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Development of Land Cover Naturalness in Lithuania on the Edge of the 21st Century: Trends and Driving Factors

Daiva Juknelienė *, Laima Česonienė, Donatas Jonikavičius, Daiva Šileikienė, Daiva Tiškutė-Memgaudienė, Jolanta Valčiukienė and Gintautas Mozgeris

Agriculture Academy, Vytautas Magnus University, Studentų Str. 11, Akademija, 53361 Kaunas, Lithuania; laima.cesoniene1@vdu.lt (L.Č.); donatas.jonikavicius@vdu.lt (D.J.); daiva.sileikiene@vdu.lt (D.Š.); daiva.tiskute-memgaudiene@vdu.lt (D.T.-M.); jolanta.valciukiene@vdu.lt (J.V.); gintautas.mozgeris@vdu.lt (G.M.)
* Correspondence: daiva.jukneliene@vdu.lt

Abstract: Landscape naturalness is an important indicator for supporting sustainable development-driven policies and suggesting associated decisions in land management. This study used CORINE Land Cover data to estimate the changes in land cover naturalness in Lithuania since 1995. All the land cover types were ranked according to naturalness level, ranging from purely anthropogenic to natural landscapes. Spatial patterns of the increase or decline in landscape naturalness were investigated at the level of municipalities. Then, publicly available geographic data were mobilised to explain the reasons behind the trends observed. A minor increase in land cover naturalness in the whole area of Lithuania was observed; however, this increase was statistically insignificant. Nevertheless, statistically significant clusters with both increasing and decreasing levels of land cover naturalness were identified when moving to the level of municipalities. The trends in the development of landscape naturalness were associated with the specificity of agricultural and forestry activities in the municipalities. The suitability of lands for agriculture due to soil, terrain, current land use specifics, and related drivers, such as the availability of land reclamation installations and the intensity of land use, were the main drivers for the declining level of land cover naturalness, usually concentrated in northern and central Lithuania. The land cover naturalness did increase in less suitable areas for agriculture, i.e., in the more forested southeastern municipalities. The study emphasised the need for a systematic and spatially explicit monitoring of the land cover patterns and their changes as well as elaborated proposals for land management policies over the next decade, which were mostly in the line with current European Union and national strategies.

Keywords: land cover; naturalness; CORINE; land cover change; hot spot analysis

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1. Introduction

There are numerous reasons why the quality of land cover matters. First, the properties of land cover and their changes over time have an impact on the environment and influence the functioning and value of ecosystems. They are critically important drivers influencing the global carbon cycle [1], the climate and climate change [2], biodiversity [3], and the landscape ecology [4,5]. On the other hand, land cover or, more appropriately in this context, land use, greatly defines the resources and benefits available for human use. Even though the natural ecosystems are efficient in delivering services to humans [6], the global trend has been that the transitions from forest land to agricultural land and from agricultural to urban land have diminished the quality of the environment [7,8]. To cope with those challenges, sustainable development, based on balancing economic, social, and environmental pillars, and emphasising the ability of future generations to meet their own needs [9], became a cornerstone of policies during the last several decades. However, to assess the impact of sustainable development-driven policies and to suggest operational approaches, a set of indicators needs to be developed to assess and monitor the status and development of the systems under focus.

Landscape pattern as an indicator for naturalness and factors behind land use intensity at regional, national, and European levels is becoming an important topic both for researchers and decision makers [10]. The level of naturalness of land cover or landscapes could be considered one of the key concepts in spatial planning, especially when the focus is on intensively used anthropogenic landscapes and the aim is of nature protection. In a very basic sense, the natural or original landscape refers to the landscape that had existed before being impacted by human culture; however, this does not exist in many parts of the world anymore [11]. Therefore, at present, the naturalness of the landscape usually refers to the degree of human impact made as an outcome of interplays between socio-economic and biophysical forces [12]. There have been numerous approaches to assess the processes going on in a landscape. Vegetation, its structure, and associated structural changes are considered one of the key indicators of landscape naturalness [13,14]. In Europe, with its long history of land use and very diverse land transformations through human intervention, the landscape structure, or the spatial distribution of ecotopes, became the solution for evaluating and comparing the landscapes [12]. It is obvious that the direct evaluation and monitoring of ecosystem processes are quite challenging tasks; thus, the landscape structure is usually explored from mapped data, available from, for example, remote sensing missions or geographic databases. For instance, the CORINE Land Cover (CLC) inventory has been running since 1985, delivering pan-European land cover information on a regular basis, which is used for a wide variety of applications in the environment, agriculture, spatial planning, and many other domains (https://land.copernicus.eu/pan-european/corine-land-cover, accessed on 9 November 2021). One of the approaches to specify the degree of landscape naturalness is to rank different land use covers using an index, which can be assumed to be a proxy of human intervention [15], and subsequently, the level to which the naturally occurring functions are preserved in the landscape; all land covers in the landscape are ranked according to their naturalness level, e.g., ranging from 0 (purely anthropogenic landscape) to 1 (natural landscape) [16], or 0 (completely artificial systems) to 100 (primary and secondary forests, natural lakes and wetlands, native grasslands and shrublands) (https://www.freshwaterhealthindex.org/tool/Ecosystem_Viltality/Drainage_Basin_Condition_(DBC)/Land_Cover_Naturalness_(LCN).html, accessed on 9 November 2021). Indexing may be elaborated based on expert judgement using different weighting techniques [16,17]. Even though the indexing of land cover naturalness is criticised as not being free from subjectivity (see Section 4), it is not used operationally; some Lithuanian municipalities have already been monitoring and evaluating land cover naturalness for several decades using indices compatible with the ones mentioned in the above references.

In this research, we adopted the approach of evaluating land covers and their change in Lithuania using land cover naturalness indices and also aimed to identify the drivers behind those trends. Humans have been shaping Lithuanian landscapes since the last Ice Age 13,000 years ago. Usually, long-term trends are involved in converting forest into agricultural land. Thus, the proportion of forest land dropped from ~80% in year 1000 CE [18] to 26% in the 1950s [19]. Climate conditions and productive soils in Lithuania favour the production of crops, resulting in more than 50% of land area being used for agriculture. The proportion of the area of natural landscapes does not exceed 15%, and such landscapes are basically concentrated in the eastern and southeastern regions that are less suitable for agriculture, the hilly western parts of the country, and the ancient delta on the shoreline [20]. The trends in land cover use changes in Lithuania during the last five decades have been an increase in the area of forest and built-up land and decrease in the area of producing land, meadow/pasture, wetlands, and land for other uses [21], with the development trajectories of the proportions of producing land and meadow/pastureland changing several times due to the development of land management and land-use relations. Nevertheless, there are serious concerns, at least at the policy, mass-media, and population levels, that the stability of landscapes in Lithuania is declining. The current structure of the landscape in the country is characterised as suboptimal, i.e., not meeting the limits for optimal landscapes set in the

national land management plan, basically due to the underrepresentation of natural areas [22]. Then, the main directions of landscape policy are incorporated into the documents of strategic planning, which assume the precise identification of landscape protection, planning, managing, and use measures. However, usually such measures are very general and sometimes fuzzy, missing clear indicators and time frames. Landscape monitoring in the country is usually restricted to the country-wide analysis of land covers, without considering the local-level political, social, ecological, and cultural context [23]. Therefore, we asked the question on the actual trends of the development of landscape naturalness in Lithuania and based our evaluation on publicly available and internationally recognised data, such as data from CORINE Land Cover. Then we looked for any spatial patterns in the distribution of changes in land cover and the level of naturalness over time. Finally, we tried to explain the changes observed using information on potential drivers extracted from freely available sources, associating them with land management implications.

2. Materials and Methods

2.1. Study Area

The study was carried out in Lithuania, a country geographically located in the very centre of Europe (Figure 1). The total area of the country is 65,200 km^2. The level of land cover naturalness was analysed by municipalities. The total number of municipalities used was 52, with an average area of 1228 km^2. We did not consider ten predominantly urban municipalities in our study.

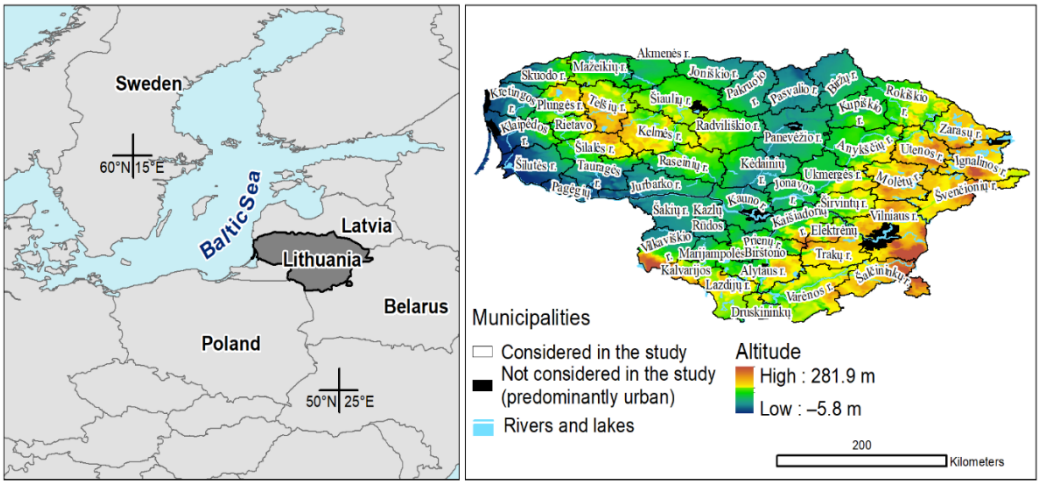

Figure 1. Study area: (**left**)—the location of the study area in Europe, (**right**)—the borders of the municipalities and elevation in Lithuania. The names of the municipalities are omitted in further illustrations, and they are basically supposed for a Lithuanian readership. Sources of the data used: (**left**)—thematicmapping.org/downloads/world_borders.php (accessed on 4 January 2022), (**right**)—GDB200 database from www.gis-centras.lt/ (accessed on 13 November 2021).

2.2. Input Data

Two types of input data were used in the current study: (i) data describing the land covers and land cover changes in Lithuania during the last two decades, used later to characterise the land cover naturalness, as well as data to support the analysis; and (ii) data explaining the factors behind the land covers and their changes over time. Therefore, to describe and analyse the land covers, we applied the following approaches:

- CORINE databases were acquired from Copernicus Land Monitoring Services (https://land.copernicus.eu/pan-european/corine-land-cover, accessed on 21 December 2021). Here, we used CORINE Land Cover data referring to 1995, 2000, 2006, 2012, and 2018. Hereafter, this data source is referred to as COPERNICUS.
- The borders of municipalities (USE_3 level) available from EuroBoundaryMap (v3.0), which is a European reference database of administrative units and boundaries

established within the framework of EuroGeographics (Available online: https://eurogeographics.org/maps-for-europe/ebm/, accessed on 21 December 2021). Hereafter, this data source is referred to as EuroBoundaryMap.

Factors used to explain the land cover change patterns and impacts on land cover naturalness were described using international and national open datasets (the full list of tested explanatory variables is provided in Table A2 in Appendix B):

- Soil spatial dataset at a scale of 1:10,000 (Dirv_DR10LT), with the soil productivity grade for each soil polygon. The average soil productivity grade was estimated for agricultural lands in each municipality.
- Land reclamation and wetness dataset at a scale of 1:10,000 (Mel_DR10LT), which was used to estimate the proportion of drained lands for each municipality.
- Dataset of special land-use conditions at a scale of 1:10,000 (SŽNS_DR10LT), which was used to estimate the proportion of lands under specific use restrictions.
- Dataset of abandoned agricultural land (AŽ_DRLT), which was used to characterise the land use intensity in municipalities, estimating the proportion of abandoned land.
- Land parcel block database referring to 2004, 2008, and 2014 (KŽS), containing the borders of agricultural, built-up, miscellaneous (mostly forest), water, and road infrastructure blocks and used to estimate the proportion of specific land use in each municipality.
- River network data from Copernicus Land Monitoring Services (https://land.copernicus.eu/imagery-in-situ/eu-hydro/eu-hydro-river-network-database, accessed on 21 December 2021). The features available from this dataset were intersected with the borders of municipalities to estimate the length of streams per area unit in each municipality.
- Data on the number of residents (JRC-GEOSTAT 2018 dataset) were acquired from the Geographic Information System of the Commission (GISCO) (https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/population-distribution-demography/geostat, accessed on 21 December 2021). The JRC-GEOSTAT 2018 is a regular grid map of 1 × 1 km cells reporting the number of residents for the year 2018 in Europe. This grid was intersected with the borders of municipalities to obtain the number of residents in municipalities for the year 2018. Additionally, data from Population and Housing Census by Statistics Lithuania (https://osp.stat.gov.lt/gis-duomenys, accessed on 21 December 2021) were used to estimate the population density in each municipality, referring to three dates (1989, 2011, and 2018).
- Data on the transportation network were acquired from the OpenStreetMap project database (https://download.geofabrik.de/, accessed on 21 December 2021). For this study, we calculated the length of linear features per area unit in each municipality for the following road types: motorway/freeway, important roads (typically divided), primary roads (typically national), and secondary roads (typically regional).
- A raster digital terrain model (DTM) from the online service EuroGeographics Open Maps for Europe (https://www.mapsforeurope.org/datasets/euro-dem, accessed on 21 December 2021). In addition to mean, minimum, range, and standard deviation values based on the altitudes, we calculated the same characteristics for the slope and topographic wetness index [24], which were assumed to strongly correlate with soil moisture and provide indirect information on land cover and agricultural potential. Hereafter, this source of data is referred to as MapsForEurope.
- Data on various aspects characterising the agriculture in municipalities, including the intensity of agriculture, were available from the Lithuanian Department of Statistics (Statistics Lithuania).

The data used for the analysis were reorganised in such a way that the polygon feature class representing each municipality was described using a variety of attributes extracted from the above-mentioned datasets.

2.3. Mapping and Evaluating the Land Cover Naturalness

The feature classes representing CORINE land covers and referring to five dates during the last three decades were intersected with the borders of municipalities. To estimate the land cover naturalness, each level 3 CORINE Land Cover class was assigned an index value based on Skorupskas [16]. The index values used in our study are reported in Table A1 in Appendix A. Then, land cover naturalness was estimated for each municipality and, at each time point, as an area-based average value of indices for all land cover polygons. Estimated land cover naturalness and area proportions of land cover classes in municipalities were plotted on the map. The global Moran's I statistic was used to identify global spatial autocorrelation, and statistically significant hot spots and cold spots were mapped using the Getis-Ord Gi* statistic. To quantify the presence of a monotonic increasing or decreasing trend in the changes of the variables under focus, i.e., land cover naturalness and area proportions of land cover classes in municipalities, a nonparametric Mann–Kendall test was used to estimate the slope of the linear trend with the nonparametric Sen's method using the MAKESENS tools [25]. The trend analysis was conducted for each municipality. Municipalities with statistically significant trends were noted on the map.

To understand the mechanisms of land cover changes and the factors behind them, we applied an ordinary least squares (OLS) regression. First, we conducted a data mining exercise testing all potential regression models with all combinations of factors as input explanatory variables, i.e., we considered the slope of the linear trend in changes in land cover naturalness or land cover proportion as the dependent variable and combinations of the above-mentioned factors as the independent variables. The number of independent variables was changed from one to three. Moreover, the selected independent variables were tested in regression models with the number of variables ranging from one to three. The conditions for the fit of regression models were the following: (i) the coefficient of the explanatory variable must be statistically significant at a 95% confidence level; (ii) to avoid multicollinearity, the variance inflation factor for the explanatory variable must not exceed 7.5; (iii) to consider the model residuals as normally distributed, the minimum Jarque–Bera p value was required to be 0.1; and (iv) to avoid the spatial clustering of the model residuals, the maximum p value for global Moran's I was allowed to be 0.1. Selected regression models (in terms of highest adjusted R^2 and lowest corrected Akaike information criterion, under the condition that all other statistical tests—Jarque–Bera statistic, Koenker (BP) statistic, variance inflation factor, and the absence of the spatial autocorrelation of the regression residuals—were passed) were more carefully investigated and reported. Some explanatory variables resulting in the non-passing spatial autocorrelation of regression residuals were additionally checked with geographically weighted regression to detect and model potentially spatially varying relationships. As all potential factors were used as explanatory variables in the regression, we evaluated the variable's significance based on information on variable relationships and the consistency of those relationships according to the proportion of (i) times the variable was statistically significant and (ii) the times the relationship was positive or negative. Most of the processing was conducted using ArcGIS v10.8 (Esri Inc., Redlands, CA, USA).

3. Results

Current land covers and trends in land cover changes in Lithuanian municipalities since 1995 are illustrated in Figure 2. Although the values of the area proportions of major cover types are randomly distributed among the features, an inverse relationship between the dominance of agricultural areas and forest and seminatural areas is observed; that is, more forested municipalities dominate in the southeastern part of the country at the cost of agricultural lands, which dominate in north–central municipalities. Relatively larger proportions of artificial surfaces are in municipalities around larger cities. The dominant trend in the development of the area proportion of artificial surfaces was the increase in their area in 63% of municipalities since 1995, with a statistically significant trend in ten municipalities (Figure 2b). Usually, the urbanisation level was increasing around the

municipalities around larger cities. The decrease in the proportion of artificial surfaces was statistically significant in just two municipalities. The proportion of agricultural areas has been decreasing in all Lithuanian municipalities since 1995, with a statistically significant slope of a linear trend in 11 municipalities. On the other hand, the proportion of forest and seminatural areas has been increasing in all Lithuanian municipalities, with a statistically significant slope of a linear trend also in 11 municipalities. Statistically significant global spatial autocorrelation supports the hypothesis about the spatially clustered pattern of municipalities with relatively larger increases in forest area in the eastern part of the country.

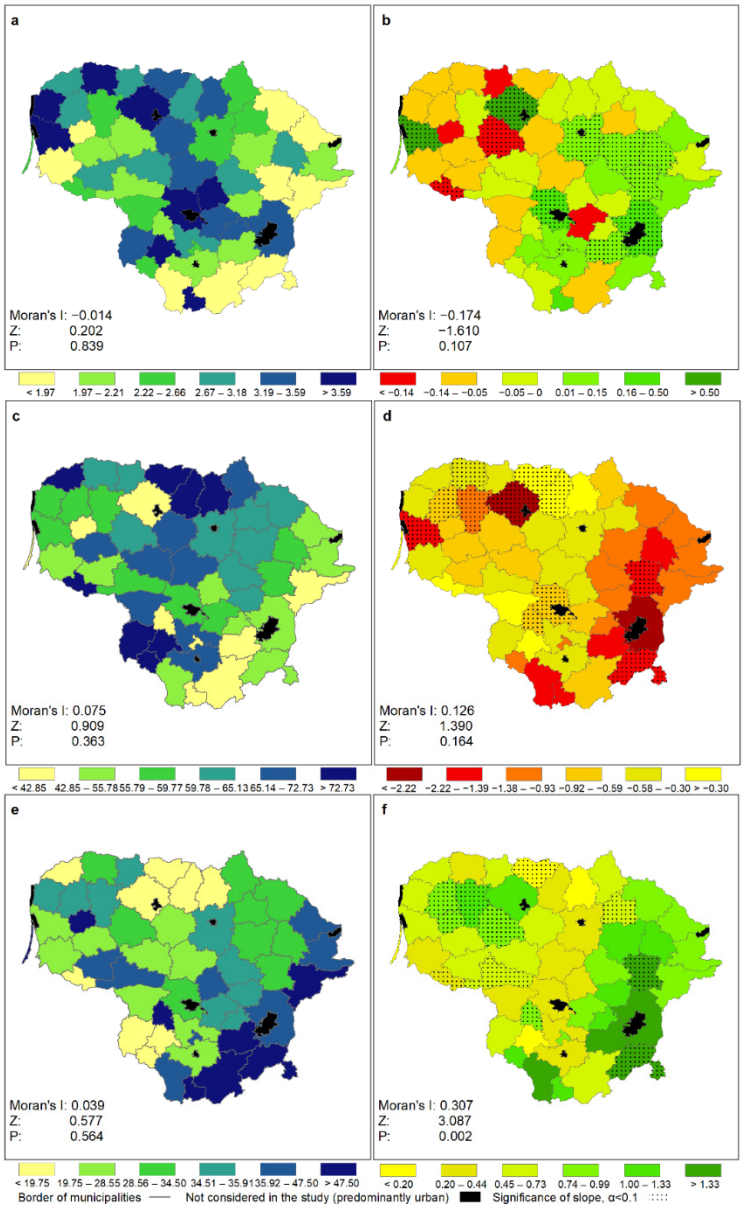

Figure 2. Area proportions (%) of land cover types in Lithuanian municipalities in 2018 (left column) and the slope of the linear trend in changes of specific land cover type during the period 1995–2018 (right column): (**a**,**b**)—artificial surfaces, (**c**,**d**)—agricultural areas, (**e**,**f**)—forest and seminatural areas.

The average value of the land cover naturalness index in 2018 was 0.587. Land cover naturalness in Lithuanian municipalities was statistically significantly clustered (Figure 3). The hot spot analysis using the Getis-Ord Gi* statistic revealed hot spots, i.e., statistically significant spatial clusters of high index values, in the southeastern part of Lithuania with a relatively high proportion of forest land, and in the west, including five municipalities

near the sea. Only one municipality was assigned as a cold spot, i.e., the cluster of low index values in the northern part of the country with most productive soils being used for agricultural activities.

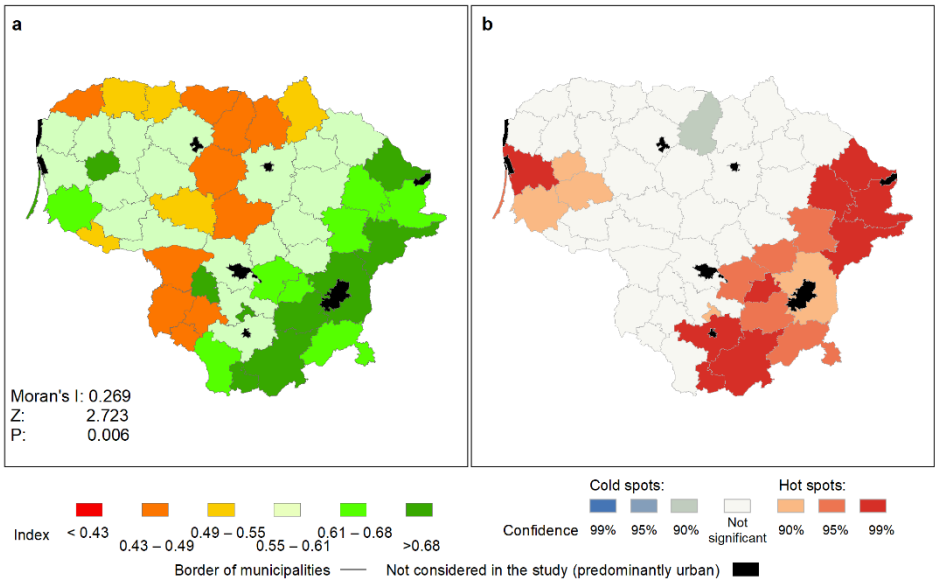

Figure 3. Land cover naturalness in Lithuania in 2018: (**a**)—land cover naturalness index in non-urban municipalities, (**b**)—statistically significant hot spots and cold spots using the Getis-Ord Gi* statistic.

The slope of the linear trend in the changes in the index value for the whole country was 0.0018 for the period since 1995, assuming the average index values for 1995 were 0.582, 2000—0.580, 2006—0.580, and 2012—0.588. This suggests some increase in land cover naturalness since 1995; however, the parameter is statistically insignificant. The development of land cover naturalness is better seen if analysed at the level of municipalities. The municipalities with relatively lower index values of land cover naturalness in 2018 usually experienced a decrease in the index value since 1995, with the opposite trends in municipalities with relatively higher index values (Figure 4). The Pearson's correlation coefficient between the land cover naturalness index in 2018 and the slope of the linear trend in changes in the land cover naturalness index since 1995 was 0.61. Eleven municipalities in the southeastern part of the country belonged to statistically significant hot spots, i.e., to the spatial cluster with improving land cover naturalness. On the other hand, three northern municipalities belonged to the opposite cluster with degrading land cover naturalness. It should be noted that the slope of the linear trend in changes in land cover naturalness was statistically significant mostly for municipalities with negative slope values, i.e., decreasing land cover naturalness.

Land cover characteristics from the CORINE database were first individually checked for their performance in explaining the changes in the land cover naturalness index. The proportion of specific land cover type (here, we used average values covering the whole analysed period) did not influence the changes in the land cover naturalness index in Lithuanian municipalities; the adjusted R^2 did not exceed 0.11 (Table 1). We also checked whether the changes in the proportion of different land covers contributed to the trends of land cover naturalness. For that, the slope of the linear trend in the changes in the proportions of land cover type was used as an independent variable in the regression. Thus, up to 47% in variance of the changes in the land cover naturalness index could be explained by the dynamics of forest and seminatural areas (and 29% by the dynamics of agricultural areas). However, statistically significant Jarque–Bera statistics suggested that the last two predictions were biased. Model residuals were always spatially autocorrelated, signalling the nonstationarity in our explanatory variables. The regression models were notably improved by applying geographically weighted regression by reducing the spatial autocorrelation of

model residuals in most cases below the levels of statistical significance. Therefore, the area proportion of the three most abundant land cover types—artificial surfaces, agricultural areas and forests and seminatural areas, according to CORINE nomenclature—explained 24–29% of the variance in changes in the land cover naturalness index in both countries. Improved adjusted coefficients of determination were achieved with the slopes of the linear trend in the changes of corresponding land cover types (0.33–0.69) as an explanatory variable in the geographically weighted regression. The Akaike information criterion was always reduced using geographically weighted regression.

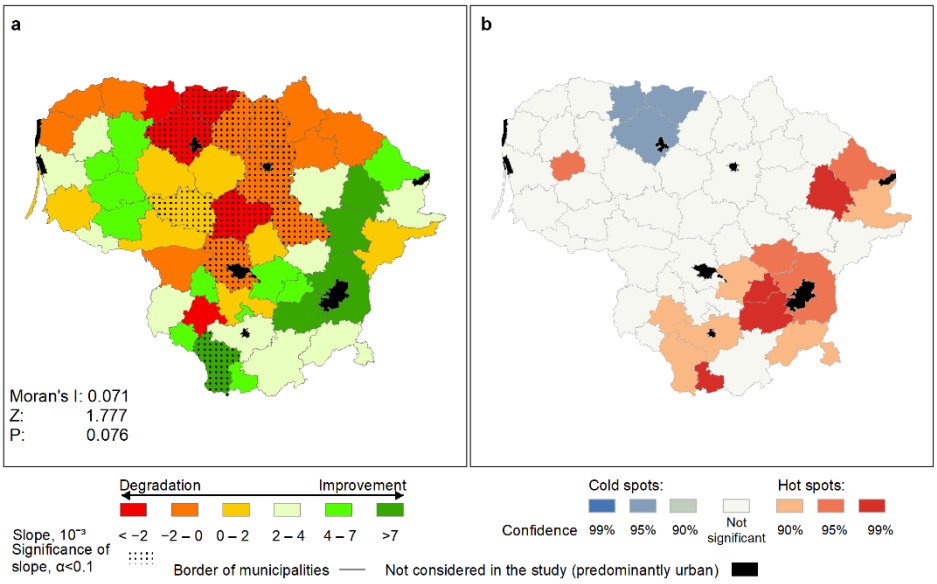

Figure 4. Changes in land cover naturalness in Lithuania during the period 1995–2018: (**a**)—slope of the linear trend in changes of the land cover naturalness index in Lithuanian municipalities, (**b**)—statistically significant hot spots and cold spots using the Getis-Ord Gi* statistic.

Table 1. Results of regression with the slope of the linear trend in changes in the land cover naturalness index as a dependent variable and land cover characteristics as explanatory variables. Bold values identify statistically significant ($p < 0.05$) statistics.

Variable	Ordinary Least Squares Linear Regression					Geographically Weighted Regression		
	Akaike Information Criterion	Adjusted R^2	Jarque–Bera Statistic	Koenker (BP) Statistic	Moran's *I* of Residuals	Akaike Information Criterion	Adjusted R^2	Moran's *I* of Residuals
Average area proportion during the period since 1995 of:								
Artificial surfaces	−431	0.051	1.541	0.576	**0.267**	−441	0.285	0.059
Agricultural areas	−431	0.049	0.515	2.699	**0.317**	−437	0.280	**0.204**
Forest and seminatural areas	−435	0.110	1.355	0.679	**0.277**	−438	0.237	0.184
Wetlands	−428	−0.017	1.761	0.283	**0.343**	−437	0.304	0.140
Water bodies	−429	0.007	0.937	**5.599**	**0.319**	−446	0.382	0.179
Slope of the linear trend in changes during the period since 1995 of:								
Artificial surfaces	−428	−0.020	1.684	1.200	**0.331**	−441	0.333	0.182
Agricultural areas	−446	0.289	**28.974**	**10.545**	**0.298**	−463	0.561	**0.238**
Forest and seminatural areas	−463	0.474	**10.578**	1.493	**0.392**	−475	0.691	**0.220**
Wetlands	−430	0.030	1.734	0.394	**0.310**	−437	0.245	0.147
Water bodies	−428	−0.018	1.573	0.000	**0.336**	−436	0.261	0.154

Various variables that are easily available from different databases and censuses, and which potentially correlated with land cover naturalness, were checked for their performance as predictors in the regression models. The Pearson's correlation coefficients between the variable and the slope of the linear trend in the changes in the land cover naturalness index are provided in Appendix B, which lists all the explanatory variables. Figure 5 summarises the information on the potential of each variable to be used as a predictor in multiple linear regression models. Some variables were found to be statistically significant in all potential variable combinations. Usually, such were the variables associated with land use intensity (e.g., the proportion of land area under intensive use from total (agricultural), land and the proportion of abandoned agricultural land in the municipality), conditions of land use (average soil productivity score and the proportion of drained lands in the municipality), mean values describing the terrain, the density of streams, and characterising the agriculture in the municipality (e.g., area proportion of the perennial grassland). Demographic factors, such as population densities from different censuses, were among the poorest candidates as explanatory variables. It should be noted that the variables which were found to be statistically significant in the models were also consistent in the relationships; for example, increased variables associated with land use intensity usually resulted in decreasing land cover naturalness, as did the poorer soils and larger proportions of drained lands.

More than 70% of the variance in the slope of the linear trend of the land cover naturalness index was explained in the best regression models, created using three and two of the best performing variables. A total of four individual variables were found that explained more than 50% of the variance. Regression models with the highest adjusted R^2 and lowest Akaike information criterion are exemplified in Table 2. The variables usually describe or shape the properties of agricultural activities and natural conditions in the municipalities.

Table 2. Examples of the best multiple linear regression models for the different number of explanatory variables.

Adjusted R^2	Corrected Akaike Information Criterion	Jarque–Bera Statistic	Koenker (BP) Statistic	Variance Inflation Factor	Moran's *I* of the Regression Residuals	Model
Three explanatory variables						
0.784	−494.8	0.33	0.76	1.38	0.88	0.012869 − 0.000119 × [Drained area prop.] *** − 0.000076 × [Intensive use prop. 2014] *** − 0.001521 × [CORINE wetland 2012] ***
0.781	−494.2	0.33	0.63	1.29	0.91	0.006178 − 0.000125 × [Drained area prop.] *** + 0.000073 × [Grassland agric. prop. 2014] *** − 0.001522 × [CORINE wetland 2012] ***
0.754	−488.2	0.48	0.13	2.04	0.94	−0.011206 + 0.000181 × [Grassland agric. prop. 2009] *** − 0.000258 × [Grassland total prop. 2009] *** − 0.000001 × [Protection zones roads] ***
Two explanatory variables						
0.715	−482.0	0.97	0.08	1.01	0.71	0.002914 + 0.000124 × [Grassland agric. prop. 2009] *** − 0.000001 × [Proportion streams 2004] ***
0.712	−481.4	0.51	0.24	1.33	0.89	0.003456 − 0.000107 × [Drained area prop.] *** + 0.000079 × [Grassland agric. prop. 2009] ***
0.711	−481.4	0.90	0.10	1.01	0.82	0.014212 − 0.000124 × [Intensive use prop. agric. 2014] *** − 0.000001 × [Proportion streams 2004] ***
One explanatory variable						
0.589	−464.7	0.57	0.09	1.00	0.62	0.008781 − 0.000145 × [Drained area prop.] ***
0.580	−463.5	0.52	1.00	1.00	0.28	0.006734 − 0.000187 × [Intensive use prop. 2014] ***
0.565	−461.7	0.85	0.16	1.00	0.43	0.023713 − 0.000534 × [Soil productivity] ***
0.551	−460.1	0.62	0.82	1.00	0.27	0.006237 − 0.000199 × [Intensive use prop. agric. 2009] ***

Note: The statistical significance of each coefficient in the model is noted as follows: ***, $p = 0.01$.

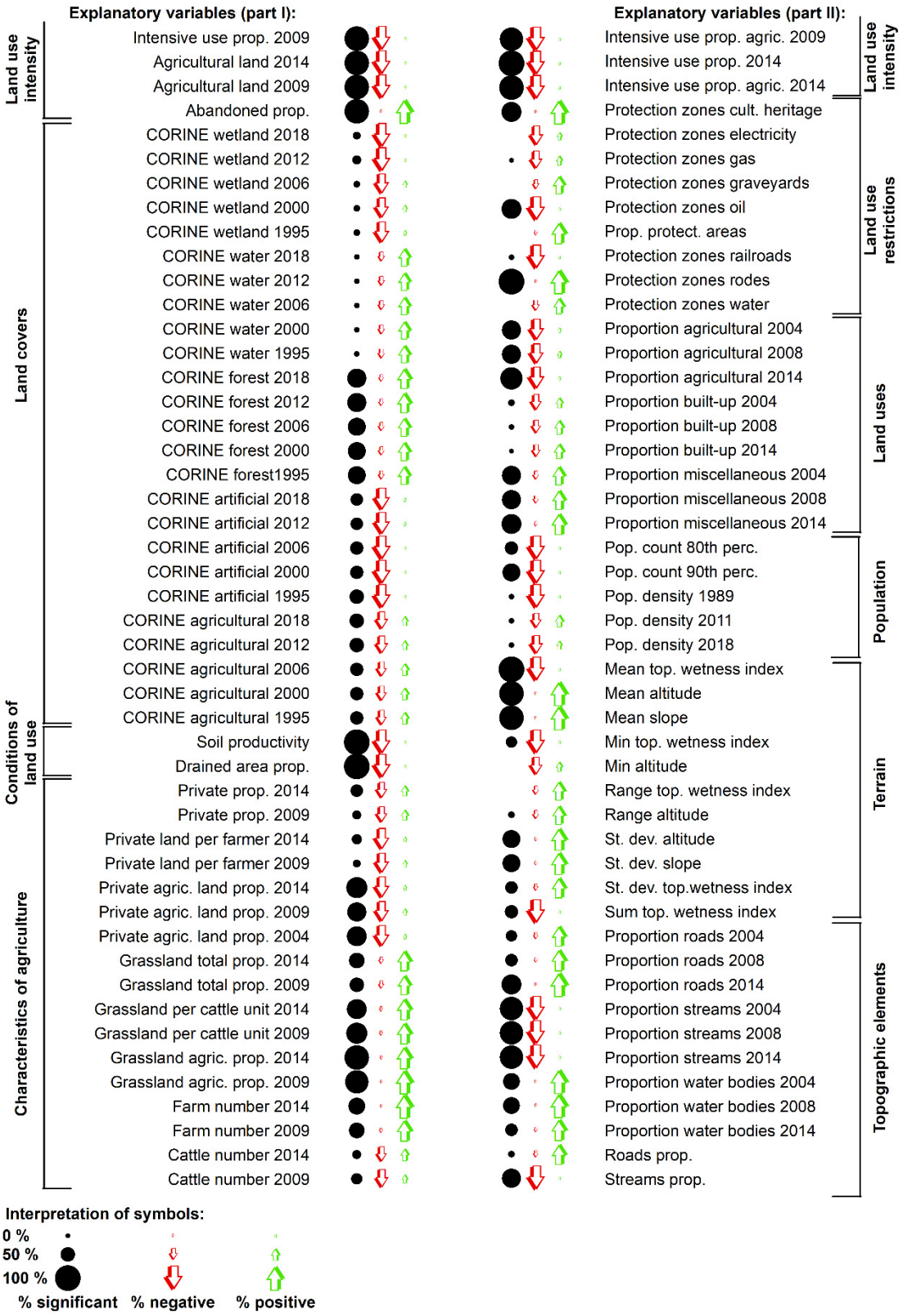

Figure 5. The proportions of times that each candidate explanatory variable was statistically significant when testing all potential regression models and the stability of candidate explanatory variables in the tested regression models.

4. Discussion

Several potential methodological limitations relevant to the approach used in the current study need to be addressed before entering the discussion of the achieved results. To our best knowledge, there is no commonly accepted methodology for evaluating the phenomenon under focus, as the spatial units used for assessment as well as the assessment scale may differ [15]. Leaving the overall concept of landscape behind for more detailed discussion, we must accept that the evaluation of landscape characteristics according to the level of anthropogenic impact differs among researchers [17,26–34]. Associating specific land cover type with a discrete index value may also be considered subjective. For example, there are several evaluation schemes used in Lithuania, including the one adopted for our study [16,17,29]. The use of municipalities as the spatial unit to aggregate the landscape characteristics has been criticised [15], suggesting that units with natural borders better describe the processes in the landscape. Nevertheless, the primary objective of the current study was not to make a finite statement on the landscape naturalness in Lithuania; rather, we aimed to detect general trends in the development of landscapes and to suggest the drivers behind such trends. Therefore, we chose to use standardised input datasets and index values for land cover types. Expecting that our findings may contribute to the support of spatial planning, we preferred the administrative borders of municipalities to, for example, the borders of natural landscape regions [35]. It should be noted that we did not aim to achieve the overall best explanation for the reasons behind the landscape's development. Our primary objective was to use open and publicly available data. We chose multiple regression as the method for explaining the drivers of land cover change, which is also very much due to its potential to introduce a spatial component into the analysis, e.g., geographically weighted regression, testing the spatial autocorrelation of residuals, etc. Finally, the choice of research level or scale has always been an important factor in similar studies. Technically, the minimum mapping unit in the CORINE database is 25 ha. Thus, smaller land covers and land cover changes automatically are not registered. Enlarging the spatial and thematic resolution of input data would result in finer land cover maps. Nevertheless, this does not automatically contribute to solving research tasks, which may require specific input data in terms of geographic areas mapped, temporal resolution, wall-to-wall coverage, compatibility of development methods, etc. We compared the CORINE Land Cover data with the land-use information that was available from the Lithuanian National Forest Inventory (NFI). The Lithuanian NFI, which provides data for National greenhouse gas reporting, involves permanent observation of land-use types on a network of 16,349 systematically distributed sampling plots with sub-meter location accuracy and annual records since 1990 [21,36,37]. Twenty-five land-use classes are identified in the NFI database, which are fewer than the number of land cover types used in CORINE in Lithuania (33). The Pearson's contingency coefficients between the CORINE Land Cover classes and the NFI land-use classes are 0.905, 0.901, 0.901, and 0.903, for years 1995, 2000, 2006, and 2012, respectively. This suggests high agreement between two datasets made at different scales and justifies the use of the CORINE database for a country-wide level of study.

Therefore, even though the overall improvement in land cover naturalness since 1995 was small and statistically insignificant for the whole country, statistically significant clusters were identified at the level of municipalities, suggesting both a decline and increase in the attribute under focus. This confirms our previous statements [21,38] that spatial units for an analysis that is finer than the whole country may contribute to the disclosure of significant patterns in the phenomena under focus. The index of land cover naturalness was significantly declining in the central part of Lithuania (Figure 4), i.e., in municipalities with more favourable conditions for agriculture. Contrary to that, the index of landscape naturalness was improving (even though mostly not significantly) in municipalities less suitable for agriculture and, therefore, containing larger proportions of forest land area. Current land cover structure automatically impacts the levels of landscape naturalness, mostly due to the specifics of agricultural and forestry activities. Nevertheless, the most significant factor for

landscape naturalness is the abundance of forest land in the municipality, being in line with the assumptions of other Lithuanian researchers [15]. This observation was later supported when analysing the drivers behind the changes in landscape naturalness; usually, the most significant factors pushing down the index values were the ones related to the properties of lands in relation to their suitability for agriculture and, therefore, more intensive past and current use, soil fertility, proportions of drained lands, and other factors impeding agriculture, such as the complexity of the terrain, the density of streams, etc. Soil productivity and the proportion of lands drained within the framework of previous land reclamation projects are associated with the peculiarities of agricultural land use—more specifically, with the proportion of meadows/grassland vs. cropland [21]. This proportion is critically important when aiming to reduce the green-house gas emissions in land use, land-use change, and the forestry sector, linking the efforts of climate change mitigation with the improvement in landscape naturalness. Land reclamation is considered another important factor that shaped Lithuanian landscapes in the second half of the 20th century [39–41]. It should be emphasised that the facilities available for land reclamation in Lithuania influence land use; for example, the afforestation of agricultural lands is dependent on the presence or absence of land with a functioning land reclamation system [42]. More specifically, afforestation is limited to the areas where the root systems of future forests may not destroy the functioning drainage system. However, information on the actual status of land reclamation systems is usually not available or is outdated [43]. Population is often reported as being an important factor influencing land-use distribution [44–50]. However, demographic factors were not found to be among the most important factors.

Landscape naturalness could be improved in Lithuania by focusing on increasing the areas of forest land and meadows/grasslands. First of all, increasing the proportion of forest land should be prioritised by coordinating the allocation of agricultural vs. forest and other natural land uses. Forest land proportion in Lithuania in 2021 was 33.7% [51]. Afforestation targets set by the politicians are to reach at least 35% by 2030 [22], whereas the forest land proportion targets set by the national forest agreement [52] mention a more ambitious 40% target. This objective is supported by national strategic political documents [53–55], especially those aimed at the effective use of EU support [56]. Thus, the EU's contribution should be targeted to support the establishment of new forests, assuming that backward processes remain under strict legal restraint. The Common Agricultural Policy (CAP) of the EU should further focus on green direct payment, especially maintaining permanent grassland, which not only supports carbon sequestration but also contributes to the protection of biodiversity [57]. In parallel, Lithuania should continue to maintain its permanent grassland [58]. As an additional option, we suggest an increase in the focus on agroforestry. Landscape naturalness could also be improved by establishing small tree and brush patches among perennial grassland or tree or brush belts around the edges of croplands. This would enable better balancing among the EU challenges in the sectors of agriculture and forestry, specified in the European Green Deal [59], Farm to Fork [60], Biodiversity [61], or Bioeconomy [62] strategies, also contributing to reducing greenhouse emissions globally, enrichening biodiversity, and sustaining fertile and healthy soils and ecologically important areas.

5. Conclusions

Even though, in general, the land cover naturalness in Lithuania has tended to improve since 1995, quite contradicting trends were observed at the municipal level, including the units for spatial planning and operational decisions to be taken. The trends indicated both an improvement and decline in the index used for landscape characterisation, and the trends were spatially clustered. The current land cover structure very much predefined the level of land cover naturalness, mostly due to the specificity of agricultural and forestry activities. The key factors predefining the changes in land cover naturalness were related to the intensity of agriculture. Thus, the proposal for the coming decade in Lithuania is

to focus on reducing the areas under a heavy load of agricultural crop production via increasing the area of forest and grassland.

Assuming that our study was conducted using freely available data, which was acquired within the framework of continuing programs, we would like to emphasise the importance of landscape monitoring programs. The applicability of landscape monitoring products goes far beyond the direct needs of spatial planning. We find that it is an important source of information to understand the processes related to human and natural interaction. Therefore, it is important to consider other spatial units than those required for spatial planning to better understand the natural limitations and opportunities of the landscapes to overcome the stress induced by rapidly changing conditions. There is no commonly accepted methodology for assessing landscape development trends nationally; we need to simultaneously validate the approach, going beyond the borders of Lithuania. The availability and contents of CORINE data makes this task easier to implement; however, the indexing of land covers needs to be coordinated among countries. In order to plan future landscapes, especially focusing on land covers and their impact on the level of naturalness, it is also critically important to have a concept for land use monitoring and management. Such a concept must cover the diversity of ecological, socio-economic, and political land use challenges to facilitate management decisions at the landscape level. Therefore, a spatially explicit assessment of the land cover patterns and their changes, as demonstrated in the current study, may enable the identification of critical areas and development trends and may provide insights for improving land management policies and associated decisions.

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Appendix A

Table A1. The values of the land cover naturalness index by CORINE Land Cover classes (adopted from Skorupskas (2006)).

Class Code	Class Name	Index Value
1.1.1	Continuous urban fabric	0
1.1.2	Discontinuous urban fabric	0.10
1.2.1	Industrial or commercial units	0
1.2.2	Road and rail networks and associated land	0.10
1.2.3	Port areas	0
1.2.4	Airports	0.10
1.3.1	Mineral extraction sites	0.20
1.3.2	Dump sites	0.10

Table A1. *Cont.*

Class Code	Class Name	Index Value
1.3.3	Construction sites	0.10
1.4.1	Green urban areas	0.50
1.4.2	Sport and leisure facilities	0.30
2.1.1	Non-irrigated arable land	0.30
2.2.2	Fruit trees and berry plantations	0.60
2.3.1	Pastures	0.50
2.4.1	Annual crops associated with permanent crops	-
2.4.2	Complex cultivation patterns	0.50
2.4.3	Land principally occupied by agriculture, with significant areas of natural vegetation	0.60
3.1.1	Broad-leaved forest	1.00
3.1.2	Coniferous forest	0.90
3.1.3	Mixed forest	1.00
3.2.1	Natural grassland	0.50
3.2.2	Moors and heathland	0.70
3.2.4	Transitional woodland/shrub	0.80
3.3.1	Beaches, dunes, sands	0.70
3.3.3	Sparsely vegetated areas	0.70
3.3.4	Burnt areas	0.50
4.1.1	Inland marshes	1.00
4.1.2	Peatbogs	0.20
5.1.1	Water courses	0.90
5.1.2	Water bodies	0.90
5.2.1	Coastal lagoons	0.90
5.2.2	Estuaries	-
5.2.3	Sea and ocean	1.00

Appendix B

Table A2. The list of tested potential explanatory variables.

Alias	Description of the Variable	Source Dataset	Pearson's Correlation Coefficient *
	Characteristics of agriculture		
Cattle number 2009	Total number of cattle per area unit in the municipality in 2009	Statistics Lithuania	−0.289
Cattle number 2014	Total number of cattle per area unit in the municipality in 2014	Statistics Lithuania	−0.191
Farm number 2009	Number of farms per area unit, according to the Register of Farmers in 2009	Statistics Lithuania	0.228

Table A2. *Cont.*

Alias	Description of the Variable	Source Dataset	Pearson's Correlation Coefficient *
Farm number 2014	Number of farms per area unit, according to the Register of Farmers in 2014	Statistics Lithuania	0.282
Grassland agric. prop. 2009	Proportion of the area of perennial grassland from the total agricultural land area in 2009, %	Statistics Lithuania	0.693
Grassland agric. prop. 2014	Proportion of the area of perennial grassland from the total agricultural land area in 2009, %	Statistics Lithuania	0.656
Grassland per cattle unit 2009	Area of the perennial grassland per one cattle unit in 2009	Statistics Lithuania	0.525
Grassland per cattle unit 2014	Area of the perennial grassland per one cattle unit in 2014	Statistics Lithuania	0.530
Grassland total prop. 2009	Area proportion of the perennial grassland in 2009	Statistics Lithuania	0.153
Grassland total prop. 2014	Area proportion of the perennial grassland in 2014	Statistics Lithuania	0.223
Private agric. land prop. 2004	Area proportion of agricultural land in private lands in 2004	Statistics Lithuania	−0.523
Private agric. land prop. 2009	Area proportion of agricultural land in private lands in 2009	Statistics Lithuania	−0.506
Private agric. land prop. 2014	Area proportion of agricultural land in private lands in 2014	Statistics Lithuania	−0.538
Private land per farmer 2009	Area of private land per one farmer in 2009	Statistics Lithuania	−0.281
Private land per farmer 2014	Area of private land per one farmer in 2014	Statistics Lithuania	−0.305
Private prop. 2009	Proportion of private land area in 2009	Statistics Lithuania	−0.262
Private prop. 2014	Proportion of private land area in 2014	Statistics Lithuania	−0.300
	Conditions for land use		
Drained area prop.	Proportion of drained areas	Mel_DR10LT	−0.773
Soil productivity	Average soil productivity score for agricultural land	Dirv_DR10LT	−0.757
	Land covers		
CORINE artificial 1995	Area proportion of artificial surfaces in 1995	COPERNICUS	−0.282
CORINE artificial 2000	Area proportion of artificial surfaces in 2000	COPERNICUS	−0.278
CORINE artificial 2006	Area proportion of artificial surfaces in 2006	COPERNICUS	−0.274
CORINE artificial 2012	Area proportion of artificial surfaces in 2012	COPERNICUS	−0.266
CORINE artificial 2018	Area proportion of artificial surfaces in 2018	COPERNICUS	−0.265
CORINE agricultural 1995	Area proportion of agricultural areas in 1995	COPERNICUS	−0.265
CORINE agricultural 2000	Area proportion of agricultural areas in 2000	COPERNICUS	−0.258
CORINE agricultural 2006	Area proportion of agricultural areas in 2006	COPERNICUS	−0.259
CORINE agricultural 2012	Area proportion of agricultural areas in 2012	COPERNICUS	−0.313
CORINE agricultural 2018	Area proportion of agricultural areas in 2018	COPERNICUS	−0.312
CORINE forest1995	Area proportion of forest and seminatural areas in 1995	COPERNICUS	0.383
CORINE forest2000	Area proportion of forest and seminatural areas in 2000	COPERNICUS	0.380
CORINE forest2006	Area proportion of forest and seminatural areas in 2006	COPERNICUS	0.380
CORINE forest2012	Area proportion of forest and seminatural areas in 2012	COPERNICUS	0.443
CORINE forest2018	Area proportion of forest and seminatural areas in 2018	COPERNICUS	0.443
CORINE wetland 1995	Area proportion of wetlands in 1995	COPERNICUS	−0.020
CORINE wetland 2000	Area proportion of wetlands in 2000	COPERNICUS	−0.003

Table A2. *Cont.*

Alias	Description of the Variable	Source Dataset	Pearson's Correlation Coefficient *
CORINE wetland 2006	Area proportion of wetlands in 2006	COPERNICUS	−0.002
CORINE wetland 2012	Area proportion of wetlands in 2012	COPERNICUS	−0.065
CORINE wetland 2018	Area proportion of wetlands in 2018	COPERNICUS	−0.063
CORINE water 1995	Area proportion of water bodies in 1995	COPERNICUS	0.167
CORINE water 2000	Area proportion of water bodies in 2000	COPERNICUS	0.162
CORINE water 2006	Area proportion of water bodies in 2006	COPERNICUS	0.162
CORINE water 2012	Area proportion of water bodies in 2012	COPERNICUS	0.162
CORINE water 2018	Area proportion of water bodies in 2018	COPERNICUS	0.162
	Land use intensity		
Abandoned prop.	Area proportion of abandoned agricultural land	AŽ_DRLT	0.600
Agricultural land 2009	Area proportion of declared land used for agriculture in 2009	Statistics Lithuania	−0.674
Agricultural land 2014	Area proportion of declared land used for agriculture in 2014	Statistics Lithuania	−0.669
Intensive use prop. agric. 2009	Area proportion of land under intensive use in 2009	Statistics Lithuania	−0.748
Intensive use prop. agric. 2014	Proportion of land area under intensive use from total agricultural land in 2009	Statistics Lithuania	−0.701
Intensive use prop. 2014	Area proportion of land under intensive use in 2014	Statistics Lithuania	−0.767
Intensive use prop. 2014	Proportion of land area under intensive use from total agricultural land in 2014	Statistics Lithuania	−0.692
	Land use restrictions		
Protection zones cult. heritage	Area proportion of cultural heritage protection zones	SŽNS_DR10LT	0.420
Protection zones electricity	Area proportion of protection zones around electricity lines	SŽNS_DR10LT	−0.021
Protection zones gas	Area proportion of protection zones around gas pipelines	SŽNS_DR10LT	−0.005
Protection zones graveyards	Area proportion of graveyards and protection zones around them	SŽNS_DR10LT	0.060
Protection zones oil	Area proportion of protection zones around oil pipelines	SŽNS_DR10LT	−0.292
Protection zones protect. areas	Area proportion of protected areas	SŽNS_DR10LT	0.211
Protection zones railroads	Area proportion of protection zones around railroads	SŽNS_DR10LT	−0.243
Protection zones roads	Area of protection zones around roads	SŽNS_DR10LT	0.578
Protection zones water	Area proportion of protection zones around water bodies	SŽNS_DR10LT	0.057
	Land uses		
Proportion agricultural 2004	Area proportion of agricultural blocks in the municipality in 2004	KŽS	−0.487
Proportion agricultural 2008	Area proportion of agricultural blocks in the municipality in 2008	KŽS	−0.488
Proportion agricultural 2014	Area proportion of agricultural blocks in the municipality in 2014	KŽS	−0.558
Proportion built-up 2004	Area proportion of built-up blocks in the municipality in 2004	KŽS	−0.054
Proportion built-up 2008	Area proportion of built-up blocks in the municipality in 2008	KŽS	−0.033

Table A2. *Cont.*

Alias	Description of the Variable	Source Dataset	Pearson's Correlation Coefficient *
Proportion built-up 2014	Area proportion of built-up blocks in the municipality in 2014	KŽS	0.021
Proportion miscellaneous 2004	Area proportion of miscellaneous blocks in the municipality in 2004	KŽS	0.419
Proportion miscellaneous 2008	Area proportion of miscellaneous blocks in the municipality in 2008	KŽS	0.422
Proportion miscellaneous 2014	Area proportion of miscellaneous blocks in the municipality in 2014	KŽS	0.450
	Population		
Pop. count 80th perc.	80th percentile of the population count	GISCO	−0.327
Pop. count 90th perc.	90th percentile of the population count	GISCO	−0.305
Pop. density 1989	Population density in 2011, number of inhabitants/km^2	Statistics Lithuania	−0.141
Pop. density 2011	Population density in 2018, number of inhabitants/km^2	Statistics Lithuania	−0.017
Pop. density 2018	Population density in 1989, number of inhabitants/km^2	Statistics Lithuania	−0.427
	Terrain		
Max top. wetness index	Maximum value of the topographic wetness index	MapsForEurope	−0.028
Mean altitude	Average altitude within the borders of the municipality	MapsForEurope	0.591
Mean slope	Average terrain slope within the borders of the municipality	MapsForEurope	0.591
Mean top. wetness index	Average value of the topographic wetness index	MapsForEurope	−0.689
Min altitude	Minimum altitude value within the borders of the municipality	MapsForEurope	−0.013
Min top. wetness index	Minimum value of the topographic wetness index	MapsForEurope	−0.331
Range altitude	Range of altitude values within the borders of the municipality	MapsForEurope	0.235
St. dev. altitude	Standard deviation of altitude values within the borders of the municipality	MapsForEurope	0.427
St. dev. slope	Standard deviation of relief slope values within the borders of the municipality.	MapsForEurope	0.427
St. dev. top. wetness index	Standard deviation value of the topographic wetness index	MapsForEurope	0.374
Sum top. wetness index	Sum of the topographic wetness index values	MapsForEurope	−0.211
	Topographic elements		
Proportion roads 2004	Area proportion of roadblocks in the municipality in 2004	KŽS	0.116
Proportion roads 2008	Area proportion of roadblocks in the municipality in 2008	KŽS	0.133
Proportion roads 2014	Area proportion of roadblocks in the municipality in 2014	KŽS	0.326
Proportion streams 2004	Length of streams per area unit in the municipality in 2004	KŽS	−0.557
Proportion streams 2008	Length of streams per area unit in the municipality in 2008	KŽS	−0.582
Proportion streams 2014	Length of streams per area unit in the municipality in 2014	KŽS	−0.584
Proportion water bodies 2004	Area proportion of blocks around the water bodies in the municipality in 2004	KŽS	0.376
Proportion water bodies 2008	Area proportion of blocks around the water bodies in the municipality in 2008	KŽS	0.380

Table A2. *Cont.*

Alias	Description of the Variable	Source Dataset	Pearson's Correlation Coefficient *
Proportion water bodies 2014	Area proportion of blocks around the water bodies in the municipality in 2014	KŽS	0.314
Roads prop.	Length of roads per area unit in the municipality	OpenStreetMap	0.149
Streams prop.	Length of streams per area unit in the municipality	COPERNICUS	−0.407

* Correlation estimated between the variable and slope of the linear trend in changes in the land cover naturalness index.

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