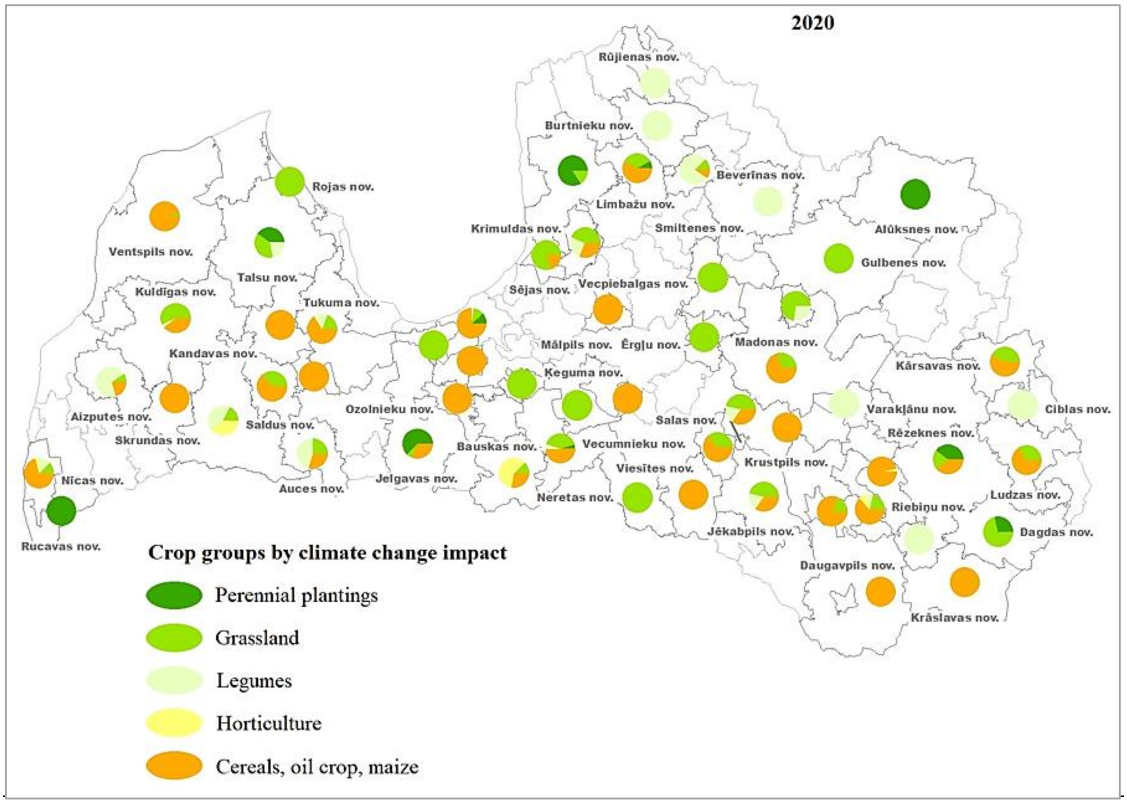
The general area of support receiving crops enlarged by 31% during the research period. That could be explained by the general activation tendencies of agriculture development in Latvia. During the last decades, the growth of agriculture production took place in the context of the dynamic economic growth of the country. The most rapid growth of agricultural output and crop output is observed for cereals and dairy products; the utilized agricultural area has grown by 9.1 % from 2010 to 2020 [30]. Following these tendencies, agricultural management of organic soil has grown as well as the application of the organic soil area for EU support. Detailed analysis of specific organic soil management systems shows that there can be identified growing trends for two systems – grassland; and cereals, oil crop and corn. During 2012-2020 managed area of grasslands in organic soils within the research data set increased by 61.9%. Very sharp grassland area increases were observed in 2017 and 2018. The general tendency of grassland increase could be explained by growing grass-fed husbandry and, consequently, grassland areas. Since significant policy changes for 2017 and 2018 cannot be identified, grassland shifts during these years could be random, short-term evidence. The area of cereals, oil crops and corn in organic soils has increased by 32.3%. In these two systems - grassland; and cereals, oil crop and corn we observed the most significant and reversal changes among the research years compared with other systems. These two cropping groups also have the greatest area coverage ratios (24% and 55%, respectively). For example area for growing legumes in organic soils during 2012-2020 decreased by 11.1% and comprized 18% of all organic soil management systems in 2020. But the area of perennial plantings in organic soils and the area for growing vegetables in organic soils has slightly increased but kept within the limits of no more than 2 % for perennial plantings and 1 % for vegetables.

Considering the climate change effect of different crops according to IPCC guidelines for national GHG inventories, the observed increase in perennial plantings (various berries, fruit trees and willows) and grassland (fallow area, various perennial types of grass and seed grass) area over the period 2012 to 2020 (by 66.1% and 61.9% respectively) can be evaluated as a positive shift towards a decrease in GHG emissions although there has also been a moderate increase in the area of crops associated with increased GHG emissions - cereals/oil crops/corn - by 32.2 % during the period. However, since the research area covers about 30% of the total organic soil area used for agriculture in Latvia, the tendencies instead of generalized conclusions can be indicated.

Analysis of the spatial dimension of the management shifts over the analysed period and research area (Figure 4) showed changing tendencies in geographical coverage. In order to compare if there are spatial changes in the geographical distribution of organic soil management practices, we have grouped all research plots by their belonging to a certain municipality. In total, 57 municipalities were covered in this analysis. Spatial analysis shows that management practices are not tied up to certain regions or municipalities. If we compare 2012 (the first year of the analysed period) with 2020 (the last year of the analysed period), only 7% of surveyed municipalities' organic soil management practices have not changed, while in the rest, 93% of analysed municipalities soil management practices have changed. However, some tendencies can be observed, indicating that specific organic soil management practices are more common in certain regions of Latvia than others. For example, in northern Latvia, perennial plantings, grasslands, and legumes are more common in organic soils. This could be explained by the fact that this part of Latvia is more mountainous than other regions and livestock farming is more common. While in the southern part of Latvia, crop farming is more common, which also reflects in organic soil management pattern occurrence - cereal, oil crops and maize growing.



(a) organic soil management by crop groups in the research area in 2012



(b) organic soil management by crop groups in the research area in 2020

Figure 4. Visualization of organic soil management by crop groups in the research area and period

Since the graphical and spatial data analysis results allow us to detect the situation but not explain whether the organic soil management shifts are policy driven or spontaneous, we chose factor and cluster analysis methods to cover this aspect.

3.2. Factor Analysis

Factor analysis helped us to organize and give structure to the extensive research data set. The relationship between a variable and a factor was initially measured using correlation analysis. A multi-correlation matrix was created considering that the larger the number of observations, the more accurately the obtained correlations describe the closeness of relationships. Factor and cluster analysis was done for all of the years investigated - from 2012 to 2020. Still, since no significant differences were observed through the period analysed (the pattern stayed the same), the following results are based on the data set for 2020.

The multi-correlation matrix shows that the most significant positive correlation (>=0.51) is for the variables - land use, soil moisture regime, terrain conditions and soil stoniness - for each of these variables with the other three analysed variables. The closest correlation is for the terrain conditions with the land use, moisture regime and soil stoniness. No correlation was found between the soil types with the other variables. A small negative correlation was found for the received support with four analysed variables, a moderate negative correlation with two variables and a weak positive correlation (-.276) with one indicator - the crop grown. The correlation results are summarized in Table 2. The support received did not correlate with the soil type and soil fertility gradient variables, which could be explained by the fact that the provision of support is not associated with soil fertility gradient and soil type.

The suitability of the research data matrix (283 EU-supported land areas with organic soil and 12 indicators that characterize it) for the factor analysis was verified by performing Kaiser-Meyer-Olkin (KMO) and Bartlett's test [31]. The test indicated the sampling compliance of KMO 0.785 and Bartlett's test Sig. = 0.000, which means that dispersion of the variables characterising analysed land units is caused or can be explained by the underlying factors and dispersion is caused by 79% of the selected variables, correlation is observed, and factor analysis is an appropriate method for the analysis of the research data matrix. We used factor analysis to determine whether it is possible to create complex factors whose value is equal to or greater than 1 for the variables characterising the land area with organic soil receiving EU support, which would explain the interrelationships of the management of the studied organic soil areas. When performing factor analysis, the features were grouped into four complex factors, which explain 68% of the total data dispersion, respectively 32% of the dispersion is explained by other factors. Each selected factor consists of variables whose factor loading is greater than 0.5. There is a hidden, latent variable influence among the four complex factors variables; thus, the complex factor can be called a latent variable. The principal components or complex factors were revealed using the Varimax orthogonal rotation method. The complex factors, the variables included in them and the factor loads after applying rotation are shown in Table 3.

Table 2. Results of the initial factor correlation analysis (positive correlation)

No.	Variable	Positive correlation (0.01 level (2-tailed))			Variables with very close correlation (>0.6)
		Slight (0.1 – 0.3)	Moderate (0.31 – 0.5)	Close (>=0.51)	
		Number of correlating variables			
1	Land use	1	1	3	Terrain conditions
2	Soil moisture regime	4	1	3	Soil stoniness, terrain conditions
3	Terrain conditions	4	1	3	Land use, soil moisture regime, soil stoniness
4	Soil stoniness	4	1	3	Soil moisture regime, terrain conditions
5	Soil organic matter content	0	4	2	none
6	Soil pH $_{KCl}$	4	0	2	Degree of cultivation
7	Degree of cultivation	5	0	2	Soil pH
8	Soil type	0	0	0	none
9	Soil fertility gradient	5	0	0	none
10	Support received	1	0	0	none
11	Crop grown	1	0	0	none
12	Area supported	3	0	0	none

Table 3. Factor analysis results

Variable (information explained, %)	Factor load	Variable (information explained, %)	Factor load
1. Factor. F1 Agro-ecological conditions (26.1%)		***2. Factor. F2 Soil quality (20.9%)***	
Land use	0,79	Soil organic matter content	0,81
Soil moisture regime	0,89	Soil pH $_{KCl}$	0,88
Terrain conditions	0,90	Degree of cultivation	0,87
Soil stoniness	0,85	***3. Factor. F3 Land value (10.6%)***	
4. Factor, F4 Support (10.5%)		Soil type	-0.51
Support received	0.54	Soil fertility gradient	-0.54
Culture grown	0.89	Area supported	0.74

The first complex factor – F1 Agroecological conditions - explains 26.1% of the relationships of organic soil variables. This is the complex factor with the largest number of combined variables - 4 variables are combined, including indicators that characterize the agroecological situation of the agricultural land site – terrine conditions, soil moisture conditions, soil stoniness and land use. Increased factor loadings were found for terrine conditions (0.90) and soil moisture regimes (0.89).

The second complex factor – F2 Soil quality - explains 20.9% of the variance and includes soil quality characterising variables like the soil organic matter content, soil pH $_{KCl}$ and degree of cultivation. All indicators have high, positive factor loadings - above 0.8.

The third complex factor – F3 Land value - explains 10.6% of the variance and includes variables of soil type, soil fertility gradient and area. Two of the indicators (soil type and soil fertility gradient) correlate negatively with the third complex factor, which could be explained by the fact that the soil fertility gradient and soil type indicator values are not updated - historical data are used, which most likely no longer accurately characterize the actual situation in place.

The fourth complex factor – F4 Support – explains 10.5% of the dispersion and consists of two variables – the support received and the crop grown. The factor loads are high, positive – respectively 0.54 and 0.89.

It can be observed that the first complex factor – F1 Agroecological conditions – has the highest explanatory capacity and the highest positive factor loadings. On the other hand, the second factor – F2 Soil quality – is not far behind the first in terms of influence. Thus, we conclude that the most important variables of support receiving organic soil management are related to the agroecological conditions of the land area and soil quality, but there is a relatively minor connection between land evaluation indicators and EU support.

There is a wide variety of approaches A wide variety of approaches are used in the scientific studies on local determinants of land use change developments and evaluation of EU`'s support impact. The method chosen depends on the overall aim of the particular assessment, but the combination of various spatial and multivariate statistical analysis methods is the most common choice, and factor analysis tends to be among the tools [32-34]. The most frequently chosen variables for land use change and management patterns` analysis are: an area of agricultural land and crops in different angles; soil parameters as well as socio-economic and biodiversity variables; however, the exact set of variables depends on the specific research aims of the studies. Interrelated analysis of the EU`'s support and specific soil category's management activities in a historical period is quite an innovative approach that is, for the first time, used for evaluation of to evaluate the regularities in organic soil management. The approach is informative and perspective in the case of organic soils, considering the specificity and political importance of this soil category is soil category's specificity and political significance.

3.3. Cluster Analysis

By using complex factors obtained within factor analysis, cluster analysis was done to identify the groups of agricultural land with organic soil receiving support, depending on the influence of the complex, characterising factors on the land management practice applied. A cluster analysis was done for the entire set of observations of agricultural land with organic soil from 2012 to 2020. The number of clusters was determined by using the Elbow method, which was - 5 clusters. ANOVA analysis showed that the observed significance for all variables is lower than 0.05 (Sig. =0.000); therefore, with a 95% confidence, it can be concluded that there are differences between the calculated sets of indicators. The organic soil areas receiving support are grouped into 5 clusters (Table 4). The smallest number of areas in one of the clusters (the second) is 3, which means that this cluster could be considered an exception rather than a cluster. ANOVA analysis showed that the most significant complex factors in clustering are F2 Soil Quality and F3 Land Value, which have significantly higher F values.

Table 4. Summary of cluster analysis results

Factor	Cluster 1 (n=225)	Cluster 2 (n=3)	Cluster 3 (n=9)	Cluster 4 (n=12)	Cluster 5 (n=20)
F1 Agro-ecological conditions	0.018	1.246	-0.534	-0.922	0.401
F2 Soil quality	0.259	0.555	-2.202	-3.299	-0.022
F3 Land value	-0.096	-4.339	-1.143	-0.195	2.363
F4 Support	-0.166	0.279	2.757	-0.744	1.026

The first cluster is characterized by both positive and negative coordinates of the cluster centres. The largest number of land areas - 225 units - is grouped within this cluster. The cluster is by good soil quality and agro-ecological conditions, while the values of the land value and received support indicators are weakly negative, indicating a relatively worse situation regarding these indicators. *The second cluster* could be treated as an exception because it combines only 3 supported organic soil areas [35]. *The third cluster* includes 9 areas. The cluster is characterized by a highly positive indicator of received support and moderately or strongly negative indicators of agroecological conditions, soil quality and land value. *The fourth cluster* consists of 12 areas; all cluster centres or factor values are weak to strongly negative, which indicates low values of all factors. In *the fifth cluster*, the agro-ecological conditions, land value and received support indicators are positive. A particularly positive value is observed for land value, while soil quality is weakly negative.

The cluster centres characterize the difference between the clusters (Table 5). The greater the distance between the cluster centres, the more different these clusters are. Clusters 2 and 5 are the most distinct, and clusters 1 and 5 are the closest. The fourth and fifth clusters are similar and are not significantly different from the third.

Table 5. Distances between the cluster centres

Cluster	1	2	3	4	5
1		4.449	3.999	3.727	2.773
2	4.449		5.208	6.147	6.820
3	3.999	5.208		3.809	4.573
4	3.727	6.147	3.809		4.708
5	2.773	6.820	4.573	4.708	

Using the complex factors obtained in the factor analysis, the cluster analysis identifies four mutually different groups of agricultural land with organic soil receiving support in the analysed data set; however, numerically expressed, the 1st cluster group stands out the most. It combines 225 of the 283 analysed areas. The first cluster, or the absolute majority of the analysed areas, is characterized by a disconnection between positive values of soil quality and agro-ecological condition factors and negative values of the land value and received support indicators. The factor analysis indicates that the largest explanatory capacity and positive factor loadings are for the complex factors of agro-ecological conditions and soil quality, which indicates that the most important indicators of organic soil management receiving support are linked to these factors, and there is a relatively little connection with the land evaluation and EU support indicators. Cluster analysis in agricultural research is often used to cluster observation samples by similarity [36], aggregate parameters into categories – like an aggregation of land use patterns into different land use categories based on their geographical similarities and differences [37], classify some variables related to another variable, interpret the causes of some phenomenon and analyse origins of some mixed processes [38] and similar tasks requiring classification of large quantities of data into several groups according to specific characteristics of each group. The usage of multivariate statistical analysis methods, including cluster analysis is an innovative approach to integrated organic soil management and policy support data analysis. This approach, alongside spatial analysis and historical perspective, provides an integrated perspective and includes mathematical as well as spatial points of view.

4. Discussion

4.1. Organic Soil Management Patterns

Study results demonstrate that organic soil management in Latvia bears unexploited climate change mitigation potential; indeed, we found the most common organic soil management pattern in the research data set is also the most GHG-intensive one - cereals, oil crop and corn. Despite the high national importance of organic soil-related GHG emissions in agriculture, there has not been monitoring or regular research-based data assessment in Latvia on organic soil management patterns. Our results generally coincide with the only previous study results on Latvia's organic soil management. A study from 2017 indicates cereals and oil crops as the second most spread management pattern, but this study did not look for nor analyse the historical tendencies, and a different data set was used for assessment [11]. The lack of systematic scientific evaluation of the existing organic soil management patterns discourages knowledge-based agriculture and climate change policy planning. Without up-to-date information on field data, future policy planning faces difficulties and can be jeopardized. The study results make explicit the tendencies of the organic soil management patterns in Latvia throughout the last decade and point to the discrepancies between the identified trends and desirable movement towards climate change target achievement – meaning dominance of cereal, oil crop and corn growing pattern over grasslands.

The scarcity of research-based and statistical organic soil management pattern data is not only Latvia's or a regional problem; the absence repeats itself at the European level. Detailed organic soil management data at the countries` level are still hard to find, although some existing studies indicate wide management diversity, starting from highly productive resource systems in the Netherlands to mixed systems of high-value land with intensive land use and mid- to low-productivity and marginal land in the Nordic part of Europe [39]. The lack of publicly available data determines difficulties in comparative analysis among organic soil-rich countries, especially from a historical perspective—data are either unavailable or not comparable. Still low research activity and inactive monitoring of organic soil management patterns could be explained by the relative recency of the climate change policy in general and the organic soil issue in particular. This is especially true for countries whose GHG profiles contain a minor part of organic soil-related emissions; thus, countries are less prone to do detailed analysis on how exactly these soils are managed, and scientific activities are hesitant. Widespread activation of the political discussion and research of the field coincides with the activation of climate change mitigation incentives only since around 2014 [40]. Presumably, data on organic soil management in some details are mined, but yet used for operational policy planning and impact analysis at the national level. More pronounced activity in the light of growing climate change mitigation targets, including at the national level [41, 42], can be observed in countries with a significant proportion of organic soils under agricultural management [43, 44]. However, research has been mainly oriented towards analysis of the current situation without adding a historical perspective and analysis of the EU support usage impact.

Another aspect often mentioned as an obstacle to good management pattern data acquiring is the lack of up-to-date cartographic information on the actual area of organic soils under agricultural land use [45–49]. The availability of up-to-date cartographic data on organic soil areas becomes essential. It is also emphasized in the context of the EU`s new soil strategy for 2030 and the accompanying proposal for a Nature Restoration Law, which sets binding targets on the restoration and rewetting of organic soils in agricultural use [50]. Binding and financially capacious actions require up-to-date, precise, and georeferenced data acquired by following a comparative methodological approach, including organic soil definition.

4.2. Targeted Organic Soil Management Support Policy as an Opportunity for Climate Change Mitigation

The results of our study analysis have two main implications for scientists and policymakers in Latvia as regards the purposefulness of organic soil management in light of climate change targets. Firstly, we emphasize the current lack of accurate data on organic soil management patterns and that organic soil management data monitoring, including from a historical perspective, is essential for targeted climate change mitigation development in the agriculture sector. Based on this first notion comes the second, underscoring the current inability of the provided agricultural support measures to work towards targeted climate change mitigation in the case of organic soil management for agriculture in Latvia. Both factor and cluster analysis for all of the years analyzed (2012 - 2020) signaled the same pattern confirming that EU support for organic soil management in agricultural land in Latvia in the period 2012-2020 has not been targeted or linked to the actual agro-ecological conditions or soil quality.

Random, unspecified policy support is not capable of moving the management of this specific soil category towards achieving all levels of climate change mitigation targets. Continuation of planning and application of policy support that is not explicitly targeted, in the case of organic soil management in agriculture, could lead to a consistent non-attainment of the policy targets. Similar tendencies are revealed at the European level and in other organic soil-rich countries. European level study analyzing land use data methodologies concludes insufficiency and lack of harmonized approach regarding management data gathering and monitoring for evaluation of GHG mitigation and policies efficiency [51]. Based on information reported by countries, the same study compiles data on policy measures (mainly of European Union Common Agriculture Policy origin) applied for organic soil management, but the actual purposefulness and implications of the implied policy measures are not discussed. Our study results confirm the necessity to consider not only the number of policy measures applied but also the actual purposefulness of the actions and linkage to the site specificities; otherwise, the actual policy impact can be overrated or underrated, and policy goals can be missed. This finding is supported by studies on organic soil used for agriculture in other organic soil-rich countries; for example, on the GHG mitigation potential of agricultural peatlands [52], which found that more effective utilization of the mitigation potential requires policies to include soil type as a criterion in support decisions taking. In turn, the study on the future options for cultivated Nordic peat soils uncovers the need to base policy decisions on field scale observations and properly understand the long-term effects of the land use manipulations [53], but study, looking from another angle yet with a similar research target, - on the challenges of delivering climate change policy targets through land use policy [54], points to the importance of spatially targeted policy measures contrary to simple symbolic target indicators.

The Common Agriculture Policy (CAP) is among the most powerful policy tools implied in EU Member States' agricultural sectors, and with each new period, it is more closely linked to international and EU climate change mitigation policies [40]. In this research, we study a 9-year time horizon, but each new period of the EU's CAP implies a new regulatory and support framework; thus, the repeated analysis would reveal follow-up information on changes in organic soil management patterns in the context of the policy implications and serve as an informative indication for further policy planning. The results of our study suggest that such soil type-based management analysis could be used for soil type-based support policies. Given the percentage and character of organic soil-related GHG emissions, more scrutinized monitoring of the existing situation and more targeted policy planning in the future are suggested by this study to overcome stagnating difficulties in organic soil-related GHG mitigation.

Further research could go deeper into individual municipalities' levels, in particular, to explore factors that determine the situation when organic soils` climate change mitigation potential through management changes gives the impression of variability among regions in the presence of the same political framework. Another crucial aspect not covered in this research is the selection of management practices to be supported policy-wise. Based on the understanding acquired through the results of this study, we suggest a continuation of the research by considering the new policy incentives indicated by the European Green Deal to develop a proposal for a package of climate-friendly and cost-effective management practices for organic soil management in agriculture, thus contributing to the revealing of the appropriate path to achieving regional and national policy objectives of climate change mitigation in Latvia.

5. Conclusions

By using graphical, spatial, correlation, factor, and cluster analysis, we revealed the historical pattern tendencies of organic soil management for agriculture in Latvia for the period from 2012 to 2020, as well as the inter-correlative relationships of different management variables in the context of agriculture and climate change policy that allowed us to make indicative (since research data cover about 30% of Latvia's agriculture land with organic soil) conclusions.

- The support organic soil management patterns` shifts have received in agriculture indicates growing activity during the last decade (by about 30%), especially for two crop categories: grassland and cereals, oil crops, and corn. Looking from a climate change mitigation perspective, the increased area of cereals, oil crops, and corn tends to offset the positive mitigation effect of the overall increase in grassland area. Looking alongside a slight decrease in legumes and general stagnation for perennial plantings and vegetables, the observed support receiving organic soil management shifts through the last decade has not been directed towards achieving climate change mitigation targets.
- No correlation was observed among the variables of received support, soil type, and soil fertility gradient, which indicates that the provision of support has not been associated with soil type or fertility. Thus, it appears that soil characteristics are not adequately considered in the support provision process, and support measures are most likely not drivers of organic soil management shifts.

- Complex factors F1 (agro-ecological conditions) and F2 (soil quality) have the highest explanatory capacity and factor loadings, allowing the conclusion that the most essential variables of organic soil management are related to the agro-ecological conditions of the land area and soil quality, but there is a relatively little connection with land evaluation indicators and EU support. This observation is supported by the fact that the first and absolutely biggest cluster is characterized by positive cluster center coordinates for soil quality and agro-ecological conditions, but land value and support values are characterized by negative weekly cluster center values, thus indicating a disconnection between support and soil quality and agro-ecological variables.
- Based on the analysis performed, we can indicatively conclude that the organic soil management patterns in agriculture in Latvia for the previous decade have not been purposefully driven by support policy measures but rather by management choices purely based on local agroecological and soil quality considerations. Support policy in the case of nutrient-rich organic soil management in agriculture in Latvia has not been purposefully targeted looking from the perspectives of climate change mitigation and moving towards achieving national climate change targets.
- Our conclusions call for a general change in the perspective of nutrient-rich organic soil management in agriculture towards more targeted and research-based climate change mitigation support and management practices, thus supporting the more stable movement toward the achievement of national and international climate change mitigation targets, especially in light of climate neutrality goals.

6. Declarations

6.1. Author Contributions

Conceptualization, I.L., D.P.; methodology, I.L., D.P., P.R. and A.L.; visualization, I.L. and R.M., software, R.M. validation, I.L., D.P., and P.R.; writing—original draft preparation, I.L.; writing—review and editing, I.L., D.P., P.R. and A.L. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

Data sharing is not applicable to this article.

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6.4. Conflicts of Interest

The authors declare no conflict of interest.

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