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SPATIAL ANALYSIS OF SOIL DEGRADATION AND EROSION AND ASSESSMENT OF CHANGES IN THE SPATIAL STRUCTURE (LAND USE) OF THE LANDSCAPE

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Methodology for assessing erosion degradation and risk by financing economic activities in territorial units of elderships and cadastral areas

The purpose of the soil degradation and erosion risk assessment is to determine the degree of risk of soil degradation and erosion in agricultural areas and to assess the impact of the to-be-financed economic activities on the change in these risks.

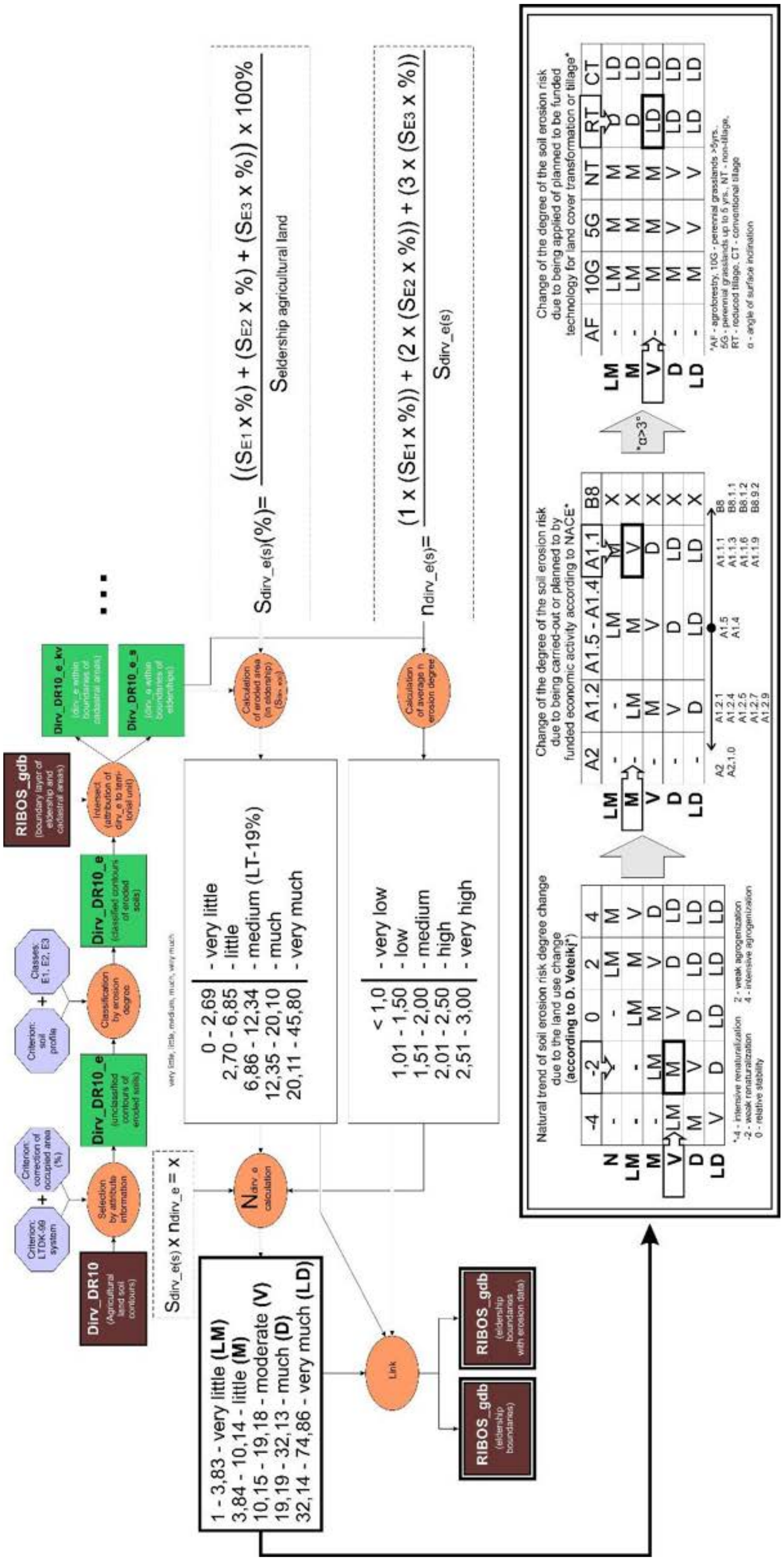
The purpose of the assessment of the change in the spatial structure (land use/land cover) of the landscape is to provide data for the assessment of the risk of soil degradation and erosion and the spatial analysis of these phenomena, presenting the value of *the index of the intensity of agrarian anthropogenization* within the administrative units (elderships and cadastral areas), determined by the structure and change of the land cover.

Software used for analysis: QGIS, MS Excel.

Data used: GIS data layers for the boundaries of elderships and cadastral areas, soil database Dirv_DR10_LT, 10x10m surface height model DTM, 10x10m surface inclination angle values model SLOPE.

The analysis methodology is based on the geographical notion that soil degradation in the general sense and erosion factors in agricultural areas (the territory of Lithuania) become relevant only when economic activities (according to NACE) that make changes to the vegetation cover, the soil surface or the very soil’s nature are introduced on agricultural land.

Principle methodological scheme for soil degradation and erosion risk assessment



The methodology for assessing the risk of soil degradation and erosion consists of the following steps:

1.1. Assessment of the areas of eroded soil on agricultural land and the degree of soil damage in them ($N_{dirv\_e(sq/s)}$)

Preparation of eroded soil data layers for cadastral areas and elderships.

1. Soil areas are selected from the **Dirv_DR10_LT** database (soil database of Lithuanian agricultural areas on scale M 1:10 000), based on the soil classification system of LTDK-99 and the nomenclature of the names TDV-96, where soil degradation currently has been identified. At the same time, data on the degraded area and its percentage in each area are also extracted and a new **Dirv_DR10_LT_e** data layer is compiled, containing only eroded soils.
2. In the created soil data layer (**Dirv_DR10_LT_e**) the degree of soil erosion is encoded in the name of the soil and makes it possible to distinguish weakly (E1), moderately (E2) and strongly (E3) degraded soils. In the existing layer, a column of textual data is created in which all typological units of soils are grouped into three groups (E1, E2, E3): VKE1, JvN1, JvE1 and E1 are classified as weakly degraded – E1; JvN2 and E2 are classified as moderately degraded – E2; and Nkm and E3 for the strongly degraded – E3.
3. The compiled data layer of eroded soils of the territory of Lithuania is overlapped with the layers of the boundaries of the cadastral areas and, respectively, the elderships. In this way, two layers of data are obtained: **Dirv_DR10_LT_e_kv** and **Dirv_DR10_LT_e_sen**. These layers contain in themselves information about the fact and degree of soil erosion (E1, E2, E3), their areas (Shape area) and belonging to the territorial unit (for elderships - column SHN, for cadastral areas - KOD_VIET column). Soil erosion data are associated with the codes of the administrative territorial units analysed, and not with their names, since each code is unique, while the names of elderships and cadastral areas sometimes can coincide with each other.

Risk analysis of eroded soils will not be carried out in relation to territorial units (elderships or cadastral areas), but in relation to the area of agricultural land located in them. This direction of analysis was chosen because the risk of soil erosion should be assessed only in relation to areas where this erosion is potentially possible due to the potential economic activities that may affect the degree of soil erosion and the increase in areas. Thus, forestry land, water bodies and built-up areas are excluded from the analysis.

1. The area for which an analysis will be carried out in each eldership and cadastral area is calculated. The Lithuanian soil database polygon type layer **Dirv_DR10_LT** (contour) is intersected with the layers of the boundaries of the cadastral areas and, accordingly, the elderships, and two new data layers are created, respectively: **konturas_kv** and **konturas_sen**. They contain information about the soils of agricultural areas located on a specific territory of the cadastral area and eldership. On the basis of these data, data tables (**Dirv_agro_kv_plotas_2023** and **Dirv_agro_sen_plotas_2023**) with the codes and names of cadastral areas (KAD_VIET) and elderships (SHN) as well as areas of

agricultural land according to the Dirv_DR10_LT database are created. This data will be used in further calculations.

Calculations of the areas of eroded soils and the average degree of erosion.

1. Calculation of the objective area within the eroded soil polygon. Since for each polygon of eroded soil is indicated the percentage of eroded soils in it, we need to calculate what is the real area of eroded soils in a particular polygon.

Shape_Area x EROZ_P = Area_EROZ_P

2. Assignment of the eroded soil polygon to the degree of erosion and to the specific territory being analysed. Before that, the corresponding columns of data (VIETOVE_EROZ for cadastral areas and SHN_EROZ for elderships) are created in a specific layer.

VIETOVE_EROZ (TXT, 10) = KOD_VIET&"_"&EROZ
SHN_(TXT,15)=SHN&"_"&EROZ

3. The sum of areas of varying degrees of erosion of eroded soil in each specific territorial unit (cadastral area and eldership) is calculated. For this, the columns created above are used, in which the code of the area and the degree of erosion of the soil range are recorded. A dbf tables (Erozija_E_kv_2023 and Erozija_E_sen_2023) are created in which the information is placed:

Summarize by VIETOVE_EROZ: *KOD_VIET – Average* *LOCATION – FIRST* *EROZ - First* *Area_EROZ_P - sum*	*Summarize by SHN_EROZ:* *SHN – First* *NAME – First* *EROZ - First* *Area_EROZ_P - sum*

4. Deduction of the degree of erosion from the code of the degree of erosion and the conversion of its textual information into a numeric one, recording the value in the newly created data column EROZ_L (short integer). From the data in the column First_EROZ, data are selected (select by attribute) and numerical values are assigned to them respectively: E1 = 1, E2 = 2 and E3 = 3. They are recorded using Field Calculator.
5. Conversion of the eroded soils polygon according to the degree of erosion identified in it. Conversion data is saved to the newly created data column A_EROZ_PxL

Field Calculator: A_EROZ_PxL = Sum_Area_EROZ_P x EROZ_L

6. The total amount of areas of eroded soils polygons and these polygons converted according to the degree of erosion within each specific territorial unit (cadastral area and eldership)

is calculated. A dbf table (Erozija_kv_2023 and Erozija_sen_2023) is created in which information is placed:

Summarize by : Ave_KOD_VIET *First_VIETOVE – First* *Sum_Area_EROZ_P – Sum* *A_EROZ_PxL - Sum*	*Summarize by First_SHN:* *First_NAME – First* *Sum_Area_EROZ_P – Sum* *A_EROZ_PxL - Sum*

7. The created tables, respectively, are supplemented with data on the areas of agricultural areas from **the tables of Dirv_agro_kv_plotas_2023** and **Dirv_agro_sen_plotas_2023**. This is done by using the JOIN function in the Attribute table. The tables are linked respectively through the KOD_VIET (cadastral places) and SHN (for elderships) classifications. The augmented area fields are moved to the newly created corresponding data columns (type *double*) Area_kv_agro (for cadastral areas) and Area_sen_agro (for elderships)

Field Calculator/ Area_kv_agro = Sum_Shape_Area (Dirv_agro_kv_plotas_2023)
Field Calculator/ Area_sen_agro = Sum_Shape_Area (Dirv_agro_sen_plotas_2023)

8. The tables created are supplemented, respectively, with the average surface inclination data from the tables **SLOPE_10x10_kv** and **SLOPE_10x10_sen**. This is done by using the Join function in the Attribute table. The tables are linked accordingly through the KOD_VIET (cadastral places) and SHN (for elderships) classifications. The values of the angles of inclination are transferred to the newly created corresponding columns of data SLOPE_MEAN (double).

Field Calculator/ SLOPE_MEAN = MEAN (SLOPE_10x10_kv)
Field Calculator/ SLOPE_MEAN = MEAN (SLOPE_10x10_sen)

9. Calculation of the percentage of eroded soils from agricultural land ($S_{dirv\_e(sq/s)}(\%)$) and inclusion in the newly created data column EROZ_P (double)

Field Calculator / EROZ_P = (Sum_Sum_Area_EROZ_P x 100) / Area_kv_agro
Field Calculator / EROZ_P = (Sum_Sum_Area_EROZ_P x 100) / Area_sen_agro

10. Calculation of the average degree of erosion ($n_{dirv\_e(kv/s)}$) in each cadastral area and eldership and its inscription into the newly created data column EROZ_L (double)

Field Calculator / EROZ_L = Sum_A_EROZ_PxL / Sum_Sum_Area_EROZ_P

11. Calculation of the degree of erosion risk ($N_{dirv\_e(kv/s)}$) in each cadastral area and eldership and its inscription into the newly created data column PxL (double).

Field Calculator / PxL = EROZ_P x EROZ_L

1.2. The trend of change in the structure of land use/land cover according to CORINE data analysis.

The path to finding *the trend of change in the land cover of agrarian areas*

12. Selected the Level 3 CORINE land cover types that are relevant for the assessment of the risks to the soil posed by agriculture.

13. After analysing the CORINE land cover classification and classification features, four types of land cover were selected for analysis (all types of Agricultural areas relevant to Lithuania in the CORINE classification, except for *'222. Fruit trees and berry plantations'*):
    a. 211 Non-irrigated arable land
    b. 231 Pastures
    c. 241 Annual crops associated with permanent crops
    d. 242 Complex cultivation patterns
    e. 243 Land principally occupied by agriculture, with significant areas of natural vegetation

14. Agricultural activities and at the same time their impact on the soil differ in different types/classes of land cover. The presence/prevalence of arable farming in a given type of land cover was chosen as the main criterion determining the intensity at which the soil is adversely affected. After analysing the differences in the selected CORINE land cover classes according to their structure, revealed in the CORINE preparation methodology, the following classes of land cover are divided according to anthropogenization in the following order (according to the anthropogenic load for agrarian soils observed within their areas) by assigning appropriate scores of intensity of impact on the soil:

    0 – soil cover is not used for agriculture, so both natural and anthropogenic classes of land cover are assigned 0 score.
    1 – the anthropogenic impact of agricultural activity on the soil is observed (the greatest naturalness among agricultural fields): 231 (pastures do not suffer from ploughing, although the digressive effect of cattle on the soil may occur in places); impact intensity score 1 is given.
    2 – average anthropogenic impact (average naturalness): 243 (areas of natural vegetation interspersed between the arable areas, expressed as a micro-frame of the landscape); the impact score of 2 is given;
    3 – minimum naturalness, maximum anthropogenic impact on agrarian soil: 211, 241, 242 (the main or greater part of these areas is periodically ploughed); the impact score of 3 is given;

15. Each land cover area in the database is given a previously presented soil impact (anthropogenization) score according to its land cover code for each year of CORINE data retrieval (1995, 2000, 2006, 2012, 2018). With the assessment of land cover areas by the intensity of the impact of agriculture in scores, it is possible to continue to seek for the generalization of this effect in space and time in formal areas: elderships and cadastral areas. The following are the stages of applying spatial data GIS operations.

16. Intersection of information layers:
    a. Eldership areas with geoinformation layers of CORINE 1995, 2000, 2006, 2012 and 2018;
    b. Cadastral areas with geoinformation layers of CORINE 1995, 2000, 2006, 2012 and 2018.
    c. As a result of the multi-layer intersection, two information layers of complex structure are obtained (approximately 800-900 thousand polygons within the borders of Lithuania each). Let's conditionally call them *Seniun_95-18* and *Kadastr_95-18*. These layers (one with the boundaries of the eldership, the other with the boundaries of cadastral areas) contain all the sequences of change of the CORINE land cover in the intersection arenas.

17. For further analysis, in layers *Seniun_95-18* and *Kadastr_95-18*, only those intersection polygons need to be selected, in the land cover sequences of which at least once (during 1996-2018) land cover classes 211, 231, 241, 242 and 243 appear. For this purpose, in the topological tables of the layers *Seniun_95-18* and *Kadastr_95-18*, logical operations of the selection according to the attribute information (the presence of the above classes of land cover) are carried out.

    For example: "CODE_95t" = '211' OR "CODE_95t" = '231' OR "CODE_95t" = '241' OR "CODE_95t" = '242' OR "CODE_95t" = '243'
    "CODE_00" = '211' OR "CODE_00" = '231' OR "CODE_00" = '241' OR "CODE_00" = '242' OR "CODE_00" = '243'
    "CODE_06" = '211' OR "CODE_06" = '231' OR "CODE_06" = '241' OR "CODE_06" = '242' OR "CODE_06" = '243'
    "CODE_12" = '211' OR "CODE_12" = '231' OR "CODE_12" = '241' OR "CODE_12" = '242' OR "CODE_12" = '243'
    "CODE_18" = '211' OR "CODE_18" = '231' OR "CODE_18" = '241' OR "CODE_18" = '242' OR "CODE_18" = '243'

18. Selected intersection areas (polygons) with relevant sets of land cover sequences are preserved separately as layers of elderships and cadastral areas, conditionally called *Seniun_95-18_211-243* and *Kadastr_95-18_211-243*.

19. In the topological tables of the layers *Seniun_95-18_211-243* and *Kadastr_95-18_211-243*, new columns are created in which the land cover classes are converted into agricultural impact intensity scores (from 0 to 3); (actions with tables can also be performed in Excel). In this way, in the topological tables of *the Seniun_95-18_211-243* and *Kadastr_95-18_211-*

243 layers, a sequence of scores is also created for each intersection polygon (for example, 0-0-1-1-3).

20. It is appropriate to characterize the score sequences of anthropogenic impact on the soil by the line of a formally calculated trend. The Excel spreadsheet is used. Using the values of the score sequence and the *Forecast.Linear* command, the initial and last value of the predicted section of the trend is determined, then their difference is found, let's call it, a tendency that shows: (1) the direction of the sequence (if the difference is negative, means the effect of agriculture on the soil decreases in the area, if the difference is positive - the effect of agriculture increases) and (2) the rate (the speed) of transformation of the sequence (in any of the above two directions) (Table 20.1). The Excel file with trends is joined to the topological tables of the layers of *Seniun_95-18_211-243* and *Kadastr_95-18_211-243*.

Table 20.1. An example of the score trend and the tendency of the anthropogenization calculated according to the sequences of land cover change.

The sequence of types of land cover					Anthropogenization Score					Calculated trend		Tendency
'95	'00	'06	'12	'18	'95	'00	'06	'12	'18	Beginning	End	
242	242	231	324	243	3	3	1	0	2	2,8	0,8	-2
231	211	243	242	242	1	3	2	3	3	1,6	3,2	1,6

21. Knowledge of the tendency in each of the several hundred thousand intersection polygons related to agricultural activities also makes it possible to determine the average tendency of the impact of agriculture in administrative units, in this case in each eldership and cadastral area. For this purpose, in the topological tables of the layers *Seniun_9518_211-243* and *Kadastr_95-18_211-243*, the tendency values are multiplied by the areas (area) of the intersection polygons – becoming weight coefficients. By summing up these products by elderships and cadastral areas and dividing them by the area of these territorial units, the average tendency of change in the land cover of each eldership and cadastral area is obtained. It should be noted that the result obtained summarises *the tendency of land cover change* only in those areas of the eldership or cadastral area where one of the selected types of agricultural-related land cover was observed at least once in the period 1995-2018 (211, 231, 241, 242, 243). Therefore, the mean value of the tendency *does not reflect the prevalence of agrarian lands* in an administrative unit.

Finding the values of the anthropogenization indicator of agrarian land cover

22. We express the anthropogenization of agrarian land in this work through the prevalence of arable land in agrarian areas, by giving to the types of land cover the anthropogenic load score (areas with CORINE codes 211, 231, 241, 241, 242, 243 represented in scores from 1 to 3; 0 points are received by the other classes of land cover, if there are any in the sequences of land cover change through 1995-2018 - they do not experience the agricultural activities affecting the soil).

23. The average score of the anthropogenization indicator in agrarian areas for each administrative unit was calculated by analogy with the average tendency of land cover change (using the weighted average when the weight factor was the area of the polygon assessed by the scores). Only for that, the CORINE land cover data of the last available year – 2018 – rewritten into the impact scores – was used. Thus, each eldership and cadastral area received the value of this average score in the range from 0 (there are no arable lands in the administrative territory) to 3 points (in the administrative territory, all agrarian areas are basically arable land).

Determination of the intensity of agrarian anthropogenization in elderships and cadastral areas

24. According to the anthropogenization score of agrarian areas and the tendencies in the change of land cover, tables were compiled (one for the generalization of the data of the elderships, the other for the generalization of the data on cadastral areas), which made it possible to distinguish the hazard classes of the intensity of agrarian anthropogenization (and at the same time the *risk of soil degradation*) according to the structure of the land cover (Tables 24.1 and 24.2).

Table 24.1. Levels of agrarian anthropogenization intensity in territorial units (elderships and cadastral areas) according to the predominance of arable lands in agrarian areas (the average anthropogenization score of agrarian areas) and the tendencies of increasing-decreasing their share (change in land cover) (1995-2018).

Numeric value	The level of agrarian anthropogenization intensity	Level of risk of soil degradation due to land cover structure and its change	Level description (through the predominance of arable lands in agrarian areas and the tendencies of their change)
1	Intensive weakening of agrarian anthropogenization	Very low risk	Very small or small share of arable lands and there is a tendency to a rapid decline in share of arable lands
2	Noticeable weakening of agrarian anthropogenization	Low risk	Very small share of arable lands remain stable, small share of arable lands remain stable or decreasing, the average amount of share of arable lands with a tendency to decline rapidly
3	Moderate agrarian anthropogenization	Medium risk	The average amount of share of arable land remains stable, very small or small share of arable lands with a tendency to expand, large or very large share of arable lands with a tendency to shrink rapidly or moderately rapidly
4	Noticeable strengthening of agrarian anthropogenization	High risk	A very large share of arable lands with a slight tendency to decline, large share of arable lands remains stable or expand unremarkably, moderately large share of arable lands with a tendency to expand
5	Intensive strengthening of agrarian anthropogenization	Very high risk	Very large share of arable lands with a tendency to expand moderately or rapidly, large share of arable lands with a tendency to expand strongly

25. The levels of agrarian anthropogenization intensity are at the same time the levels of risk of soil degradation due to the structure of the land cover and its changes. These levels are distinguished by the grouping of the values of the land cover indicators of agrarian areas (anthropogenization scores and tendencies in land cover change) in elderships and cadastral areas as shown in Table 24.2.

Table 24.2. Indicators collation matrices describing the distribution of elderships and cadastral areas according to tendencies in land cover change (CORINE data for 1995-2018) and the average anthropogenization score of agrarian areas (CORINE data for 2018). In the cells of table content are the number of administrative units (elderships and cadastral areas respectively), attributed to a certain group.

		Average tendency of land cover change (**elderships**)					
		-3,6...-0,5	**-0,5...-0,1**	**-0,1...0,1**	**0,1...0,5**	**0,5...3,6**	**Total**
Average Anthrop. score	**0...0,6**	6	2	8	1		17
	0,6...1,2	11	1	1			13
	1,2...1,8	50	10	4	2		66
	1,8...2,4	57	137	18	2	2	216
	2,4...3		45	150	52	2	249
	Total	**124**	**195**	**181**	**57**	**4**	**561**

		Average tendency of land cover change (**cadastral areas**)					
		-3,6...-0,5	**-0,5...-0,1**	**-0,1...0,1**	**0,1...0,5**	**0,5...3,6**	**Total**
Average Anthrop. score	**0...0,6**	13		1			14
	0,6...1,2	38	4	1	1		44
	1,2...1,8	124	40	8	3	1	176
	1,8...2,4	91	268	55	10	3	427
	2,4...3	1	141	403	198	14	757
	Total	**267**	**453**	**468**	**212**	**18**	1418

Explanations	
Average anthropogenization score for agrarian areas (selected types of CORINE land cover) - reflects the predominance of arable lands among agrarian areas in administrative units in 2018 (values from 0 to 3)	
0...0,6	very little share arable lands
0,6...1,2	little share of arable lands
1,2...1,8	moderate share of arable lands
1,8...2,4	a large share of arable lands
2,4...3	a very large share of arable lands
The average tendency of anthropogenization change (change in the anthropogenization score of agrarian areas according to selected CORINE types; tendency values can vary from -3.6 to 3.6)	
-3,6...-0,5	very rapid decline in arable land area
-0,5...-0,1	rapid decline in arable land area
-0,1...0,1	areas of arable land remain stable
0,1...0,5	rapid growth of arable land areas
0,5...3,6	very rapid growth of arable land areas

26. The spatial distribution of the agrarian anthropogenization intensity (AAI) (the risk of soil degradation due to the structure of the land cover) in elderships and cadastral areas is presented in Figures 7 and 8 and in the column KKT of the database.

27. The indicator obtained on the basis of the analysis carried out, reflecting the intensity of agrarian anthropogenization (AAI), is recorded in the column KKT (*[kraštovaizdžio kaitos tendencija]* – trend in landscape change) of the database.

1.3.By type of financed economic activity (NACE)

28. The slope the surface of the agricultural area shall be assessed only when it is planned to carry out economic activities falling within the range A1.1.1 to A1.1.9 of the NACE activities. The assessment is carried out when the angle of inclination of the surface is $\alpha > 3°$.

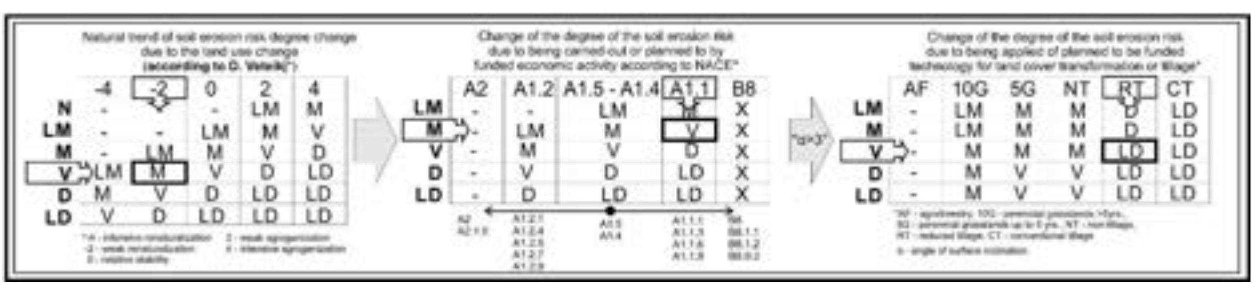
1.4.According to the prevailing slope of the surface.

Calculation of the average slopes for cadastral areas and elderships.

29. The DTM 10x10m surface altitude model is translated into the model of surface inclination angles (SLOPE).
30. The SLOPE model applies *the Zonal statistics* function by overlaying it with the boundary layers of cadastral areas and elderships and at the same time calculating the average slopes (angles of inclination) for these areas. These data will be needed for the selection of areas identified as having a potential risk of soil erosion due to surface inclination (areas with surface inclination >3°)

1.5.According to the planned use of agricultural technologies.

31. When the slope of the surface exceeds 3°, in order to clarify the impact of the planned economic activity on soil erosion, it must be indicated which tillage technology will be used: non-tillage (NT), reduced tillage (RT), or conventional tillage (CT).
32. An example of determining the risk of soil erosion assessment is given in the diagram.



33. All analytical data are presented in spatial data (*.shp) and statistical information (*.xls) formats. The data tables presented in them are expressed in columns and rows. Each row corresponds to a single territorial unit, the unique number of which is given: in column SHN - elderships and in the column of KOD_VIET - cadastral areas. Explanations of the information contained in the columns are given in the tables below (Tables 33.1 and 33.2).

Table 33.1. Explanations of the data table of the eldership layer.

Elderships layer	
ICC	Unique Identifier of Lithuania at EU level
SHN	Unique LT administrative unit number
ISN	Unique EU administrative unit number
NAMN	Name of eldership
DESN	Type of eldership
TAA	Type of administrative area according to the EU boundary map (EBM specification): 2 - land area; 3 – islands (there none at the level of LT elderships); 4 – special areas (there none at the level of LT elderships); 5 – coastal waters; 7 – inland waters; 8 – disputed areas (there none at the level of LT elderships).
Shape_Leng	Boundary length, m
Shape_Area	Total area, m^2
SLOPE_10m	The average angle of inclination of the surface of the territory using 10x10m cells
EROZ_P_agr	The area of eroded soils from the area of agricultural land, m^2
EROZ_L_agr	Average degree of erosion of eroded soils: 0 – soils not affected by erosion, when the ploughing layer is intact and its thickness is at least 25cm; 1 – weak erosion when the upper ploughing layer is damaged (thickness <25cm); 2 – moderate erosion, in which the arable layer is destroyed and the subsoil is eroded; 3 – strong erosion, when the soil is practically destroyed all the way to the soil-forming rock (primary carbonates are found).
PxL	Degree of risk of soil erosion – the ratio between the area of eroded soils and the degree of their erosion
PxL_TXT	Risk classes for soil erosion: N – not-assessable; LM – very little; M – little; V – moderate; D – large; LD – very large;
KKT	Agrarian anthropogenication classes in the context of the risk assessment of soil degradation and erosion (see Table 24.1): 0 - there is no risk or it is not assessable (there is no arable land, the structure of land use consists of water bodies, urbanized areas, forests or the land of the other designation); 1 – very low risk (very little or little share of arable lands and there is a tendency to a rapid decline in share of arable lands); 2 – low risk (very little share of arable lands remain stable, little share of arable lands remain stable or decreasing, the average amount of share of arable lands with a tendency to decline rapidly); 3 – medium risk (the average amount of share of arable land remains stable, very little or little share of arable lands with a tendency to

	expand, large or very large share of arable lands with a tendency to shrink rapidly or moderately rapidly); 4 – high risk (a very large share of arable lands with a slight tendency to decline, large share of arable lands remains stable or expand unremarkably, moderately large share of arable lands with a tendency to expand); 5 – very high risk (very large share of arable lands with a tendency to expand moderately or rapidly, large share of arable lands with a tendency to expand strongly).
SLOPE	Classes of the average surface inclination in degrees: 0 – 1,5 1,5 – 3,0 3,0 – 5,0 5,0 – 8,0 > 8,0
DeR	Correction of the risk class of soil erosion taking into account the significance of agrarian anthropogenization (column KKT). Possible values: N – not-assessable; LM – very small; M – small; V – average; D – large; LD – very large.
DeR_SLOPE	General risk of soil erosion (degradation). Correction of the risk class for soil erosion in the DeR column, taking into account the data in the SLOPE column. Possible values: N – not-assessable; LM – very small; M – small; V – average; D – large; LD – very large.
OPTIMIST	Risk classes for soil erosion according to an optimistic scenario. Possible values: N – not-assessable; LM – very small; M – small; V – average; D – large; LD – very large.
PESIMIST	Risk classes for soil erosion in a pessimistic scenario. Possible values: N – not-assessable; LM – very small; M – small; V – average; D – large; LD – very large.

Table 33.2. Explanations of the data table for the layer of cadastral areas.

Layer of cadastral areas	
AREA_CODE	Unique LT cadastral area number
AREA_NAME	Name of the cadastral area
MUNICIPALI	Belonging to the municipality
Shape_Leng	Boundary length, m
Shape_Area	Total area, m^2
SLOPE_10m	The average angle of inclination of the surface of the territory using 10x10m cells
EROZ_P_agr	The area of eroded soils from the area of agricultural land, m^2
EROZ_L_agr	Average degree of erosion of eroded soils: 0 – soils not affected by erosion, when the ploughing layer is intact and its thickness is at least 25cm; 1 – weak erosion when the upper ploughing layer is damaged (thickness <25cm); 2 – moderate erosion, in which the arable layer is destroyed and the subsoil is eroded; 3 – strong erosion, when the soil is practically destroyed all the way to the soil-forming rock (primary carbonates are found).
PxL	The degree of risk of soil erosion is the ratio between the area of eroded soils and the degree of erosion of them.
PxL_TXT	Risk classes for soil erosion: N – unappreciated; LM – very small; M – small; V – average; D – large; LD – very large.
KKT	Agrarian anthropogenication classes in the context of the risk assessment of soil degradation and erosion (see Table 24.1): 0 - there is no risk or it is not assessable (there is no arable land, the structure of land use consists of water bodies, urbanized areas, forests or the land of the other designation); 1 – very low risk (very little or little share of arable lands and there is a tendency to a rapid decline in share of arable lands); 2 – low risk (very little share of arable lands remain stable, little share of arable lands remain stable or decreasing, the average amount of share of arable lands with a tendency to decline rapidly); 3 – medium risk (the average amount of share of arable land remains stable, very little or little share of arable lands with a tendency to expand, large or very large share of arable lands with a tendency to shrink rapidly or moderately rapidly); 4 – high risk (a very large share of arable lands with a slight tendency to decline, large share of arable lands remains stable or expand unremarkably, moderately large share of arable lands with a tendency to expand); 5 – very high risk (very large share of arable lands with a tendency to expand moderately or rapidly, large share of arable lands with a tendency to expand strongly).
SLOPE	Classes of the average surface inclination in degrees:

	0 – 1,5 1,5 – 3,0 3,0 – 5,0 5,0 – 8,0 > 8,0
DeR	Correction of the risk class of soil erosion taking into account the significance of agrarian anthropogenization (column KKT). Possible values: N – not assessable; LM – very small; M – small; V – average; D – large; LD – very large.
DeR_SLOPE	General risk of soil erosion (degradation). Correction of the risk class for soil erosion in the DeR column, taking into account the data in the SLOPE column. Possible values: N – not assessable; LM – very small; M – small; V – average; D – large; LD – very large.
OPTIMIST	Risk classes for soil erosion according to an optimistic scenario. Possible values: N – not assessable; LM – very small; M – small; V – average; D – large; LD – very large.
PESIMIST	Risk classes for soil erosion in a pessimistic scenario. Possible values: N – not assessable; LM – very small; M – small; V – average; D – large; LD – very large.

Data analysis and result assumptions

In the presented report, the trends of soil degradation and erosion of Lithuanian agrarian (agricultural) territories are examined at the level of elderships and cadastral areas. The results obtained at both levels do not contradict each other (Figures 1 and 2), only their information coarseness differs. The more detailed the level, the more accurate the results are obtained. This change is due to the fact that a smaller administrative territorial unit has a more homogeneous surface in terms of its origin and morphometric parameters. In turn, in such an area, more uniform soil formation conditions are created and more uniform economic activities are carried out. Therefore, compared to elderships, at the level of cadastral areas, there is an increase in areas characterized by a larger area of eroded soils and, accordingly, areas where areas of eroded soils are not identified. However, the general trends in such areas remain – the eroded areas are concentrated in the uplands, especially in the Baltic Uplands (characterized by a hilly agrarian landscape), and the areas least affected by erosion – in the lowlands and, in particular, in their plain fragments. The level of cadastral areas allows to highlight the heterogeneity of the lowlands. As we can see (Fig. 2), fragments of agrarian clay lowlands are revealed, which are characterized by a wavy surface, which, in turn, due to their intensive tillage, creates conditions for the formation of foci of erosion.

The extent and degree of erosion of Lithuanian soils depends on a number of factors, which can be divided into natural and anthropogenic. Natural factors (the angle of inclination of the surface, the granulometric composition of the soil, the content of organic and humus substances, the climate, the microclimate humidity regime, the character of vegetation cover, etc.) are the most stable, largely determining the potential for erosion. Of great importance are also the anthropogenic factors: the character of economic activity, agrotechnical and agrochemical technologies, the formation and change of the land structure, the direction and duration of the social development, national and international economic policy, the model of the economic market, etc. These factors fundamentally change and form the structure of land use in the landscape, change the character and abundance of vegetation cover, i.e. form a diverse agrarian landscape and create preconditions to manifest various soil degradation processes.

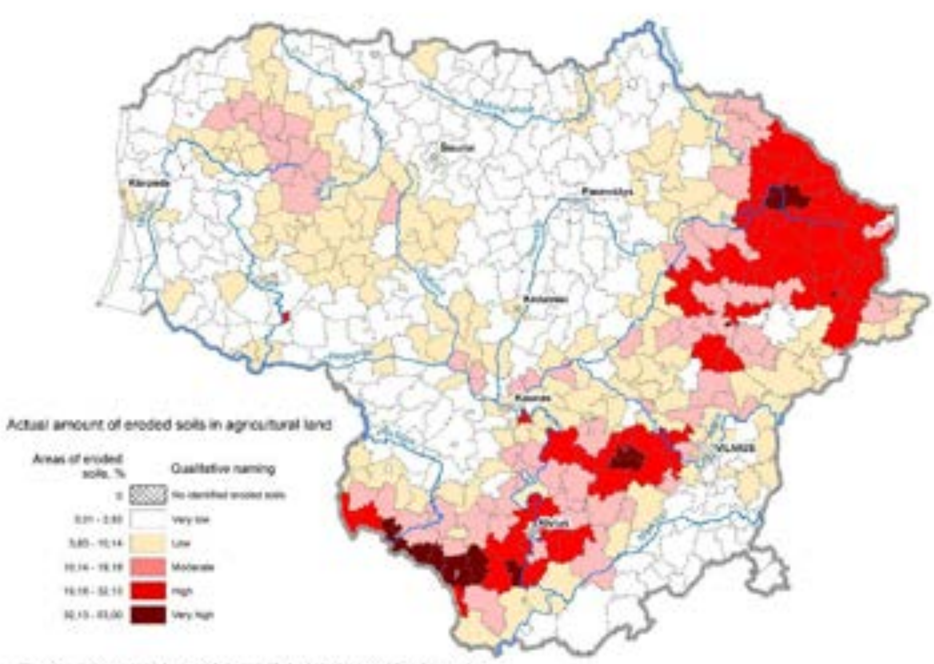


Figure 1. The area of eroded soil on agricultural land of elderships recalculated by a weighting factor using the degree of soil erosion.

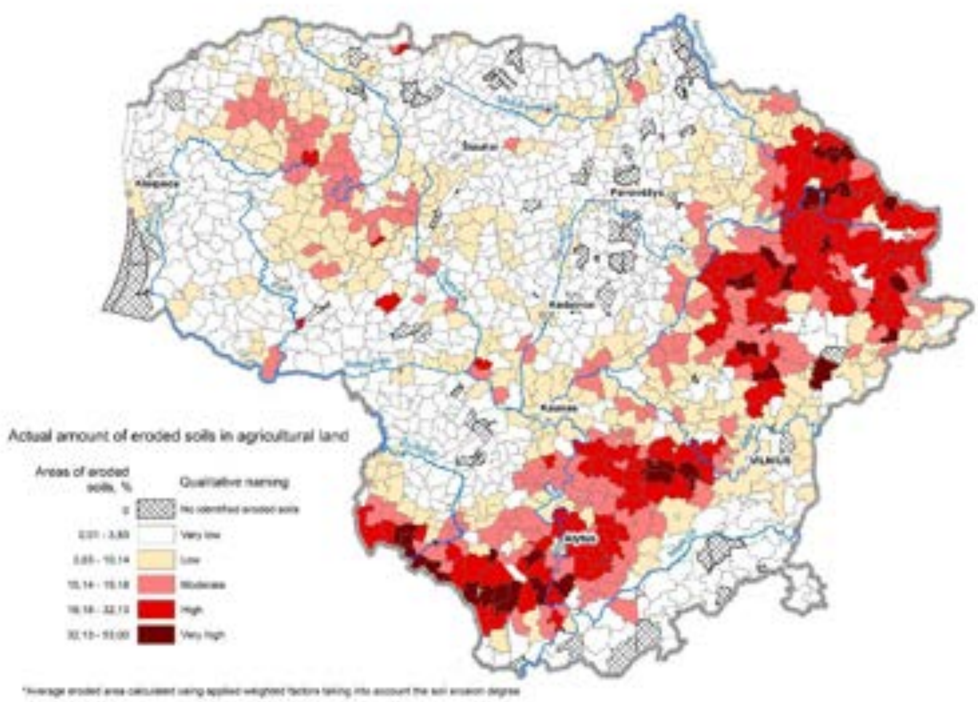


Figure 2. The area of eroded soils on agricultural land of the cadastral areas recalculated by a weighting factor using the degree of soil erosion.

The current situation of erosion of the soil cover in Lithuania is inherited from the period of Soviet occupation, when the model of economic activity and the scale and intensity of agricultural activities were fundamentally changed. The greatest influence on soil erosion was made during the period 1955-1989, when soil areas were intensively drained and adopted for agricultural purposes. This is a period when technocratic utilitarianism and the desire to assimilate the natural environment as much as possible, to generate as much agricultural production as possible, without taking into account the internal potential of existing soils and agroecosystems and the associated threats, prevailed both in Lithuania and in the entire Soviet space. During this period, the current spatial structure of the distribution of eroded soils was largely formed. How it is being changed by the current trends in the development of agriculture is very difficult to say, since the current period lasts only about 30 years, and the technologies of sustainable farming began to be applied more widely only in the last decade. Also, over the past 30 years, there have been no significant works on the assessment of soil erosion of a larger scale in Lithuania, and no attempts have been made to repeat its mapping.

To speculate about soil erosion in Lithuanian agrarian areas is difficult because the surface of Lithuania is very heterogeneous by its origin and therefore manifests different soil degradation processes. Nevertheless, it is unequivocally recognized that soil erosion caused by water is one of the most relevant processes of soil degradation. Conducted studies show that the slope (angle of inclination of the surface) is one of the most important factors determining the erosion of soil water

(Figures 4 and 5). And even visually we see that the distribution of the values of the inclination of the surface is closely related to the expansion of eroded soils (Fig. 3, 4, 5).

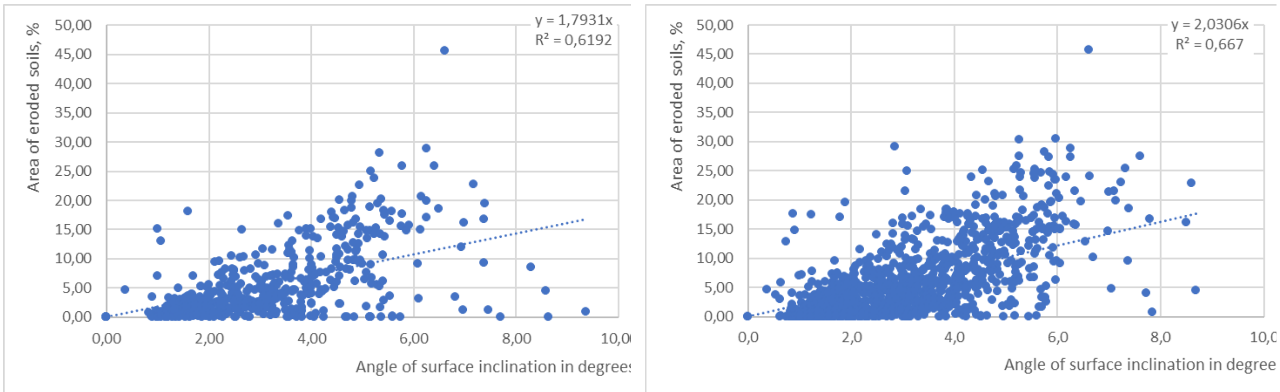


Figure 3. The relationship between the prevalence of eroded soils and the angle of inclination of the surface of the territory (elderships on the left, cadastral areas on the right).

Since soil erosion in the territory of Lithuania is not so much a natural phenomenon as a socio-economic one, standard models that focus on natural factors cannot be applied to its predicting and interpretation. Therefore, the presented connection (Fig. 3) reflects only to a limited extent the current situation. Allows you to state the facts, but does not create reliable assumptions for predicting trends in soil erosion.

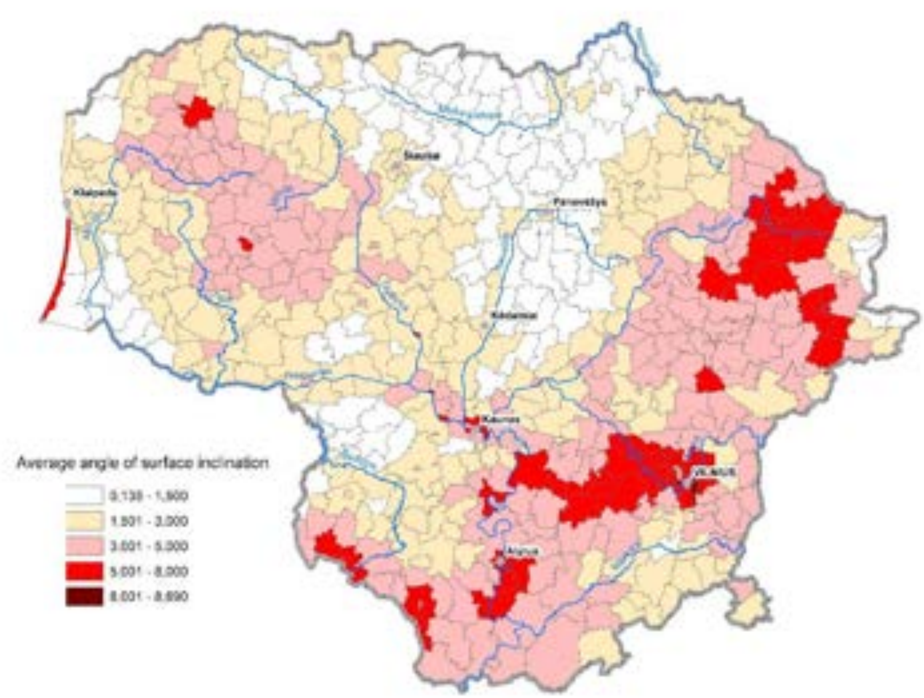


Figure 4. The average angle of surface inclination in the territories of the elderships.

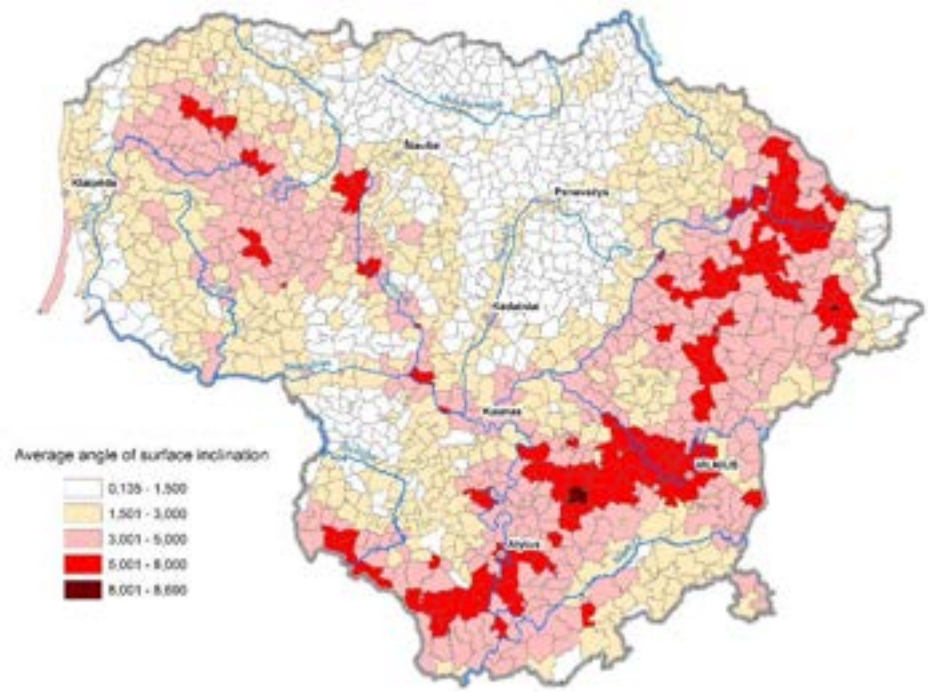


Figure 5. The average angle of surface inclination in the territories of cadastral areas.

The intensity of economic activity and its character in agriculture is rather difficult to assess, since it depends not only on the cyclicality of the crop rotations applied, but also on the socio-economic situation of the country, international economic and ecological trends. Still the analysis of the CORINE land cover data makes it possible to identify certain trends in the change of land use (landscape) structure, which largely reflect the intensity of agricultural activity and even the trends in application of agrotechnical measures. The interaction between these trends and the natural factors determining soil erosion allows insights into possible trends in soil degradation in the general sense and soil erosion in the narrow sense. The obtained data of spatial analysis of trends (Figures 7 and 8) do not contradict the data of the Lithuanian Land Fund (Figure 6) showing the change of meadow and permanent pasture areas in the territory of Lithuania. The area of these agricultural lands has been trending to decline over the last 20 years.

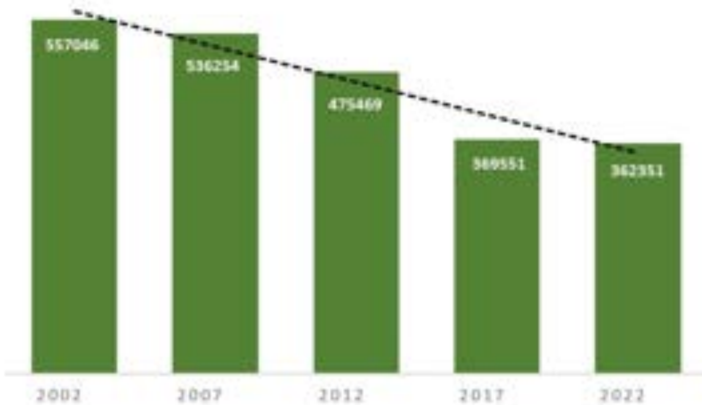


Figure 6. Change of meadow and permanent pasture areas (ha) in Lithuania (LT Land Fund 2002-2022m)

The analysis of land cover (CORINE) data (for years 1995, 2000, 2006, 2012 and 2018) by type of land cover and purpose of use (land use structures) shows that the most productive (Central Lithuanian lowlands) and medium-productive (Western Aukštaičiai Plateau and Eastern Žemaičiai (Samogitian) Plateau) Lithuanian agroecosystems are undergoing an intensification of agrarian activities. In particular, this activity is intensifying in Akmenė, Kėdainiai, Šakiai, Marijampolė municipalities. The intensive strengthening of agrarian anthropogenization, the expansion of arable agriculture fields is often named as the tendency to the formation of agrarian wastelands.

The weakening of agrarian anthropogenization is not the predominant trend in Lithuania. However, in the uplands of Eastern Lithuania, it is more pronounced. This is mainly due to a decrease in the intensity of agricultural activity due to the predominance of inefficient lands and, as a result, an increase in grassland and permanent pasture areas. Also, this trend (there is also a noticeable and intense decrease in agrarian anthropogenization) is recorded in urban elderships (Figure 7). This is associated with a decrease in the area of agricultural land due to the urban development of cities.

At the level of cadastral areas (Figure 8), the trends of agrarian anthropogenization in the regional context are the same, but due to the subdivision of the territory, the data are more detailed.

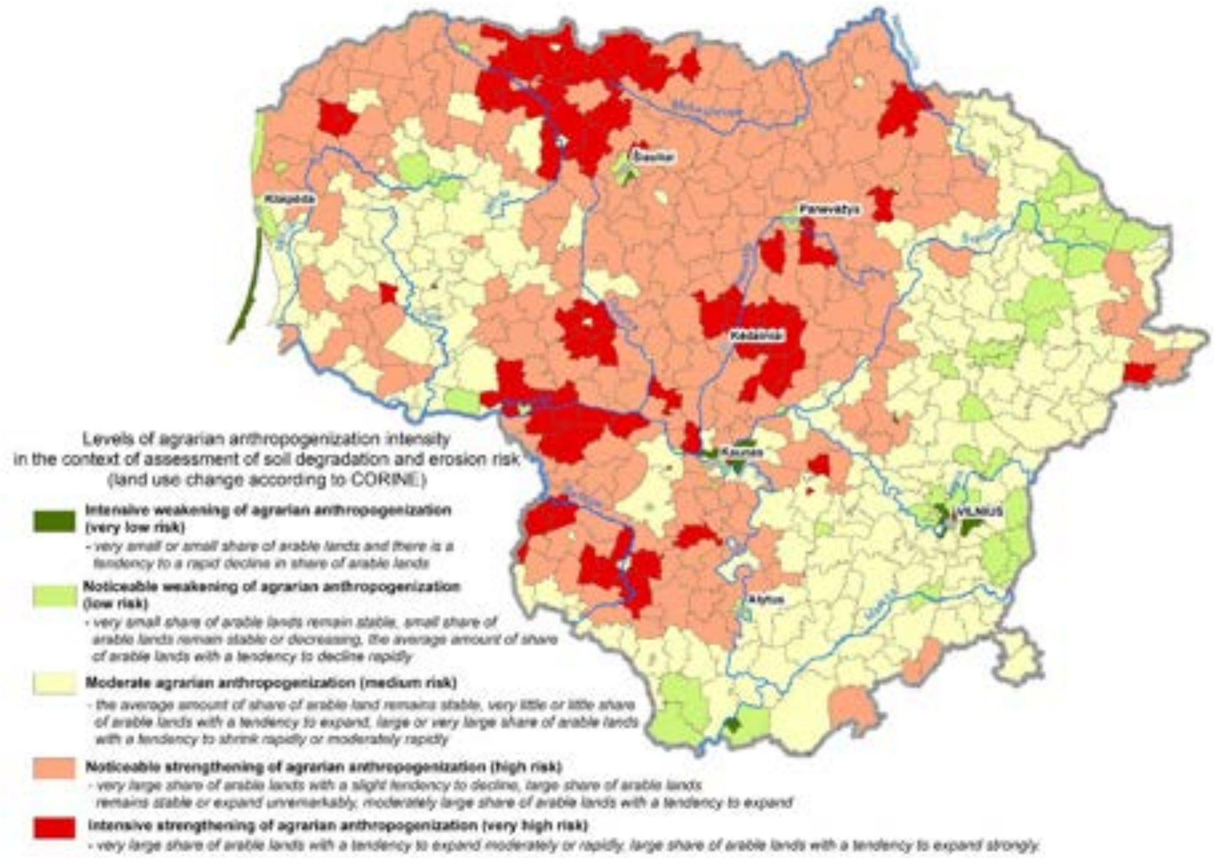


Figure 7. The intensity of the agrarian anthropogenization by assessing the change in agricultural land use in the elderships (based on the analysis of CORINE land cover).

The current trends in the change in the landscape structure allow us to identify individual regions of Lithuania, which are distinguished by the prevailing trend:

1. The South-Eastern Lithuanian region of sandy plains and Baltic moraine uplands. These are the most infertile soils in Lithuania, at the same time characterized by high susceptibility to erosion in the uplands. They are dominated by the relative stability of the structure of the land use and the increase in meadow and permanent pasture areas. This trend is associated with the low fertility and high erodibility of soils.
2. Region of Samogitian (Žemaičiai) Upland. Here, too, the predominant trend of change in the structure of the landscape is stability. Renaturalization manifests itself very weakly, since the soils are more fertile, clayey, more productive, and their erodibility is lower compared to the soils of the Baltic Uplands.
3. The region of the lowlands of Central Lithuania and the plateaus of Samogitia. These are the areas of productive soils and plain surfaces, therefore, the anthropogenization of the landscape, the intensification of the use of agroecosystems and the expansion of cultivated land areas are still increasing in them. This trend is due to the high and moderate productivity of the soils in this region.

As we can see from the trends in the change in the structure of the landscape, the development of the agricultural sector and the character of the activities directly respond not only to changes in the market economy, but also to the potential opportunities for carrying out economic activities and obtaining economic benefits. Nevertheless, we must point out that, although the problematic hilly uplands with the prevailing eroded soils are less used for agriculture and farmers here are increasingly opting for sustainable farming methods, eroded soils don't disappear, and the existing problems cannot not be solved so quickly. It is also important to know that although the soils of the lowlands of Central Lithuania are characterized by a high agro-ecological potential, the intensification of agricultural activities and the expansion of areas of arable agriculture create the preconditions for the emergence of other factors and processes of degradation of the soil. If in the uplands the main risk factor is slopes and water erosion, then in the lowlands there is wind erosion, soil compaction, and a decrease in soil organic carbon. Therefore, based on the spread of eroded soils and spatial analysis of trends in landscape structure change, it is possible to draw up a map of the general risk of soil degradation in Lithuanian agricultural areas (Figures 9 and 10). From it we can see that the greatest risk of degradation is characteristic to the territories of the Baltic Uplands, where eroded soils predominate, and the trends of renaturalization of the landscape (which allow judge the intensity of the use of sustainable agricultural technologies) are not enough. In the lowlands of Central Lithuania, two trends emerge. Weak soil degradation is relevant in parts where existing intensive farming practices are still maintained and there is a limited risk of wind erosion. The average risk of degradation is relevant in the territories of Šakiai, Akmenė and Kaunas district municipalities, where there is intensive development of arable land areas and due to the very fertile soils here, further intensification of agricultural activities. This promotes not only the risk of wind erosion, but alsothe possible loss of organic carbon and soil compaction.

A very low risk of soil degradation is characteristic of areas with a predominance of infertile soils, or with a tradition of sustainable farming and grassland farming, as well as with a predominance of wooded areas.

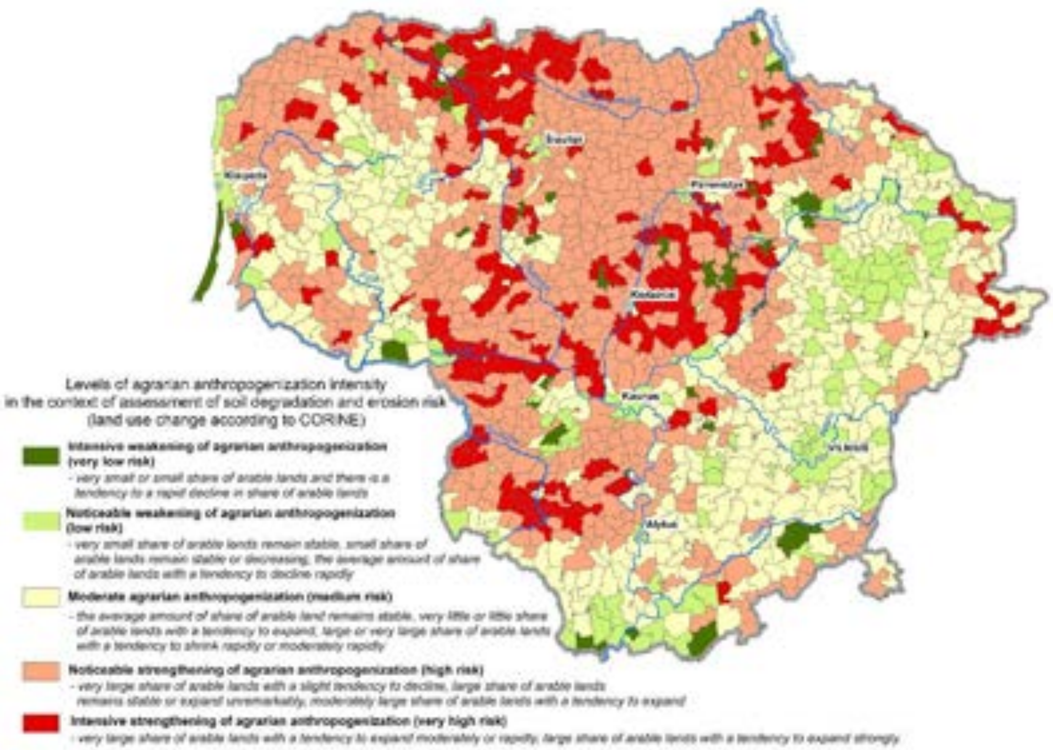


Figure 8. The intensity of the agrarian anthropogenization by assessing the change in agricultural land use in the cadastral areas (based on the analysis of CORINE land cover).

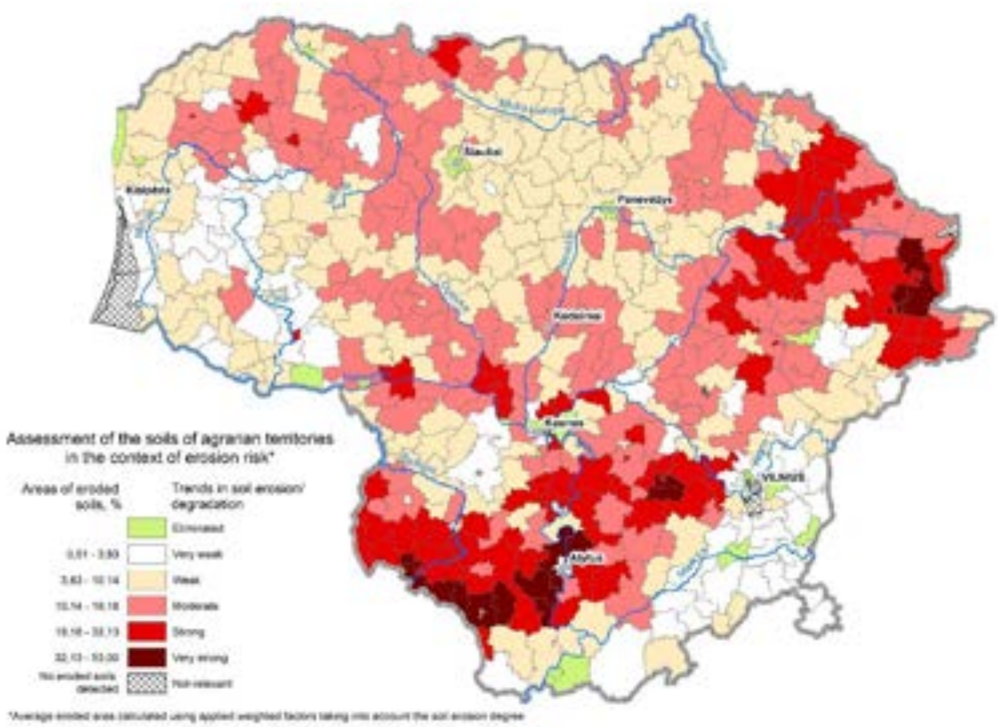


Figure 9. Trends in the general degradation of soils in agricultural areas (in the elderships)

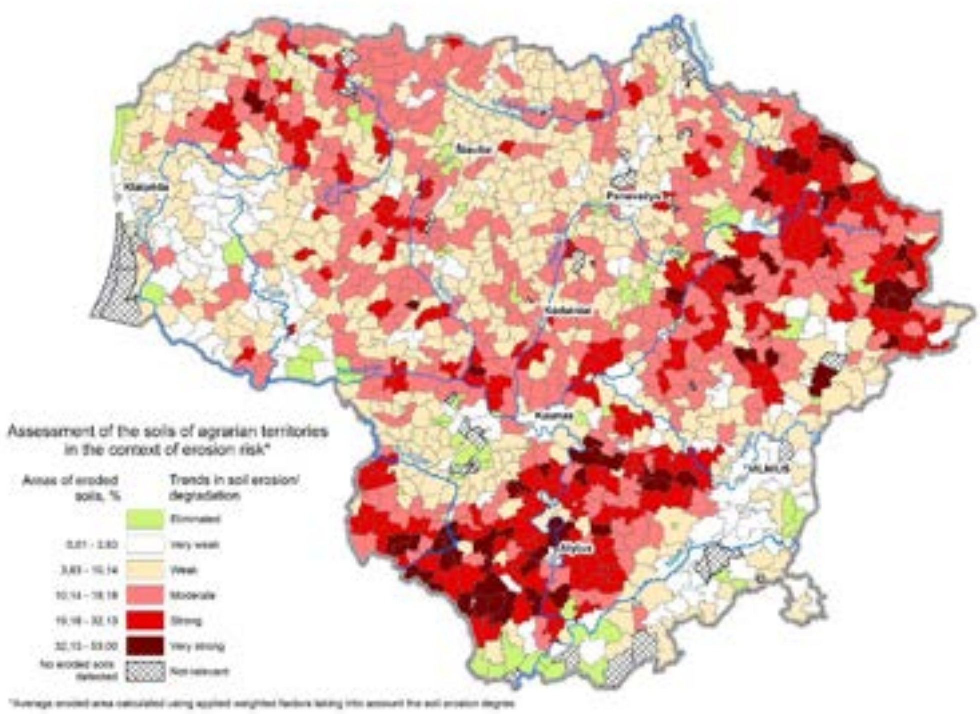


Figure 10. Trends in the general degradation of soils in agricultural areas (in the cadastral areas)

Considering the fact that the most relevant and easily (unambiguously) assessed risk of soil degradation in the territory of Lithuania is associated with soil water erosion, and bearing in mind that this is also associated with the most sensitive to agricultural activities and least productive soils, we need to eliminate from the analysis the surfaces of agricultural areas with a slope of less than 3 degrees.

This makes it possible to isolate those areas and highlight those risks that are directly related to soil erosion and are most susceptible to the applied agrotechnical measures (different tillages) (Figures 11 and 12). From the presented figures, we can see that the real risk of soil water erosion is concentrated only in the Samogitian and Baltic Uplands. Meanwhile, in the rest of Lithuania, where plain surfaces or forests predominate, the risk of soil water erosion is very weak. The main factor determining this is the slope of the surface. Thus, although due to the intensification of agriculture in the lowlands of Central Lithuania, we have a potential risk of soil degradation due to wind erosion, decrease of organic carbon, and compaction, the likelihood that this will have a significant, large-scale impact on the overall soil cover at the regional level is small.

It should also be noted that at the level of the elderships, the risk values of soil erosion (Figure 11) as well as of soil degradation (Figure 9) are equalized, flattened, thus at the same time the accuracy of their correct association with a specific land user decreases. Meanwhile, at the level of cadastral areas, the risk values of soil erosion (Figure 12) and degradation (Figure 10) are more differentiated. With diminishing of the size of the territorial unit, the number of territories where the risk assessment is irrelevant is increasing: e.g., there is no and/or cannot be agricultural land in the territorial unit due to the specific regulation of its use; or the risk is eliminated when the land use structure or the trend of its change suggests that the risk of soil erosion or general degradation will be irrelevant.

Soil degradation and erosion risk development scenarios

REALISTIC SCENARIO (data column: DeR_SLOPE) (Figures 11 and 12). This scenario builds on the existing prevalence of eroded soils, assuming that existing erosion hotspots will continue to develop in those agricultural areas with a surface inclination angle of >3°, while the prevailing trend in the change of structure of the land use that make up the landscape will be oriented to a moderate or intense increase in the area of cultivated land. Existing data at the national and district level, the moderate decrease in meadow and permanent pasture areas over the past 5 years indicate that this trend is stabilizing, and the scenario is typical for most of the territory of Lithuania with some exceptions in individual municipalities. This scenario suggests that there is a high probability that the situation will not change substantially over the next five years or that the changes will be local and of little regional or national significance.

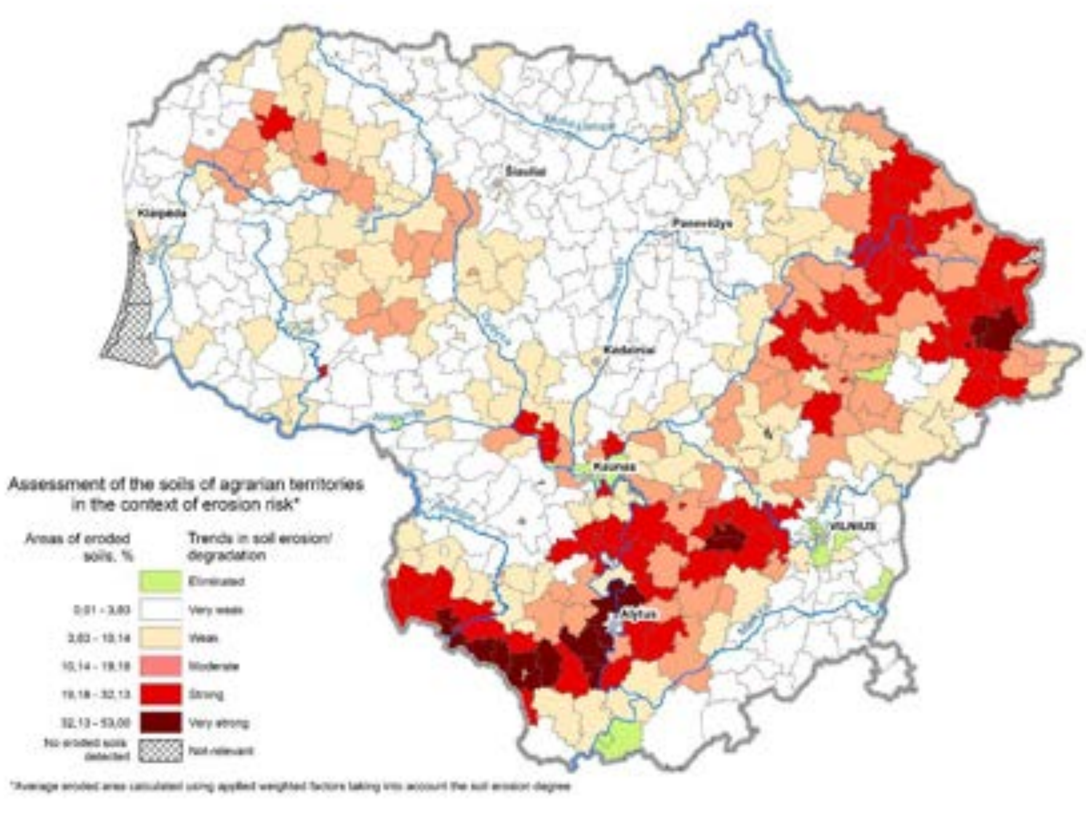


Figure 11. The realistic risk scenario for soil erosion based on the Status Quo situation in the elderships.

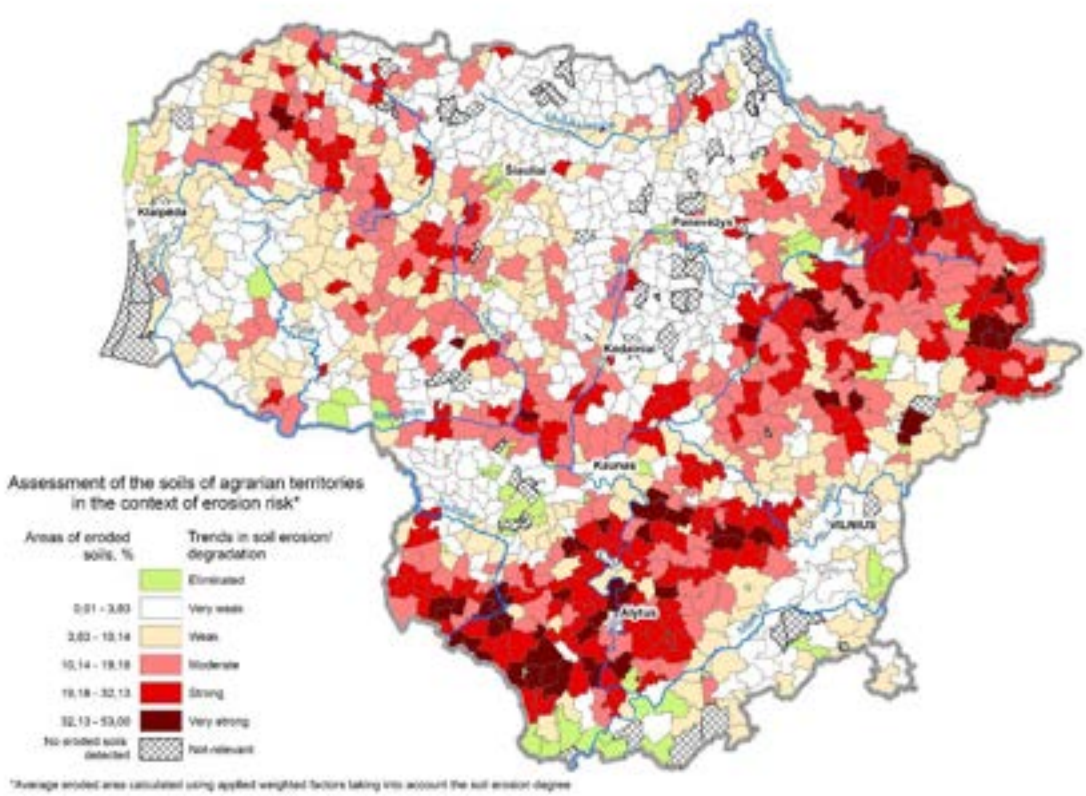


Figure 12. The realistic risk scenario for soil erosion based on the status Quo situation in cadastral areas.

OPTIMISTIC SCENARIO (data column: OPTIMIST) (Figures 13 and 14). This scenario is based on the assumption that agriculture is switching to sustainable tillage technologies throughout the territory of Lithuania (various systems of reduced tillage and non-tillage), the number of perennial grassland areas is increasing and the trends of landscape change are stabilizing: agro-greenery systems are being formed, mixed economic systems of agricultural activity are being formed in agroecosystems, new forms of farming are introduced ("carbofarming", "agroforestry", etc.). Also, this scenario is based on the assumption that these measures are applied taking into account the geo-ecological and agro-ecological potential of agroecosystems, and the state develops and maintains long-term complex measures for the development and implementation of the sustainable agricultural system. According to the compiled maps (Figures 13 and 14), we can see that this would allow the risks of soil degradation to be greatly reduced throughout Lithuania, and in the lowlands of Central Lithuania, with the most productive soils of the country, practically eliminated. The first tangible results of the implementation of such a scenario could be seen in 20-30 years.

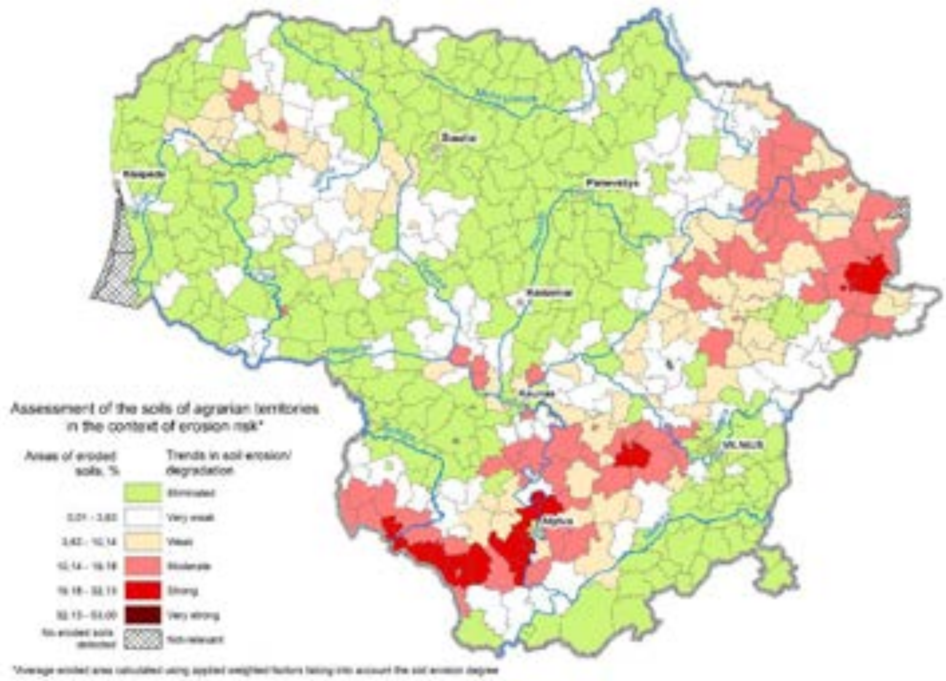


Figure 13. An optimistic risk scenario for soil erosion in the elderships based on the assumption of intensive development of sustainable farming

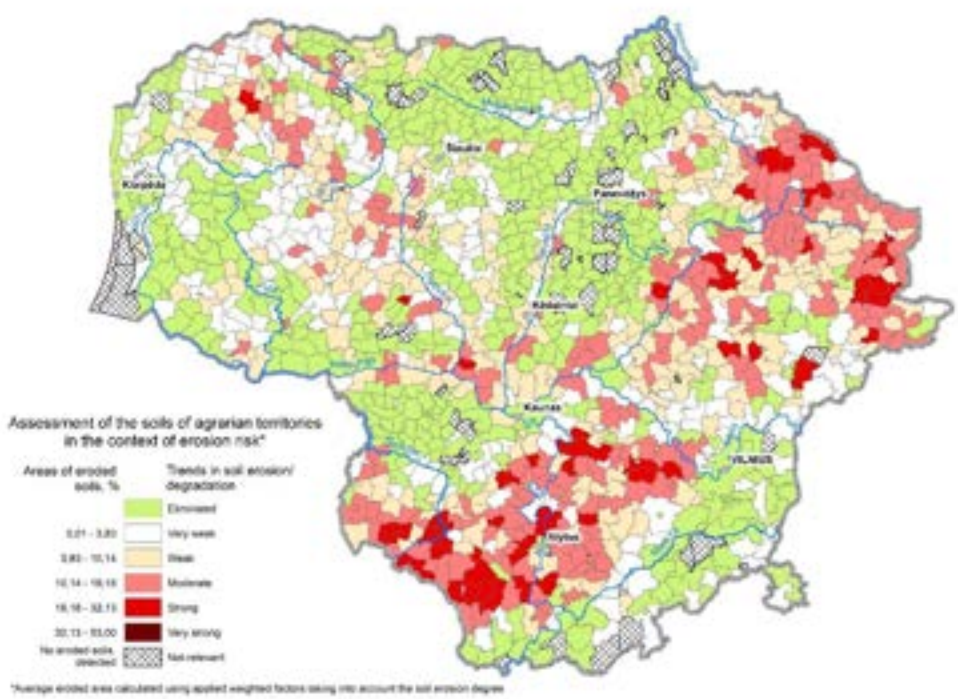


Figure 14. An optimistic risk scenario for soil erosion in the cadastral areas based on the assumption of intensive development of sustainable farming

PESSIMISTIC SCENARIO (Data column: PESIMIST) (Figures 15 and 16). The pessimistic scenario is based on the assumption that the entire Lithuanian agricultural sector increases the agrotechnical and agrochemical intensity, while the areas of arable agricultural areas continue to increase. The trend of such an increase is currently visible in the north (Akmenė district municipality) and southwest (Šakiai district municipality) of Lithuania, as well as in the agroecosystems of the plateaus of the Samogitian and Baltic Uplands. In principle, it is likely that, in this scenario, the areas of soil erosion hotspots will not increase significantly, but the degree of soil erosion will increase, wind erosion in the lowlands will intensify and, as a result, the loss of soil organic carbon will grow. In the uplands, especially in the Baltic, where there are the largest areas of eroded soils, soil fertility will continue to decrease significantly, while in the lowlands the signs of a decrease in soil fertility will not be so noticeable, but the issues of soil compaction and the loss of organic carbon and other biogenic elements, eutrophication of ground and surface elements of the hydrographic network will become significant.

The "implementation" of this scenario will "transfer" the issues of soil erosion and degradation in general from upland agroecosystems to lowlands.

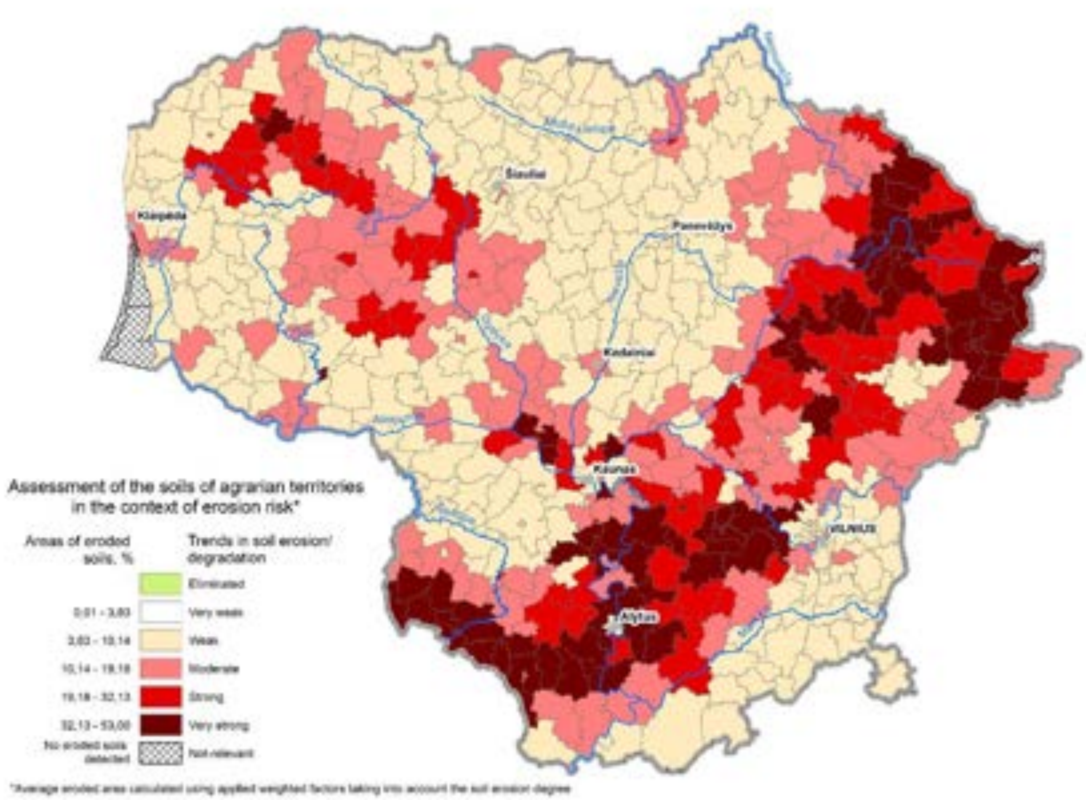


Figure 15. The pessimistic risk scenario for soil erosion/degradation in the elderships based on the assumption of maintaining the intensity of existing farming trends.

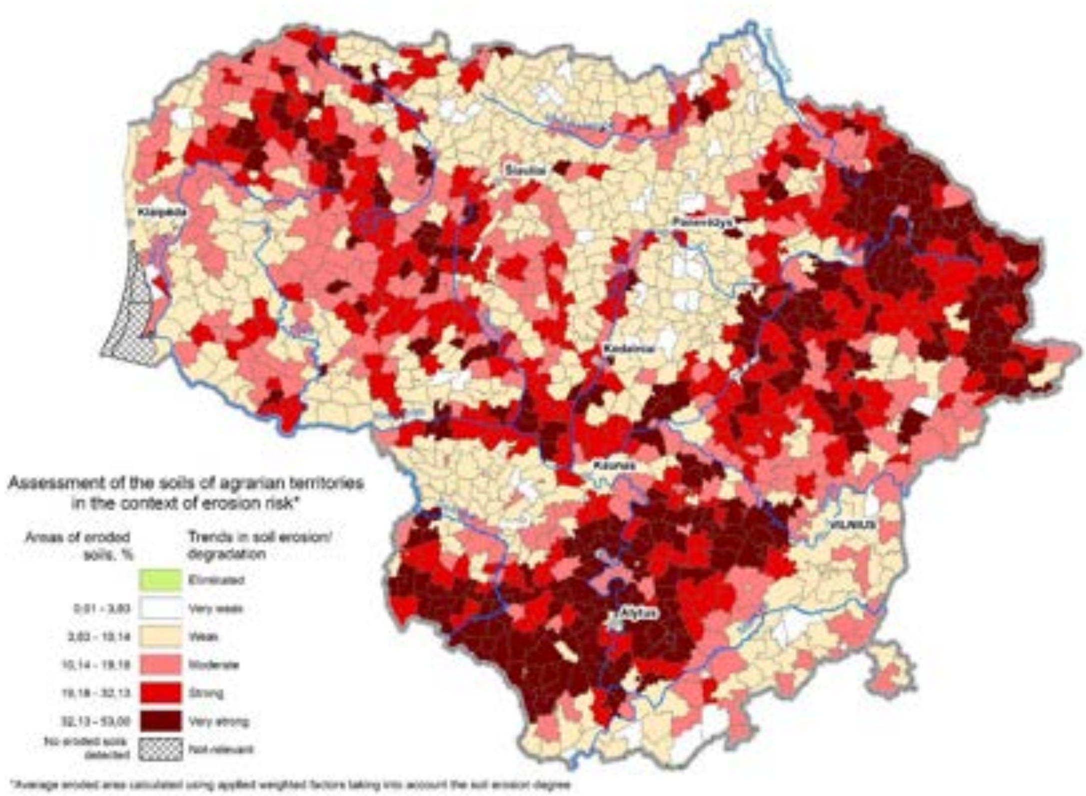


Figure 16. The pessimistic risk scenario for soil erosion/degradation in the cadastral areas based on the assumption of maintaining the intensity of existing farming trends.

SUMMARY

The carried-out analysis of the soil degradation and erosion risk assessment and the agrarian anthropogenization of the landscape is based on existing, freely available official data, the detail and accuracy of which are determined by the approved methodologies. The analysis was carried out at the level of elderships and cadastral areas, so only at this level can it be evaluated and interpreted. In the case of a particular economic subject, the data contained in this report must be critically evaluated and, where possible, adjusted using the criteria and methodological provisions set out in this report.

The data presented in the report and the results of the study show that in order to optimise the development of the agricultural sector and its financing in the context of climate change and the ecological sustainability of the landscape, great attention must be paid to regional policy and to the differentiation of measures to support and promote economic activities in agriculture.