MINISTRY OF AGRICULTURE
REPUBLIC OF LATVIA

# Testing the biophysical criteria

# for

# Areas with Natural Handicaps

UPDATED 8.12.2014

Report is prepared based on the information of the project „TESTING OF THE PROPOSED NATURAL HANDICAP CRITERIA IN THE FRAMEWORK OF THE COMMISSION COMUNICATION „TOWARDS A BETTER TARGETING OF THE AID TO FARMERS IN AREAS WITH NATURAL HANDICAPS"" summary report prepared by Ltd „L.U. Consulting (2010) and updated in accordance with criteria definitions and thresholds as agreed on Regulation (EU) No 1305/2013 (2014).

L.U. Consulting

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# 1 INTRODUCTION

## 1.1 Summary of current LFA scheme in Latvia

In the programming period 2007-2013, Latvia implemented the aid for less favored area territories that were defined according to Article 19 of Regulation (EC) 1257/1999. Taking account of criteria referred to in Article 19 of the abovementioned Regulation, in Latvia, 74,4% of the total area of the State has been determined as less favored areas covering 1,81 million ha of agricultural land.

To define LFA, the following traits have been used:

- Weighted average points of agricultural land (2002.g)
- Personal income tax per capita, LVL (2002)
- Density of population inhab/km$^2$ (01.2003)
- Proportion of employed in agriculture, above 15 years of age, against number of population , %

The first trait - fertility of land – there was an index specified as the most available on the level of parishes and the most concrete in respect of farmers: evaluation of the quality of agricultural land by points because its changes do not so much depend on weather conditions (as yield), subsidy policy and specificity of location of land. Using works by prof. A. Boruks and opinions of other experts, the qualitative evaluation 38 points scale of agricultural land has been adopted.

The second trait – economic results. Indices recommended by the Commission – added value, gross income of a farm, average salary of an employee, income/profit/expenses per farm or per ha of land – was not available in the profile of local governments. Thus, the budget index of local governments was used – personal income tax per capita in a respective local government. In 2002, the personal income tax per capita in a local government is equal to or lower than LVL 77,5 that makes 80% of the average index in the country – as a result more than 80% of all the Latvia's local governments comply with the criterion.

The third trait - population. The third trait of LFA has two indices. The first – density of population where the threshold is 50% of the average in the country. In Latvia, the average density of population is 36,1 inhabitants per km$^2$ therefore this LFA index for this country – the density of population in a local government is not higher than 18,1 inhab./ km$^2$. The second obligatory index characterizes inhabitants of a respective territory depending on agricultural activity, and for this index the proportion of population engaged in agriculture in a respective territory, has been chosen. If not less than 15 of the total number of active population are engaged in agriculture, it is considered as a sufficient threshold. More than 80% of all the local governments comply with this criterion. As a result, as EU Regulation 1257/99 and Guidelines lay down that LFA status can be obtained when the territory complies with the three mentioned traits with four indices.

Taking into consideration socio-economic and agri-climatic differences in a territorial profile, compensation rates for beneficiaries under the measure, in different LFA regions of Latvia were grouped territorially (see Figure 1):

- Category 1 LFA, covering 253 252 ha of agricultural land;
- Category 2 LFA, covering 812 304 ha of agricultural land;
- Category 3 LFA, covering 743 847 ha of agricultural land.

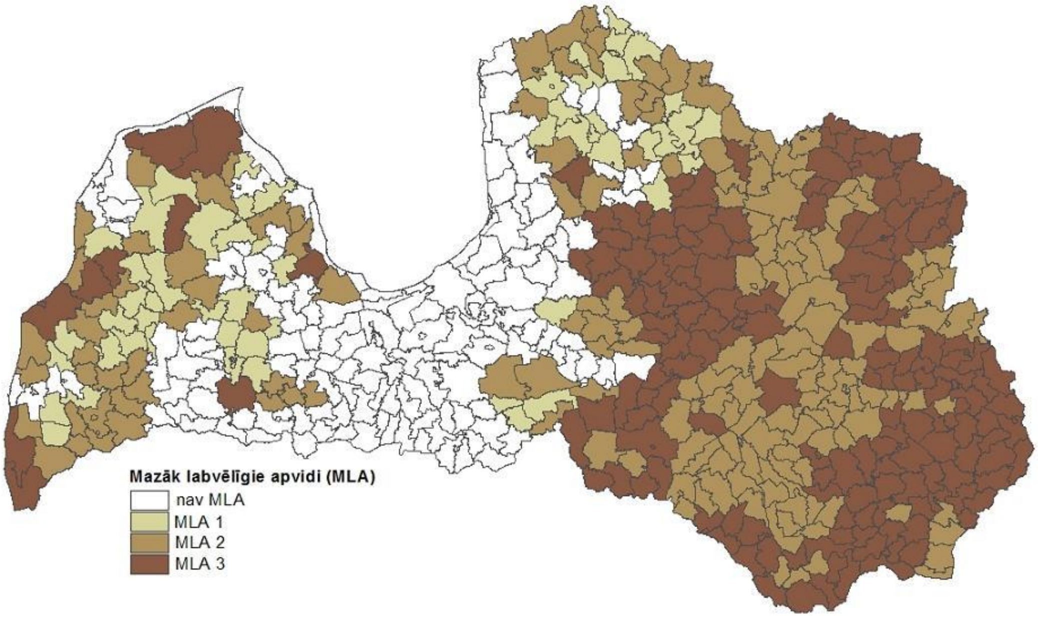



**Figure 1.1-1: Identification of LFA according to existing aid scheme (2007-2013)**

## 1.2 Summary of results of ANC scheme tested for Latvia

The simulation of Areas of Natural Constraints (ANC) for Latvia is done for the following criterions:

- Criterion : "LOW TEMPERATURE"
- Criterion : „DRAINAGE";
- Criterion : „SOIL TEXTURE AND STONINESS ";
- Criterion : „SLOPE";
- Criterion : „SOIL ACIDITY" .

The mapping of ANC, primary ,was done in 2010 in accordance with relevant requirements set by the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Towards a better targeting of the aid to farmers in areas with natural handicaps COM (2009)161 final version (21 April, 2009) EC and Guidelines for Application of Common Criteria to Identify Agricultural Areas with Natural Handicaps and Common Bio-physical Criteria to Define Natural Constraints for Agriculture in Europe, developed by Joint Research Centre where it was in compliance with EC Communication. The obtained results in 2014 were evaluated in accordance with criteria definitions and thresholds as agreed on Regulation (EU) No 1305/2013 and updated accordingly.

The summary of ANC simulation results are presented in the Figures 1.2-1, 1.2-2 .
According to temperature data, the information was transferred to the map of territorial units.

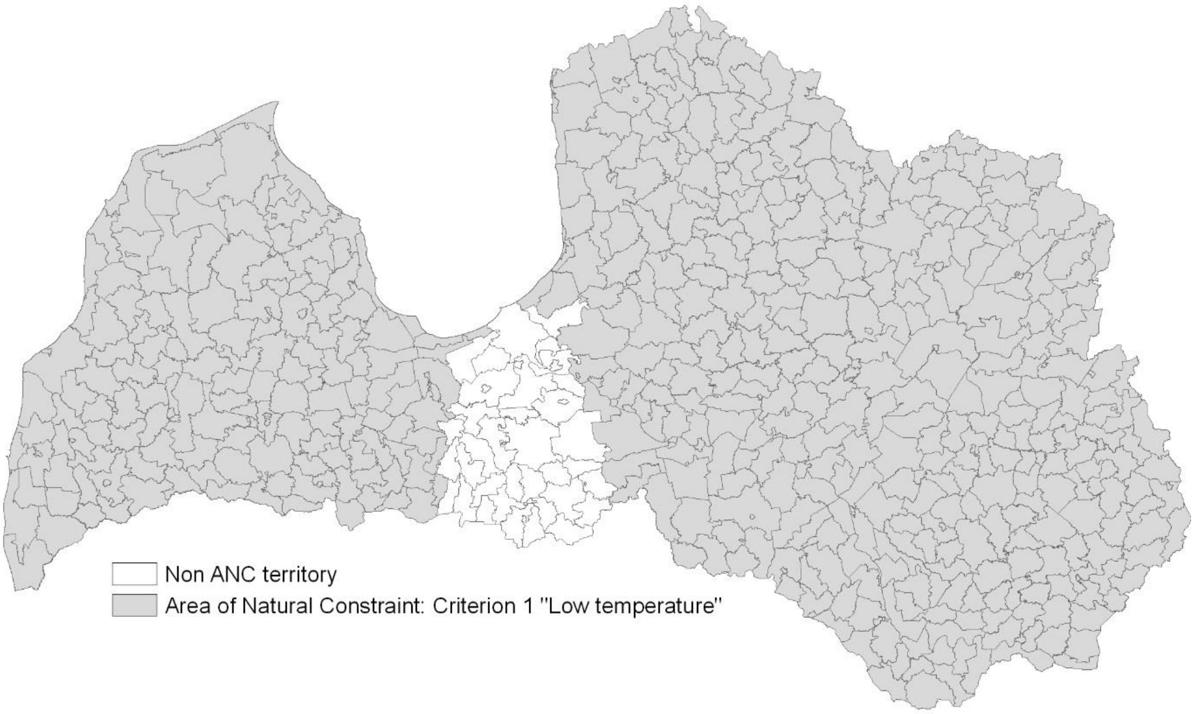



**Figure 1.2-1: Territories where the thermal-time sums is ANC criterion occurrence possibility >20% (8 measurement method, period 1968-2008) on the map of territorial units.**

By supplementing the map obtained under the criterion „Low temperature" with soil results, the map does not change.

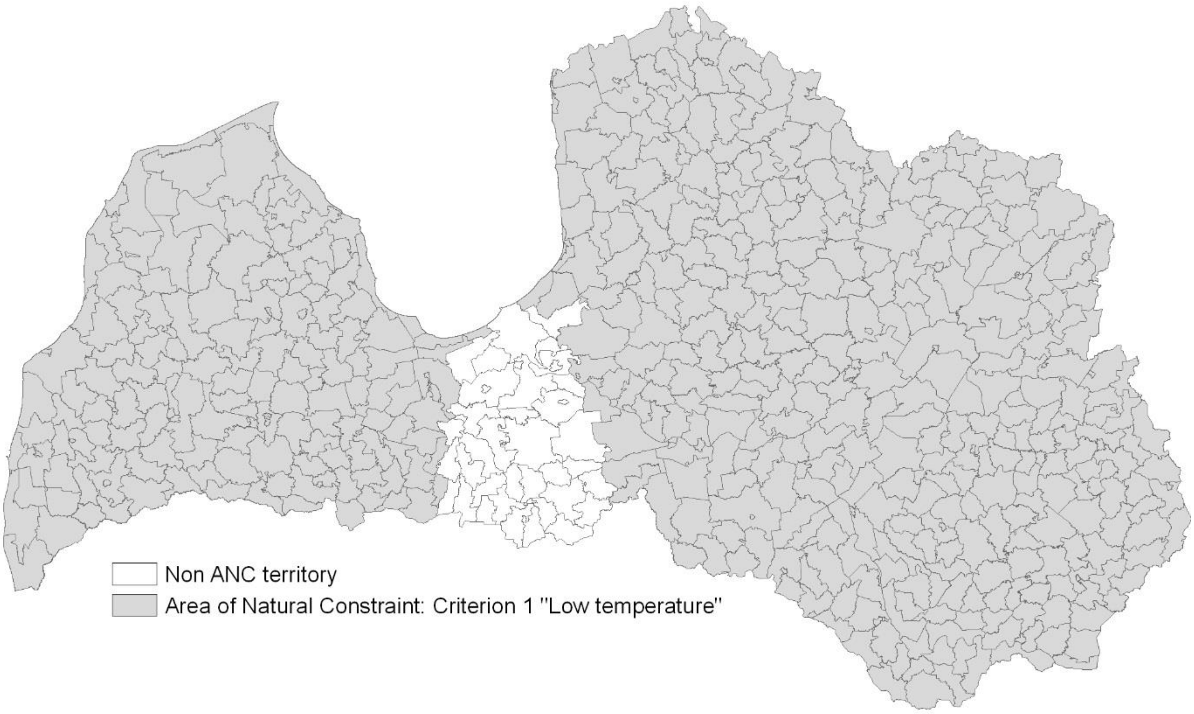



**Figure 1.2-2: Territories where the thermal-time sums is ANC criterion occurrence possibility >20% (8 measurement method, period 1968-2008) on the map of territorial units with soil results.**

Given the analysis and observations based on biophysical criterions described in report the final territory regarded as ANH is provided in Figure 1.22-2

# 2 DATA

## 2.1 Description of Climate data

The only source of climate data is the Latvian Environment, Geology and Meteorology Center (LEGMC), an institution responsible for acquisition of meteorological data, data aggregation and climate data compilation. Meteorological observations in Latvia are carried out by LEGMC in 36 observation stations, but not all stations have uninterrupted time series data. The density of meteostations is 1 station per 1500km2 permanently located throughout the Latvian territory. The location of stations is appropriate, to describe in sufficient detail the Latvian weather and climate. The density of stations is governed by international regulations. The average distance between meteorological stations is 42km.

According to the Commission's guidelines a minimal time series data length used by modulation is 30 years. The Ministry of Agriculture ordered LEGMC to prepare data on air temperatures for the period of 41 year (1968-2008) from 24 meteorological stations, that had uninterrupted air temperature time series data. See list of meteorological stations used in ANC testing provided in table 2.1-1.

**Table 2.1-1: List of Meteorological stations in Latvia used for climate ANC criteria testing**

| Meteorological station | | Coordinates | |
|---|---|---|---|
| | | Latitude | Longitude |
| 1 | Ainaži | 57º52'04.45" N | 024º21'57.48" E |
| 2 | Alūksne | 57°26'22.48" N | 027°02'07.36" E |
| 3 | Rīga | 56°57'02.16" N | 024°06'57.86" E |
| 4 | Bauska | 56º24'57.01" N | 024º10'58.48" E |
| 5 | Dobele | 56º37'11.65" N | 023º19'10.68" E |
| 6 | Gulbene | 57°07'55.98" N | 026°43'07.80" E |
| 7 | Jelgava | 56º40'39.00" N | 023º44'14.53" E |
| 8 | Kolka | 57°44'49.39" N | 022°35'23.39" E |
| 9 | Mērsrags | 57°19'59.64" N | 023°06'47.45" E |
| 10 | Pāvilosta | 56°53'18.19" N | 021°11'21.53" E |
| 11 | Priekuļi | 57°18'57.09" N | 025°20'19.16" E |
| 12 | Rēzekne | 56°32'40.96" N | 027°16'50.34" E |
| 13 | Rūjiena | 57°53'11.71" N | 025°22'17.84" E |
| 14 | Saldus | 56°40'31.46" N | 022°30'13.10" E |
| 15 | Skulte | 57°18'02.27" N | 024°24'43.87" E |
| 16 | Skrīveri | 56°38'33.28" N | 025°07'41.54" E |
| 17 | Stende | 57°11'00.21" N | 022°33'02.75" E |
| 18 | Ventspils | 57°23'44.02" N | 021°32'14.29" E |
| 19 | Zīlāni | 56°31'11.94" N | 025°55'06.45" E |
| 20 | Zosēni | 57°08'06.28" N | 025°54'20.23" E |
| 21 | Rucava | 56°09'43.04" N | 021°10'23.58" E |
| 22 | Dagda | 56°05'52.99" N | 027°32'46.74" E |
| 23 | Liepāja | *56°28'31.35" N* | *021°01'14.36" E* |
| 24 | Daugavpils | *55°56'03.05" N* | *026°39'33.18" E* |

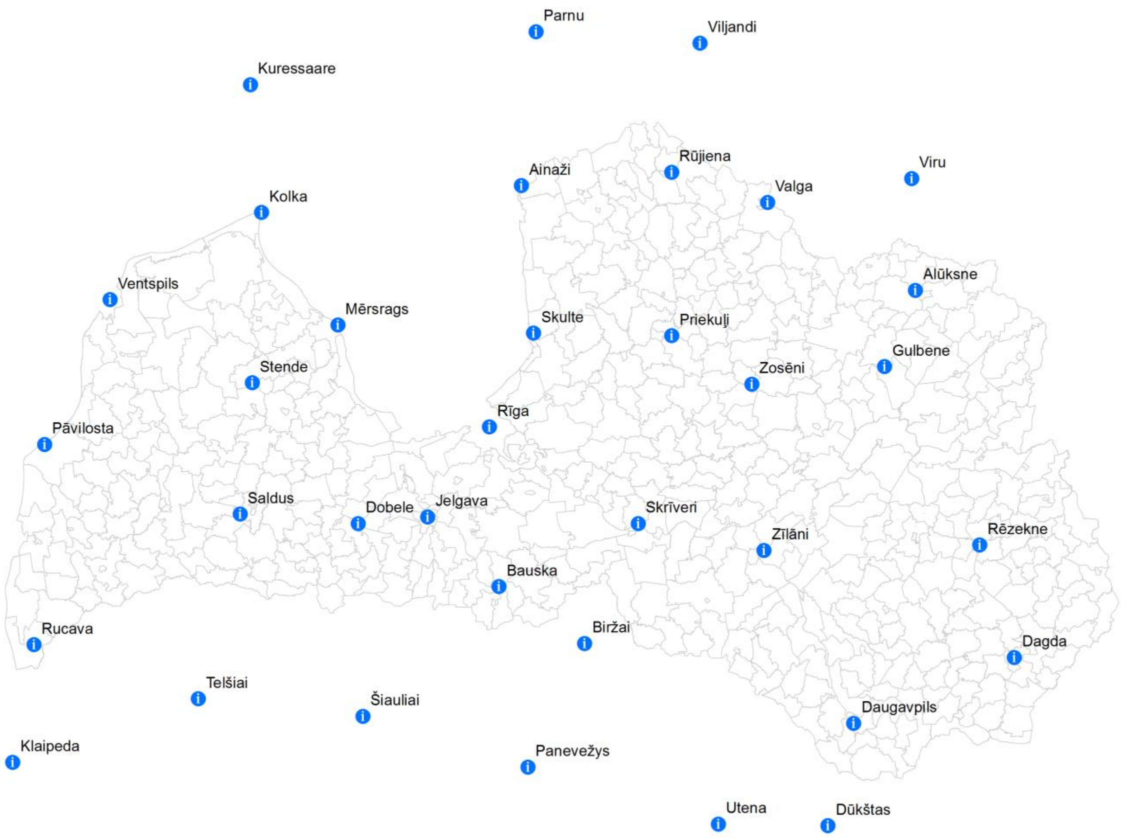



**Figure 2.1-1:** ***Meteorological stations in Latvia, Lithuania and Estonia used in delineation of climate ANC territoriesin Latvia,*** **including stations in Estonia and Lithuania used in delineation of ANC territories in Latvia.**

In addition to data from Latvian meteorological stations, meteostation data from Northern part of Lithuania and Southern part of Estonia have been used to support delineation of ANC according to climate criteria "Low temperature" in Northern and Southern part of the country. In particular 5 meteorological station data in Estonia (Kurressaare, Parnu, Valga, Viljandi and Viru) have been used as well as 6 Lithuanian meteorological station data (Šiauliai, Panevezys, Utenai, Dukštas, Klaipeda and Laukuva) have been utilized in establishing ANC territories according to climate criteria "Low temperature"..

When calculating and determining the ANC criterion „Low temperature, choice of spatial interpolation method plays considerable role, as the climate data have been obtained from point sources and need to be extrapolated, attributed to the rest of the territory. The way how the data from point sources have been extrapolated determines the size of territory that complies with the ANC climate criteria.

IDWA (*inverse distance weighting*), spline curves, polynomial regressions, trend surface analysis, kriging and co-kriging methods are most widely used spatial data interpolation methods in meteorology and climatology (Collins and Bolstad 1996; Hutchinson and Corbett 1995; Phillips et al. 1992; Hutchinson 1991; Tabios and Salas 1985). For interpolation of temperature data, the temperature data often are combined with the data of height above the Sea level, by using height and temperature interrelations, a more precise temperature maps are produced. Of all these methods, traditionally more often different type of spline and kriging (*co-kriging*) methods are used for climate data interpolation.

Different approaches are used in data interpolation methods, of which the most common is the regression analysis and inverse data weighting. The most essential difference between these approaches is what criteria are used to weight data point value against the distance between points. The criterion can be inverse distance weighting, kriging, spline. Depending on what weighs are used, the methods are classified as deterministic or stochastic. Stochastic methods use statistics criteria to determine weight factors

Kriging interpolation method basically uses a combination of linear value weights of data points by means of which values are determined in unknown spatial points. The more widely used kriging methods use "semivariogram" that describes spatial correlation between data points and their spatial dispersion. Weights of data points are dependent on a spatial arrangement and configuration of data points. The kriging interpolation method gives a possibility to determine uncertainty of the interpolated surface or error. The use of semivariogram in the kriging interpolation method is essential, by this method the spatial dispersion of the interpolated variable is determined thus receiving significant information on density of data points, spatial dispersion and arrangement. Basically, the information is used in semivariogram determines interpolation results. Commonly used semivariograms include linear, spherical, exponential and Gauss division models.

The most of discussions in literature refer to the use of kriging/co-kriging and spline spatial interpolation methods in interpolation of spatial data. A successful application of kriging method mostly depends on whether assumption on division/dispersion of statistical data is correct. In a number of literature sources it is indicated that the kriging interpolation method provides a more precise and quantitatively better results.

Taking into account that dispersion of data points is sufficiently even, average distance between data points (meteostations) is around 42km, and the spline interpolation method was chosen in extrapolation and preparation of ANC maps. ANC criteria maps have been prepared in ESRI ArcGIS environment, using Spatial Analyst extension. Data interpolation method used: co-kriging.

## 2.2 Digital Soil data description

The principal sources of information used for simulation and mapping of the ANC Criterion: "SOIL TEXTURE AND STONINESS" are Soil Mapping and Land Evaluation Files. Each of such Files consists of Soil Maps (in scale 1:10 000) and Soil Mapping Compendiums where soil survey data are summarized.

Basic soil survey data were obtained during Soil Mapping and Land Evaluation Campaign when soil agricultural survey was carried out at the former collective farm level by using approved methodology ([1], [2],[3], [4]). Information available at State Land Service.

[1] Technical Standart for Soil Mapping and Land Evaluation . 1962 (in Latvian - Tehniskie norādījumi zemes vērtēšanas lauku darbu izpildei);

[2] Metodology for Soil Mapping and Land Evaluation in Latvia. 1983 (in Latvian - Metodika augsnes kartēšanai un saimniecības iekšējai zemes vērtēšanai Latvijas PSR);

[3] Metodological and technical guide for agro-chemical soil mapping (6th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1991

[4] Metodological and technical guide for agro-chemical soil mapping (5th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1985

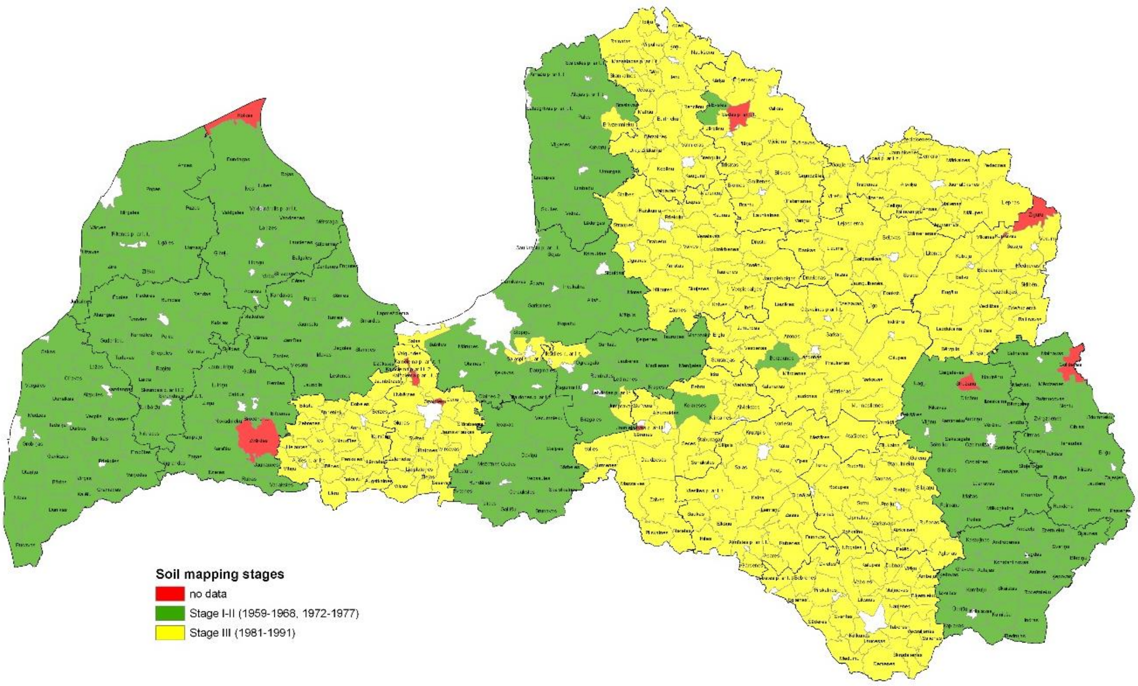



**Figure 2.2-1:** ***Soil mapping in Latvia – territory covered***

Soil mapping in Latvia

- **Stage I** (1959-1968) - first approach, covering 13 regions (of 26) in Latvia
- **Stage II** (1972-1976) - Review and complementing of 1st soil mapping stage data by taking into account extensive soil drainage activities in 60ties and 70ies
- **Stage III** (1981-1991) - further land evaluation and soil mapping covering 11 regions
- **activities in 90ties** - Minor activities mainly related to review and processing of land evaluation and soil data from earlier stages

The scale of data unit is <9 ha of agricultural land. Soil Mapping Compendiums data is based on sampling data representing 1- 9 ha area plots with similar soil characteristics (soil acidity, fertilizing intensity, drainage conditions etc.) and land use:

- Large scale and extensive assessment and mapping of agricultural land in state collective farms of former Latvian SSR;
- Detailed soil data available from more than 500 000 soil pit data;
- Soil maps and agricultural land assessment maps produced for each collective farm (scale 1:10 000);
- Summary of land use, soil types, soil granulometry, soil drainage, stoniness and cultivation data available for each collective farm

To simulate the ANC Criterion: "SOIL TEXTURE AND STONINESS" 767 Soil Mapping Files were used all together.

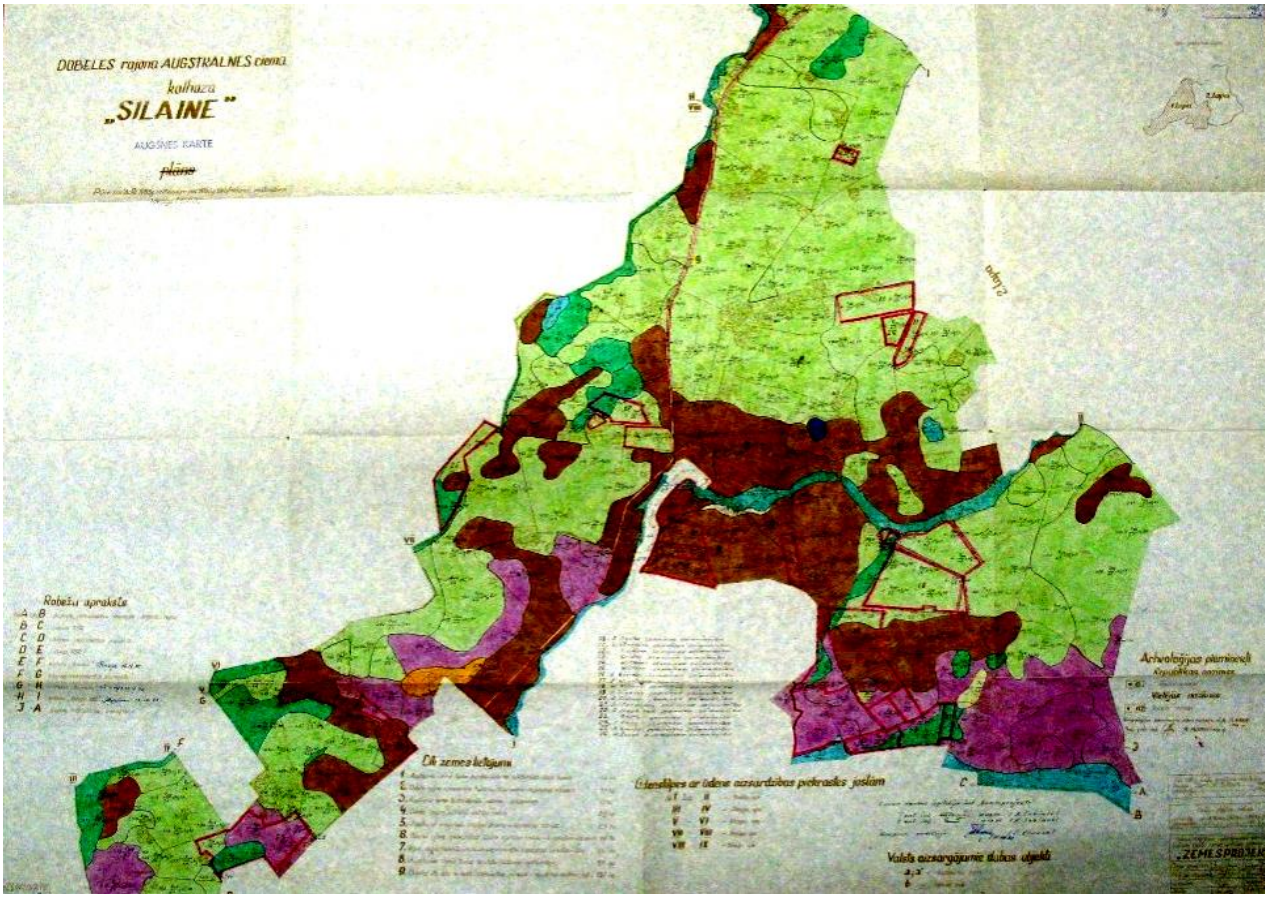
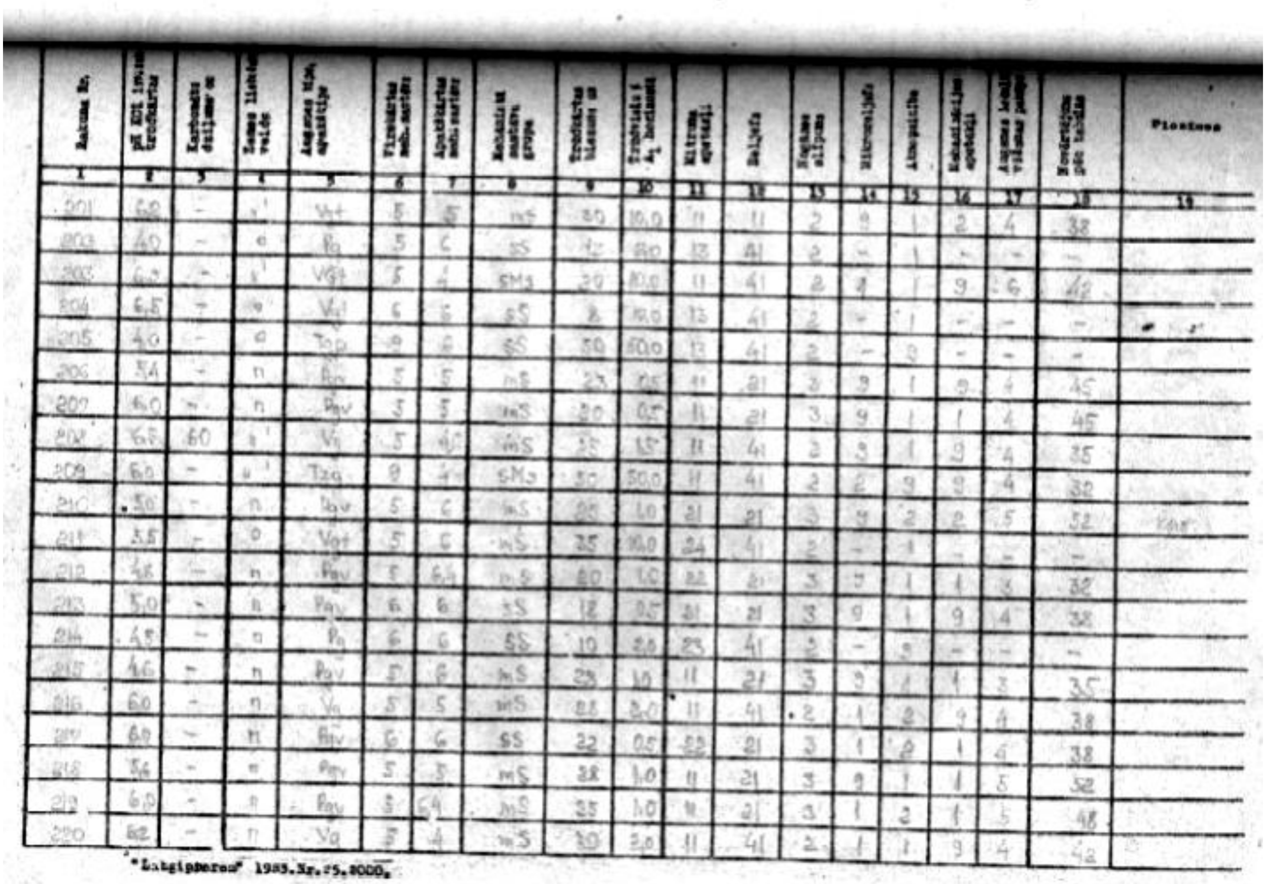



**Figure 2.2-2: Soil map example (format – A0, A1 )**

Agricultural land and soil mapping dataset - soil pit data:

- Soil type;
- Soil texture and granulometry;
- Thickness of humus horizon;
- soil pH (KCl) (B,C horizons);
- Description of microrelief;
- Information on soil moisture conditions;
- Soil erosion;
- Stoniness and rock outcrop;
- Level of soil cultivation;
- Current and prospective land evaluation (grading 1-100).



| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 Piezīmes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 201 | 6.2 | – | n | Vgt | 5 | 5 | mS | 30 | 10.0 | 11 | 11 | 2 | 9 | 1 | 2 | 4 | 38 | |
| 203 | 4.0 | – | o | Pg | 5 | 6 | sS | 42 | 8.0 | 13 | 41 | 2 | – | 1 | – | – | – | |
| 203 | 6.2 | – | n | VGt | 5 | 4 | SM3 | 20 | 10.0 | 11 | 41 | 2 | 4 | 1 | 9 | 6 | 42 | |
| 204 | 6.5 | – | o | Vgl | 6 | 6 | sS | 8 | 10.0 | 13 | 41 | 2 | – | 1 | – | – | – | |
| 205 | 4.0 | – | o | Top | 9 | 6 | sS | 50 | 50.0 | 13 | 41 | 2 | – | 9 | – | – | – | |
| 206 | 5.4 | – | n | Pgv | 5 | 5 | mS | 23 | 0.5 | 41 | 21 | 3 | 9 | 1 | 9 | 4 | 45 | |
| 207 | 6.0 | – | n | Pgv | 3 | 5 | mS | 20 | 0.5 | 11 | 21 | 3 | 9 | 1 | 1 | 4 | 45 | |
| 208 | 6.6 | 60 | n | Vg | 5 | 4 | mS | 35 | 1.5 | 11 | 41 | 2 | 3 | 1 | 9 | 4 | 35 | |
| 209 | 6.0 | – | n | Tzg | 9 | 4 | SM3 | 30 | 50.0 | 11 | 41 | 2 | 2 | 9 | 9 | 4 | 32 | |
| 210 | 5.0 | – | n | Pgv | 5 | 6 | mS | 25 | 1.0 | 21 | 21 | 3 | 9 | 2 | 2 | 5 | 32 | Kar. |
| 211 | 3.5 | – | o | Vgt | 5 | 6 | mS | 35 | 10.0 | 24 | 41 | 2 | – | 1 | – | – | – | |
| 212 | 4.8 | – | n | Pgv | 5 | 6.4 | mS | 20 | 1.0 | 22 | 21 | 3 | 9 | 1 | 1 | 3 | 32 | |
| 213 | 5.0 | – | n | Pgv | 6 | 6 | sS | 12 | 0.5 | 21 | 21 | 3 | 9 | 1 | 9 | 4 | 38 | |
| 214 | 4.5 | – | n | Pg | 6 | 6 | sS | 10 | 2.0 | 23 | 41 | 2 | – | 9 | – | – | – | |
| 215 | 4.6 | – | n | Pgv | 5 | 6 | mS | 25 | 1.0 | 11 | 21 | 3 | 9 | 1 | 1 | 3 | 35 | |
| 216 | 6.0 | – | n | Vg | 5 | 5 | mS | 28 | 2.0 | 11 | 41 | 2 | 1 | 2 | 9 | 4 | 38 | |
| 217 | 6.0 | – | n | Pgv | 6 | 6 | sS | 22 | 0.5 | 22 | 21 | 3 | 1 | 2 | 1 | 4 | 38 | |
| 218 | 5.6 | – | n | Pgv | 5 | 5 | mS | 38 | 1.0 | 11 | 21 | 3 | 9 | 1 | 1 | 5 | 32 | |
| 219 | 6.0 | – | n | Pgv | 5 | 6.4 | mS | 35 | 1.0 | 11 | 21 | 3 | 1 | 2 | 1 | 5 | 48 | |
| 220 | 6.2 | – | n | Vg | 5 | 4 | mS | 30 | 2.0 | 11 | 41 | 2 | 1 | 1 | 9 | 4 | 42 | |

"Latgiprozem" 1983.Nr.25.3000.

**Figure 2.2-3:** ***Soil mapping dataset - soil pit data***

There is 500 000 soil pit data in total, average 300-2500 soil pits per collective farm.

The following information from the Soil Mapping Compendiums is used to simulate criterion:

- General information on soil mapping and land evaluation file – overall information on collective farm and details on agricultural land being used by the collective farm
- Explication of data on soil types and soil texture.

Under the project, Soil pit data are collected in electronic format (Access), but they have not been prepared in digital format with an attachment to a specific point of soil pit thus, the data cannot be used to model overlapping of several criteria.

- For ANC simulation purposes summary data of soil acidity and organic matter content have been obtained from State Agrochemical Research Centre :
- Soil acidity
- Humus (organic matter) content in the soil

## 2.3 Digital Elevation Model

For preparation of maps digital elevation model of Latvia from Rural Support Service's is used. For data accuracy purposes digital elevation model data are connected with data on prevailing slope in each administrative unit or their groups.

To prepare the necessary mapping material, slope angle information is obtained from a digital elevation model, gathering information about the relief of the area (in this case - the area of the whole country). Slope angle maps are developed from a digital elevation model, using ESRI ArcGIS Desktop software Spatial Analyst and 3D Analyst.

The basis for calculating a slope angle a digital elevation model is used, which offers starting data in raster format. A preparation of a digital elevation model and thematic rasters, as well as geospatial data analysis and mapping visualization is available due to ArcGIS Spatial Analyst and 3D Analyst extensions.

Acquired data with ArcGIS 3D Analyst extension is used for data transformation needs. During the work process a thematic raster format (ESRI GRID) layer with 20 m cell size was prepared. A slope angle was calculated for this new-made data layer using 3D Analyst extension Slope from the elevation model, making raster data with slope angle values.

Using ArcGIS Spatial Analyst area for rasters data were created and data fields developed, which contain coded information about specific class territory amount. Raster's data are converted as Feature Class and their attribute tables are expanded with earlier calculated data. Feature Class data layer does not contain information about agriculture land areas and for that reason new data fields have been added to attribute tables that contain information about sloping territories being marked proportionally. In its turn newly-acquired data are attributed to agriculture lands and are used for symbolization of cartographic parts where overall territory for each class can be seen.

Taking into account that mapping results obtained by using digital elevation model were too general to characterized Latvian relief conditions the final mapping of this criterion is based on soil erosion data.

## 2.4 Administrative boundaries used

From 3 January 2011, Latvia has been divided in 110 Municipalities and 9 cities and 21 regional development centres and 449 parishes.[5]


**Figure 2.4-1: The administrative territorial division of Latvia as of January 1, 2012.**

According to what is said in the draft Regulation "Proposal for a Regulation of the European Parliament and of the Council on support for rural development by the European Agricultural Fund for Rural development (EAFRD)" Article33 in paragraph 3 : "Respect of those conditions shall be ensured at the level of local administrative units ("LAU 2" level) or at the level of a clearly

[5] http://www.likumi.lv/doc.php?id=185993

delineated local unit which covers a single clear contiguous geographical area with a definable economic and administrative identity",  to determine ANC in Latvia, the Regional  („Novads"  - „LAU 2" level) territorial division unit – PARISH is applied.

## 2.5 Agricultural land data used

In Latvia, information on agricultural land can be obtained from several data sources:
- State Land Service
- Central Statistical Bureau
- Rural Support Service

### (a) State Land Service

The State Land Service is an institution directly subordinated to the Ministry of Justice, and it performs the following functions:
- Ensuring operation of the State Real Estate Cadaster;
- Ensuring operation of the State Register of Addresses;
- Ensuring operation of the information system on territories with constraints;
- Ensuring operation of the Central highly detailed topographical information database;
- Carrying out of cadastral evaluation of real estate;
- Participating in implementation of the State land reform policy;
- Carrying out cadastral survey of buildings and groups of premises..
- According to the information provided by the State Land Service, and according to target groups of real estate use there are 2 390 904 ha of agricultural land , in Latvia.

### (b) Central Statistical Bureau

CSB is a direct administration institution, which is the major performer and coordinator of statistical work in the country. The Central Statistical Bureau provides data on the use of agricultural land.

The area of cultivated agricultural land is 1 796 286 ha

### (c) Rural Support Service

In compliance with EU Regulation No 3508/1992 and No 2419/2001,every EU Member State had to implement an Integrated Administration and Control System (IACS). The aim of the system is setting up a uniform European Union payment accountancy and control system, which according to the Regulations must be improved and developed. The Field Register is one of IACS elements.

The Field Register has been established as a geographical information system (GIS), which maintains information on agricultural land in the form of field blocks.

The Field block map covers the entire area of agricultural land in the territory of Latvia, depicts part of the information necessary for the Rural Development Plan, and serves as an overview of interrelated location of field blocs in the territory

The total number of field blocks is 281 356 and their total area is 1 958 654,8 ha.

# 3 CRITERIA CALCULATION METHODS AND RESULTS

## 3.1 Criteria: Low temperature

Of all climate criteria Latvia has analyzed the Criterion 1 – Low Temperature constituting two indicators: the Length of Growing Period and the sum of active temperatures in ºC days (Thermal Time Sum). To analyze both criteria Latvia made use of temperature observation data in 41 year period, from 1968 to 2008.

As a result Latvia has made calculations according to the "Updated common bio-physical criteria to define natural constrains for agriculture in Europe" based on data provided by the Latvian Environmental, Geological and Meteorological Agency.

Methodology in calculating day average temperature:

a) Minimum and maximum day and night air temperature (max/min temperature method):

$$T_{avg1} = \frac{T_{\min} + T_{\max}}{2},$$

$T_{min}$ – is day and night minimum temperature, °C,
$T_{max}$ – day and night maximum air temperature, °C;

b) Results of 8 measurements during day and night (8 measurement method):

$$T_{avg2} = \frac{(T_1 + T_2 + \cdots + T_8)}{8},$$

$T_1 ... T_8$ –temperature measurements, °C.

Latvia is situated in a climatic zone with expressed temperature diurnal oscillations in spring and autumn seasons, characterized with high variance between the maximum and minimum daily temperatures. Results show considerable difference of 8 measurement method and the maximum and minimum temperature method. Both methods were used in calculating average daily temperature and compared.

Latvia considers that average day and night temperature, which has been calculated on the basis of eight observations, is more impartial indicator and further calculations should be based on them.
Analyzing the available data over the period of 41 years, the length of growing period and the thermal time sum for every day have been calculated. The data obtained were broken down by years. ANC condition is met if the length of growing period is equal or less than 180 days and the thermal time sum is equal or less than 1500C days in a respective year. As 41 year data have been analyzed the respective territories are considered to be ANC if the condition is met for 20% or at least 9 cases out of 41 year.

Severely limiting low temperature according to the methodology (Updated common bio-physical criteria to define natural constraints for agriculture in Europe Definition and scientific justification for the common biophysical criteria, JRC 2014) is said to occur if $TS_5$ is less than 1500°Cd ($T_b$=5°C) or $LGP_{t5}$ is less than 180 days. As a refinement for the computation, the start of the growing period is defined from the fifth day when 5 consecutive days fulfil the condition of having daily average temperature ($T_{avg}$) above 5°C. Conversely, the end of the growing period is defined from the fifth day when at least 5 consecutive days will have their average daily temperature below 5°C.
In order to take account of between year variability of meteorological conditions, a probabilistic approach is applied as stipulated by the methodology. 80% / 20% probability exceedance / non exceedance approach is applied in calculation, i.e. if in 9 or more years out of 41, the threshold value for severe low temperature condition is reached, the land is classified as being under severe low temperature constraint limitation.

**Data sources**

ANC occurrence probabilities for both Criterion 1 – Low Temperature indicators have been calculated for all meteorological stations. ANC occurrence probabilities have been calculated using 8 measurement method and max/min temperature method. Probabilities of ANC criteria occurrence are summarized in tables 3.1-1 and 3.1-2 below.

*Criterion – Length of Temperature Growing Period*

Probabilities of occurrence of ANC criterion Length of temperature growing (<180 days, daily average t>5ºC) period calculated using max/min temperature approach range from 0-46%. 4 meteostations – Alūksne, Gulbene, Zosēni and Rēzekne exceed 20% probability. Very close to 20% probability threshold is Rūjiena meteostation. Substantially more meteostations (~1/3) comply with ANC criterion if using 8 measurement method. Average probability occurrence calculated using max/min method is 11%, whereas for 8 measurement method – 16%. Results obtained using 8 measurement approach compared to max/min temperature approach shows increased occurrence of probabilities. Up to 100% increase has been observed in 9 stations, 100% increase of probability occurrence is observed in 4 stations, more than 2 times – in 4 stations. No difference in probability occurrence calculated using both methods has been observed in 6 stations. The average probability of ANC criterion occurrence calculated according to 8 measurement method show up to 40% increase compared to ANC probability occurrence calculated according max/min temperature method. See table 3.1-1.

**Table 3.1-1: Probabilities of occurrence of ANC criterion: the Length of Temperature Growing Period (min/max and average 8 temperature measurement methods)**

| **Meteostation** | **Probability of ANC criteria occurrence** Length of Temperature Growing Period **(Time series period: 1968-2008)** | |
|---|---|---|
| | **Max/min temperature method** | **8 measurement method** |
| **Ainaži** | 14.6% | **22.0%** |
| **Alūksne** | **46.3%** | **53.7%** |
| Bauska | 2.4% | 2.4% |
| Daugavpils | 7.3% | 9.8% |
| Dobele | 2.4% | 2.4% |
| **Gulbene** | **29.3%** | **29.3%** |
| Jelgava | 2.4% | 2.4% |
| Kolka | 7.3% | 9.8% |
| Liepāja | 0% | 0% |
| Mērsrags | 2.4% | 4.9% |
| Pāvilosta | 2.4% | 4.9% |
| **Priekuļi** | 14.6% | **24.4%** |
| **Rēzekne** | **22.0%** | **29.3%** |
| Rīga | 2.4% | 2.4% |
| Rūjiena | 19.5% | **31.7%** |
| Saldus | 2.4% | 12.2% |
| Skrīveri | 7.3% | 14.6% |
| Skulte | 4.9% | 14.6% |
| Stende | 9.8% | 17.1% |
| Ventspils | 0% | 2.4% |
| **Zīlāni** | 9.8% | **22.0%** |
| **Zosēni** | **41.5%** | **43.9%** |
| Rucava | 0% | 0% |
| **Dagda** | 19.5% | **34.1%** |

*Criterion – Thermal Time Sum*

15 meteostations (according max/min method) and 20 (according to 8 measurement method) out of 24 comply with Thermal Time Sum criterion (Temperature sum (degree-days) defined by accumulated daily average temperatures > 5°C), Thermal Time sums <1500º), calculated from 41 year data set. The range of probability occurrence calculated using max/min temperature approach ranges from 10%-80%. Average probability occurrence calculated using 8 measurement method is 41.8%, maximum occurrence probability 76% - Zosēni meteostation, minimum 15% (Rīga station). See Table 3.1 -2 below. The average probability of ANC criterion occurrence calculated according to 8 measurement method show up to 30% increase compared to ANC probability occurrence calculated according max/min temperature method.

**Table 3.1-2: Probabilities of occurrence of ANC criterion: Thermal time sums (min/max and average 8 temperature measurement methods)**

| Meteostation | Probability of occurrence of ANC criteria – Thermal Time sums (Time series length: 1968-2008) | |
|---|---|---|
| | Max/min temperature method | 8 measurement method |
| **Ainaži** | **46.3%** | **51.2%** |
| **Alūksne** | **61.0%** | **70.7%** |
| Bauska | 12.2% | 17.1% |
| **Daugavpils** | 14.6% | **21.9%** |
| **Dobele** | 17.1% | **26.8%** |
| **Gulbene** | **48.8%** | **56.1%** |
| Jelgava | 14.6% | 19.5% |
| **Kolka** | **58.5%** | **61.0%** |
| Liepāja | 9.8% | 19.5% |
| **Mērsrags** | **46.3%** | **51.2%** |
| **Pāvilosta** | **41.5%** | **48.8%** |
| **Priekuļi** | **29.3%** | **46.3%** |
| **Rēzekne** | **36.6%** | **46.3%** |
| Rīga | 12.2% | 14.6% |
| **Rūjiena** | **43.9%** | **53.6%** |
| **Saldus** | **24.4%** | **51.2%** |
| **Skrīveri** | 17.1% | **29.3%** |
| **Skulte** | **24.4%** | **34.1%** |
| **Stende** | **53.7%** | **58.5%** |
| **Ventspils** | **22.0%** | **46.3%** |
| **Zīlāni** | 14.6% | **29.3%** |
| **Zosēni** | **80.5%** | **75.6%** |
| **Rucava** | 22.0% | **36.6%** |
| **Dagda** | **24.4%** | **39.0%** |

**Lithuania**

Temperature Time Sum criteria occurrence probabilities calculated from Lithuanian station temperature data were utilized to aid delineation of ANC climate criteria in Latvia. Lithuanian ANC occurrence probabilities have been provided from climate – average temperature time series data that were aligned with Latvian climate time series data (41 year period, 1968-2008). List of ANC criteria probabilities are provided in Table 3.1-3. ANC probabilities have been used to aid delineation of ANC areas in southern part of Latvia.

**Table 3.1-3: Probability of ANC criterion: Thermal time sums (8 temperature measurement method) occurrence in Lithuanian meteostations**

| Meteostation | Probability of occurrence of ANC criteria – Temperature time sum |
|---|---|
| **Biržai** | **17.1%** |
| **Dūkštas** | **31.1%** |
| **Klaipeda** | **10.8%** |
| **Panevežys** | **14.3%** |
| **Šiauliai** | **17.1%** |
| **Telšiai** | **24.2%** |
| **Utena** | **16.3%** |

**Estonia**

Both the Thermal time sum and the Length of temperature growing period criteria occurrence probabilities obtained from Estonian meteorological station data have been utilized to aid delineation of climate factor ANC areas in Latvia. The length of time series ranges from 1977 – 2007. It has to be noted though that few stations data have gaps and there is no full data available for 30 year period as required by guidelines. Estonian meteostation data that have been used to aid delineation of ANC territories in Northern part of Latvia is provided in Table 3.1-4 below.

**Table 3.1-4: Probability of ANC criterion: Thermal time sums (8 temperature measurement method) occurrence in Estonian meteostations**

| Meteostation | ANC criteria occurrence probabilities | | Data used for ANC delineation in Latvia |
|---|---|---|---|
| | Length of tempeature growing period | Thermal time sum | |
| Ristna | 26% | 61% | |
| **Pärnu** | **27%** | 17% | × |
| Tallinn | 39% | 58% | |
| Nigula | 29% | 52% | |
| Kuusiku | 33% | 63% | |
| Türi | 35% | 52% | |
| Jõgeva | 42% | 58% | |
| V-Maarja | 55% | 77% | |
| Jõhvi | 48% | 68% | |
| Narva | 42% | 65% | |
| Tiirikoja | 48% | 68% | |
| Tartu | 29% | 32% | |
| **Viljandi** | **29%** | **39%** | × |
| **Valga** | **26%** | **26%** | × |
| **Võru** | **29%** | 20% | × |
| **Kuressaare** | **45%** | **45%** | × |

**Delineation of Climate Criterion 1 "Low Temperature" severely limiting areas in Latvia**

Maps showing the areas of occurrence of Climate Criterion 1 Low Temperature indicators Length of Growing Period and Thermal Time Sums are provided in Figures 3.1-1 and 3.1-2. Both maps show delineated ANC areas and probability distribution. All meteorological stations used in ANC area delineation and occurrence of probability of particular ANC criterion are provided on maps.

Calculated ANC area affected by the Length of Growing Period severely limiting threshold is **47%** calculated according to 8 measurement method and 29% calculated according to min/max temperature method. See Figure 3.1-1. Area affected by Thermal Time Sum criterion is substantially larger, i.e. territory where occurrence of Thermal Time Sum criterion exceeds 20% amounts to **88%** of the territory of the country as calculated according to 8 measurement method. See Figure 3.1-2.

Methodology specifies that threshold limits for ANC criterion is either 180 days for the Length of Growing Period indicator OR 1500 degree days for Thermal Time Sum indicator. Therefore the Thermal Time Sum criterion calculated according to 8 measurement method is considered as ANC for Climate Criterion 1 Low Temperature

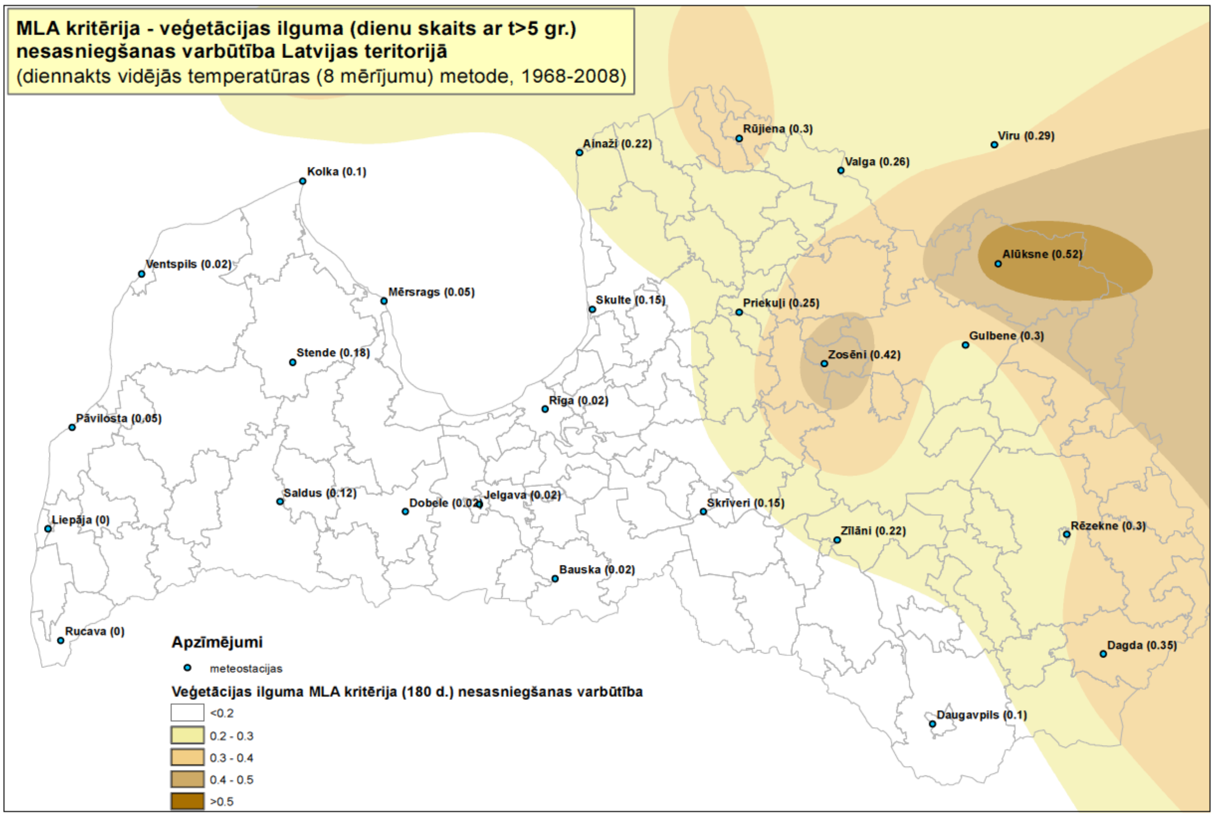



**Figure 3.1-1: : Delineation of ANC criterion: Length of the Temperature Growing Period occurrence probabilities (8 measurement method, data range 1968-2008).**

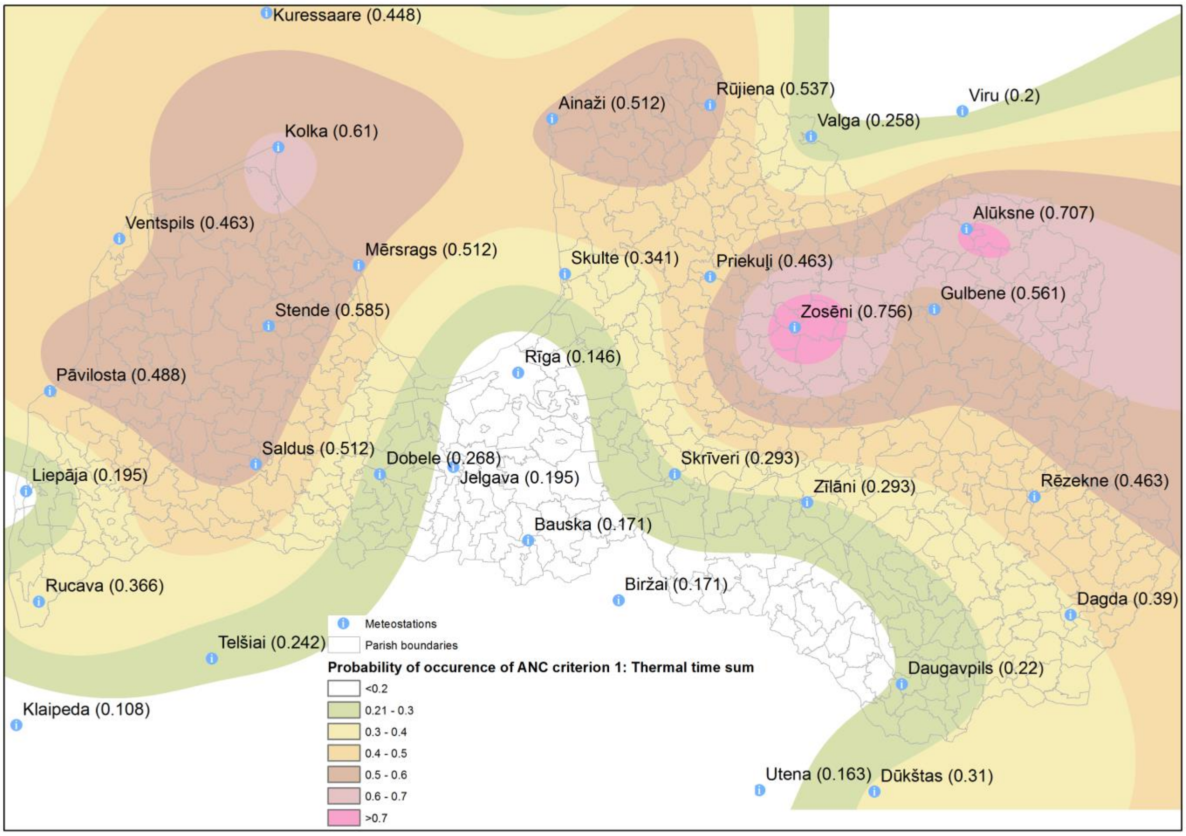



**Figure 3.1-2: Delineation of ANC criterion Thermal Time Sum occurrence probabilities (8 measurement method, data range 1968-2008).**

One station from the overall climate data set – Liepāja station show inconsistent results compared to nearby stations. This is explained by the urban influence of Liepāja city. The station data shows different results compared to nearest rural Rucava and Pāvilosta stations.

Therefore, Liepāja meteostation is excluded from the Latvian climate data set used in delineation of Climate criterion ANC.

Liepāja meteostation.

Probability of occurrence of ANC criterion – Thermal time temperature sums in Liepāja station is 19.5%, whereas in other nearby coastal stations – Rucava and Pāvilosta – 36.6% and 48.8% respectively. Difference in probability occurrence in meteorological stations located in so close to each other leads to consider urban influence to climate variables in Liepāja station. Statistical analysis of temperature data for all three stations supports the hypothesis that mean annual temperatures in Liepāja station differs from that of Rucava and Pāvilosta stations in terms of higher mean daily temperatures. As a result of statistical analysis no significant difference (alpha 0.05) in mean annual daily temperatures in Rucava and Pāvilosta station data has been observed though.

In particular, analysis of 41 year annual mean temperature data set shows that there is significant (paired t-test p-value = 2.2e-16, df = 40, alpha=0.05) difference in mean temperatures between Liepāja station and Rucava station, located 50km to the South of the Liepāja city (Figure 3.1.3.). Comparing Liepāja station data – annual mean temperatures to those of Pāvilosta station, located 40km to the North of Liepāja shows significant (paired t-test p-value = 2.2e-16, df = 40, alpha=0.05) difference in mean temperatures. No significant (paired t-test p-value = 0.259, df = 40, alpha=0.05) difference in mean annual temperatures is observed between Rucava and Pāvilosta stations data sets, however. See comparison of mean annual temperature data sets of all three stations in Figure 3.1-4.

All three meteorological stations are located nearby the coast, under direct influence of the Baltic Sea. See figure The entire territory covered by stations lies within one climatic region, moderately mild and wet. The proximity of the Baltic Sea accounts for moderately marine climatic conditions in the area. Liepāja station is located in S part of the city, outskirts of Liepāja city, 1.3 kilometers from the Baltic Sea, 4m a.s.l. Rucava station is located in the most South-Western part of Latvia, 10 km east from the Baltic Sea coast, 18m a.s.l. The topography of area is very flat - Seaside Lowland. The station is located in the agricultural area. Within the radius of 300 m there is area, covered with farmland and small groups of trees. Distance to Liepāja station <50km. Pāvilosta station is located in outskirts of Pāvilosta town, scarcely built area, less than 1 km from the Baltic Sea, 8m a.s.l. Distance to Liepāja station ~40km.


**Figure 3.1-3: Location of Liepāja, Rucava and Pāvilosta meteostations**

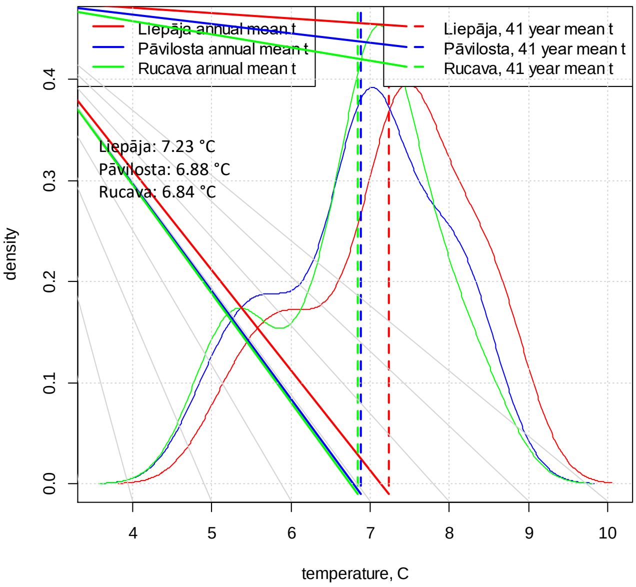



**Figure 3.1-4: Comparison of annual mean temperature data sets – Liepāja, Rucava and Pāvilosta meteostations (time series data 1968-2008)**

Thus data of Liepāja station is excluded from the climate data framework in order to exclude possible urban influences (such as heat island effect) and use data from other two nearby coastline stations Rucava (50km) and Pāvilosta (40km) instead.

Figure 3.1-5 shows interpolated distribution of probability of occurrence of Climate Criterion 1 "Low Temperature" indicator Thermal Time Sum with Spline interpolation method, having Liepāja station excluded from the climate data set. Map shows delineated ANC areas and probability distribution.

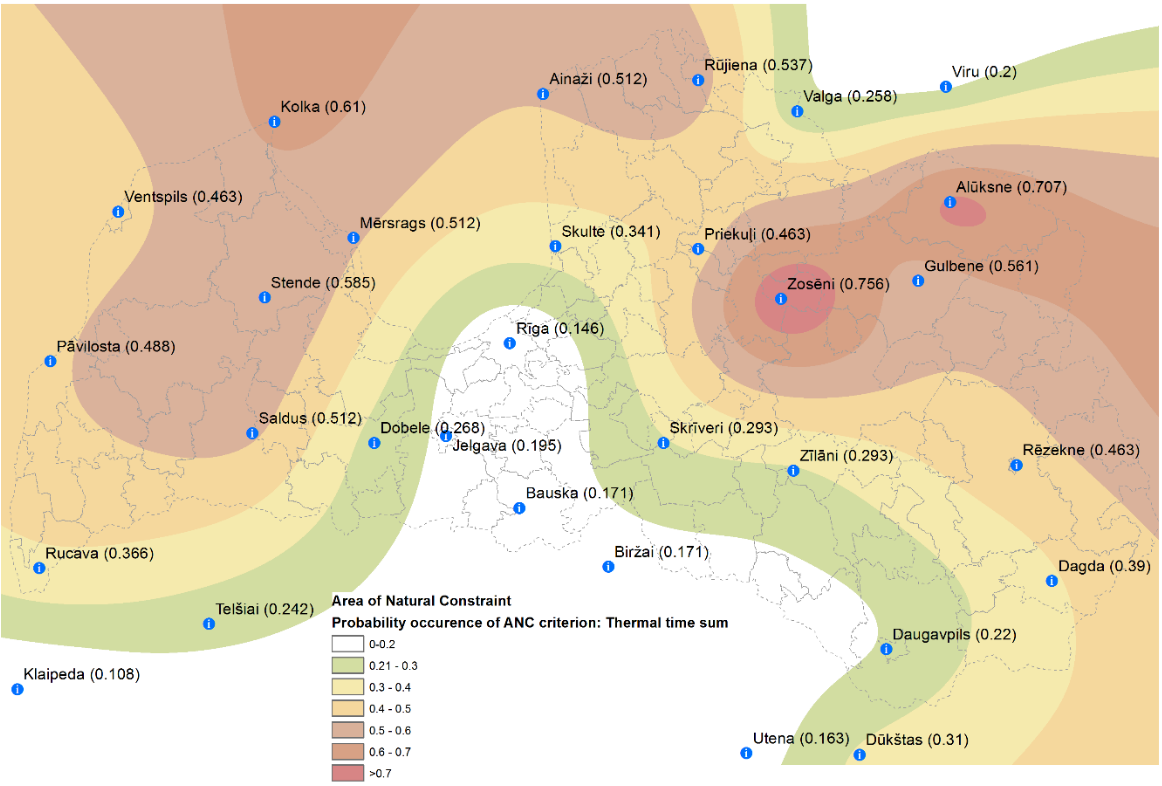



**Figure 3.1-5: Territories where ANC criterion thermal-time sum ANC criterion occurrence possibility exceeds 20% (8 measurement method, period 1968-2008). Liepāja meteostation excluded from the climate data set as described above.**

### Uncertainty assessment, cross-validation of interpolation results

Cross-Validation is commonly used statistical technique to evaluate the performance of interpolation method and compare for interpolation results. Cross-Validation evaluates the interpolation method by following algorithm - repeating the following procedure for each interpolation method to be evaluated: a) remove a known point from the data set; b) use the remaining points to estimate the value at the point previously removed, and (c) calculate the predicted error of the estimation by comparing the estimated with the known value. After completing the procedure for each known point, two common diagnostic statistics, Root Mean Square Error (RMSE) and the standardized RMSE, are calculated to assess the accuracy of the interpolation method.

Climate ANC criterion 1 "Low temperature" – Thermal time sum correlates spatially with other climate affecting variables. One of climate ANC criterion "Low temperature" affecting variables is relief – height above sea level. During the ANC delineation process a positive correlation has been established among the meteostation Thermal time sum occurrence probability and the height above the sea level.

In order to account for the effect of elevation on spatial variation of ANC criterion Thermal Time Sum a geostatistical interpolation techniques shall be applied. An advantageous feature of such methods is that those allow for the statistical determination of the accuracy of predicted surface - spatial variation of ANC criterion with certain degree of uncertainty – least prediction error. Geostatistical interpolation techniques are based on the assumptions that locations that are closer together will be more similar than locations that are farther apart. As a result, the values of closer points are weighted more heavily than those further away. The empirical semivariogram or relationship is used to link between point data and regionalized surfaces. Semivariogram relates the distance between points to the difference squared between their values; it is the graphical representation of the similarity of points with distance. The model that is best fit to the semivariogram is then used in the interpolation method that creates a surface prediction.

The geostatistical interpolation methods chosen for refinement of the ANC delineation process are: kriging and co-krco-kriging. In order to refine the ANC delineation process a spatial co-kriging interpolation method has been utilized. Co-kriging interpolation method is a modification of standard Kriging interpolation method based on spatial dependence between known points using a multivariate variogram and multivariate ancillary data. Co-kriging interpolation process utilize information on more than one variable and calculation includes estimating the autocorrelation for every variable and cross-correlations between variables.

Digital Elevation Model (DEM) is used as a secondary input variable to co-kriging interpolation. A 20 horizontal meter resolution DEM was used, resampled down to 500 meters. The occurrence probability of ANC criterion Thermal Time Sum correlates moderately with elevation of the meteostation (Pearson r = 0.599, $r^2$=0.3599, p = 0.018, alpha=0.05), meaning 36% of variation in occurrence of ANC criterion Thermal Time Sum can be linked to relief, elevation (meters above sea level). See relationship of occurrence probability of ANC criterion Thermal Time Sum and the elevation of the meteostations in Figure below (3.1-.6).

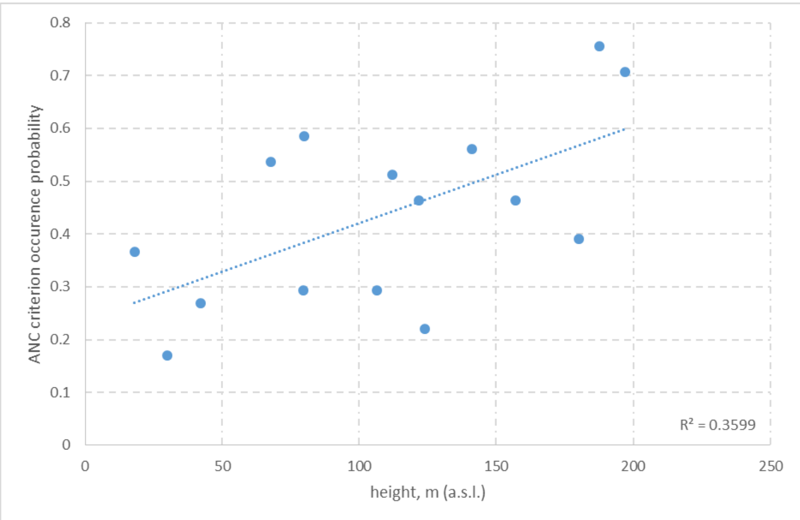



**Figure 3.1-6: Relationship of ANC criterion occurrence probability vs relief, elevation (height above sea level). Statistics: Pearson r = 0.599, $r^2$=0.36, p = 0.018**

A co-kriging interpolation method has been used to interpolate the ANC criterion Thermal time sum occurrence probability data obtained from long term mean temperature data from weather stations and the elevation data derived from the digital terrain model. Three co-kriging methods - ordinary, simple and universal kriging using several types of mentioned variogram models were tested and their error validated: ordinary co-kriging with constant and first order trend removal, Simple co-kriging with normal score transformation with and without trend removal. Universal co-kriging with first and second order trend removal. See Figure 3.1-.7 for comparison of co-kriging interpolation methods and variograms.

Spatial dependence decreases as a distance between two stations increases, and sample points beyond a certain distance will have little or no correlation with a point value to be estimated. Therefore, it is common practice to select directional configuration and the number of control points that will be used in the prediction of an unknown value. No directional difference in spatial dependence was assumed, and an isotrophic model was used. For sample-point selection, simple and quadrant strategies were used for all data sets. For the simple strategy, no direction was specified, and 5 control points or the minimum of 2 points that fell within a search circle were used for both interpolation methods. For the quadrant strategy, 5 control points or the minimum of 2 sample points that fell within each of the four cardinal sectors of a search circle were used.

Selection of a fitting model to a semivariogram is principal issue in kriging interpolation process. Data characteristics, visual inspection, and cross-validation are important in a model-selection process. In this assignment the semivariogram of each composite data was fitted with several conceptually plausible models: circular, spherical, exponential and Gaussian being considered as an optimal models. A validation of each of models allows for the quantification of error in a large scope assessment of model prediction accuracy and select for the highest accuracy model.

Cross validation is commonly carried out to check for the accuracy of the interpolation method in order to choose the most appropriate method. The accuracy is validated by removing a point with known value from the data set, interpolating the value at that point and calculating a difference between predicted and the known value. For cross validation purpose diagnostic statistic indicators such as root mean square error (RMSE) and root mean square standardized error (RMSSE) are used. Statistic indicators provides assessment of uncertainty by estimating variability of predictions of known values.

Comparison of tested co-kriging interpolation methods is provided in Figure 3.1-.7 to illustrate accuracy and variation of tested variogram models within chosen co-kriging interpolation algorithms. Analysis of test results show that simple co-kriging method, using normal score data transformation and Gaussian approximation shows least variance of mean root square error for tested co-kriging interpolation methods and semivariogram models. Semivariogram models that show best fit are spherical and Gaussian models. Thus, for interpolation purpose a simple co-kriging interpolation method, using Gaussian approximation have been applied.

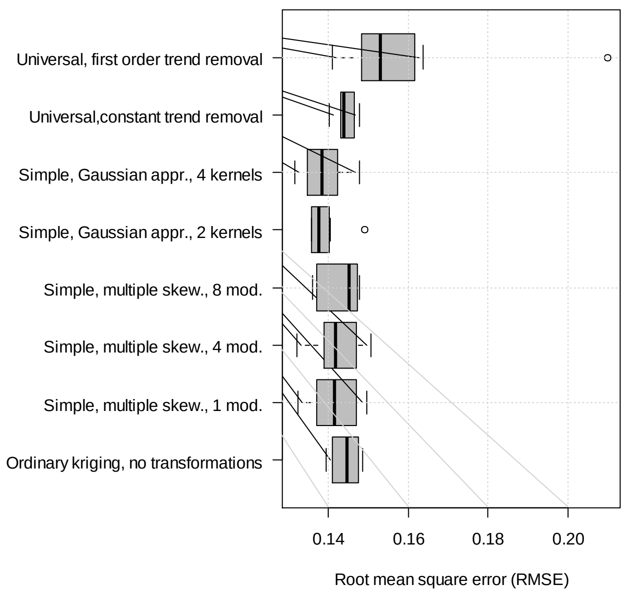


**Figure 3.1-7: Comparison of tested co-kriging interpolation method and semivariogram models**

Table 3.1-5 shows results of cross-validation of selected simple co-kriging interpolation method used to delineate ANC territories. Co-kriging interpolation cross-validation data statistics: Pearson r=0.992, $r^2$=0.984, p= 0.027. Root Mean Square Error: 0.021, Root Mean Square Standardized Error: 1.067.

Root Mean Square Standardized Error should be close to one if the prediction standard errors are valid. If the root-mean-squared standardized error is greater than one, the variability in predictions is underestimated. If the root mean square standardized error is less than one, the variability of predictions is overestimating. In the case of ANC interpolated model, the root mean square standardized error is 1.067.

Figure 3.1-8. shows the regression of predicted ANC probability values on measured ANC probability values for 23 Latvian stations with 95% confidence interval. The error of the interpolation is not statistically significant. Regression statistics: Pearson r=0.992, $r^2$=0.984, p= 0.027, Root Mean Square Error: 0.021.

Interpolated occurrence probabilities of ANC criterion "Thermal time sum" are provided in Figure 3.1-9. The error map shows that largest error take place at Rucava station (underestimation at 7.0 percentage points) and Skulte station (underestimation at 5 percentage points). Rucava station is located at the Baltic Sea coast. Skulte station is located in at Riga Gulf.

**Table 3.1-5: Uncertainty estimation of results obtained using chosen co-kriging interpolation method – simple co-kriging with Gaussian approximation variogram.**

| Station | Measured ANC criterion probability | Predicted ANC criterion probability | Error | Standard Error |
|---|---|---|---|---|
| Ventspils | 0.4634 | 0.4640 | 0.0006 | 0.0353 |
| Kolka | 0.6098 | 0.5926 | -0.0171 | 0.0030 |
| Mērsrags | 0.5122 | 0.5053 | -0.0068 | 0.0044 |
| Pāvilosta | 0.4878 | 0.4808 | -0.0070 | 0.0059 |
| Saldus | 0.5122 | 0.5055 | -0.0067 | 0.0044 |
| Dobele | 0.2683 | 0.2774 | 0.0091 | 0.0074 |
| Jelgava | 0.1951 | 0.1963 | 0.0012 | 0.0033 |
| Bauska | 0.1707 | 0.1716 | 0.0009 | 0.0027 |
| Rīga | 0.1463 | 0.1529 | 0.0066 | 0.0023 |
| Skulte | 0.3415 | 0.2944 | -0.0470 | 0.0377 |
| Skrīveri | 0.2927 | 0.2797 | -0.0130 | 0.0083 |
| Ainaži | 0.5122 | 0.4967 | -0.0155 | 0.0048 |
| Rūjiena | 0.5366 | 0.5176 | -0.0190 | 0.0040 |
| Priekuļi | 0.4634 | 0.4816 | 0.0182 | 0.0068 |
| Alūksne | 0.7073 | 0.6752 | -0.0322 | 0.0036 |
| Gulbene | 0.5610 | 0.5739 | 0.0129 | 0.0030 |
| Rēzekne | 0.4634 | 0.4757 | 0.0123 | 0.0217 |
| Daugavpils | 0.2195 | 0.2351 | 0.0156 | 0.0047 |
| Zīlāni | 0.2927 | 0.2961 | 0.0035 | 0.0401 |
| Zosēni | 0.7561 | 0.7279 | -0.0282 | 0.0043 |
| Stende | 0.5854 | 0.5803 | -0.0051 | 0.0030 |
| Rucava | 0.3659 | 0.2923 | -0.0735 | 0.0347 |
| Dagda | 0.3902 | 0.3699 | -0.0204 | 0.1456 |
| RMSE | | | | 0.021 |
| RMSSE | | | | 1.067 |

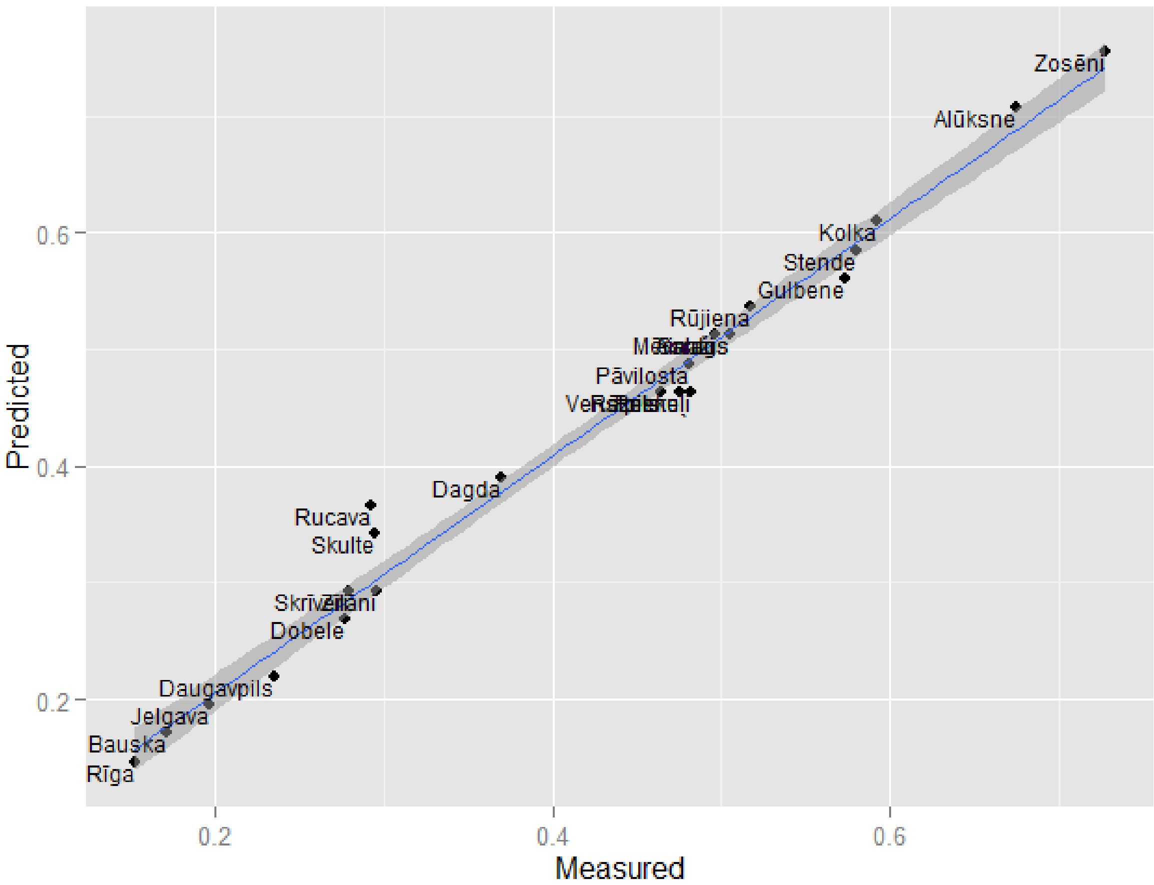



**Figure 3.1-8: Simple co-kriging interpolation method cross-validation: measured ANC probability values vs predicted ANC probability values. Linear regression model, 95% confidence interval. Statistics: Pearson r=0.992, $r^2$= 0.984, p= 0.027.**

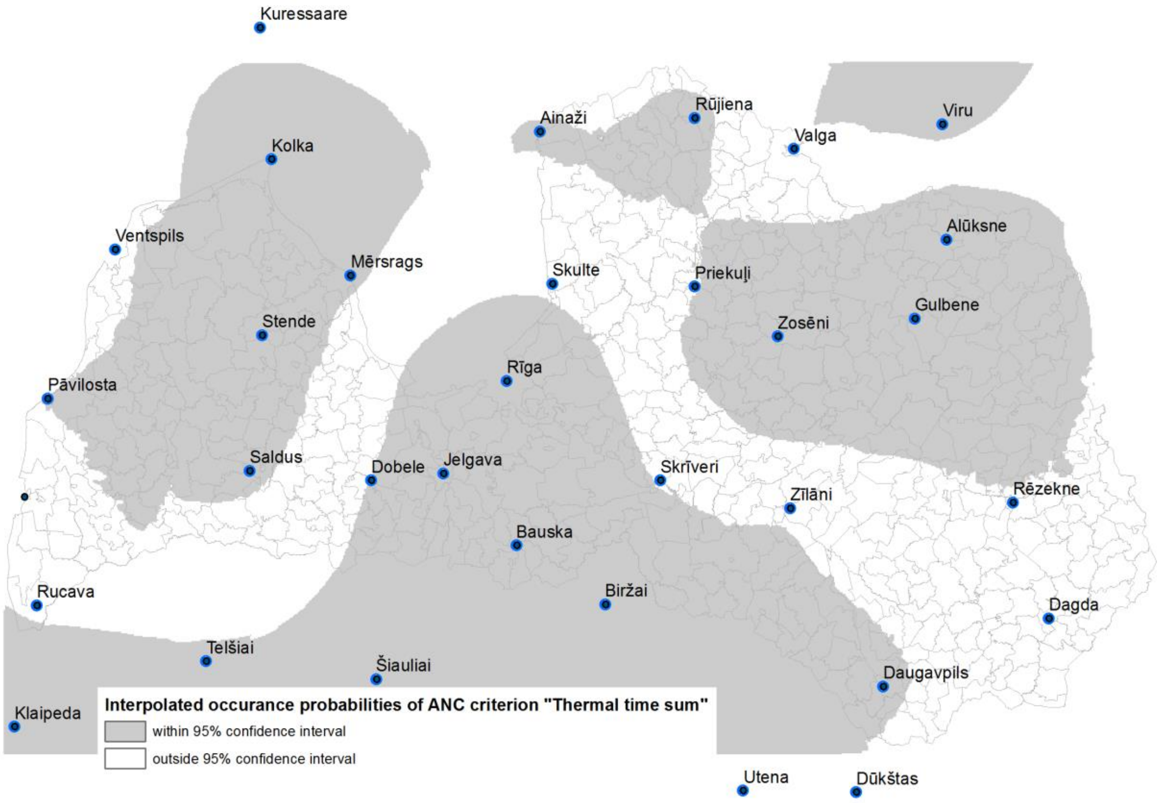



**Figure 3.1-9: Interpolated occurrence probabilities of ANC criterion "Thermal time sum"**

Statistical test was performed to the interpolated model. Cells with 95% statistical significance were used for final interpolation. Uncertainty (error) map of simple co-kriging interpolation method is provided in Figure 3.1-10 which shows spatial distribution of co-kriging interpolation error. The highest standard errors are observed in the South-East part of the country, where errors average from 7-16 per cent. The error is largely related to few stations (data) available for interpolation and due to the fact that no data is available from Russian or Belorussian stations.

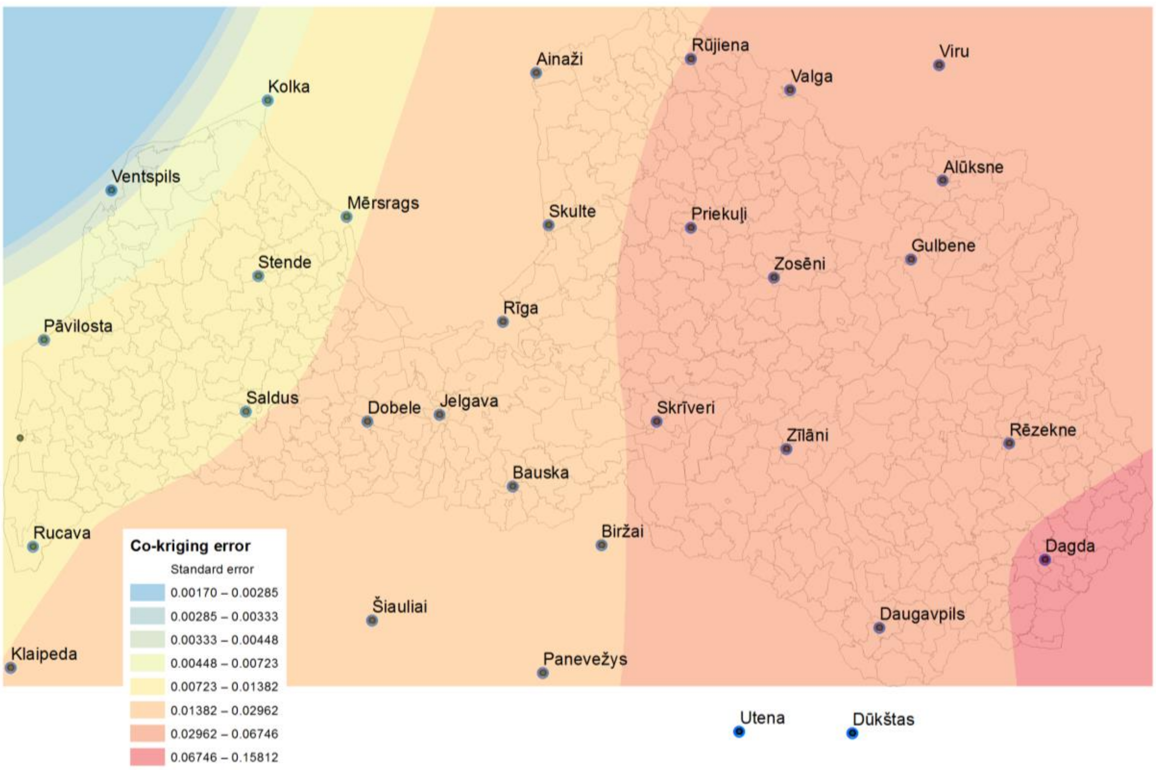


**Figure 3.1-10: Uncertainty (error) map of co-kriging interpolation method**

**Co-kriging interpolation results**

Distribution of probability occurrence of ANC criterion Thermal Time Sum using co -kriging interpolation approach is provided in Figure 3.1-11.

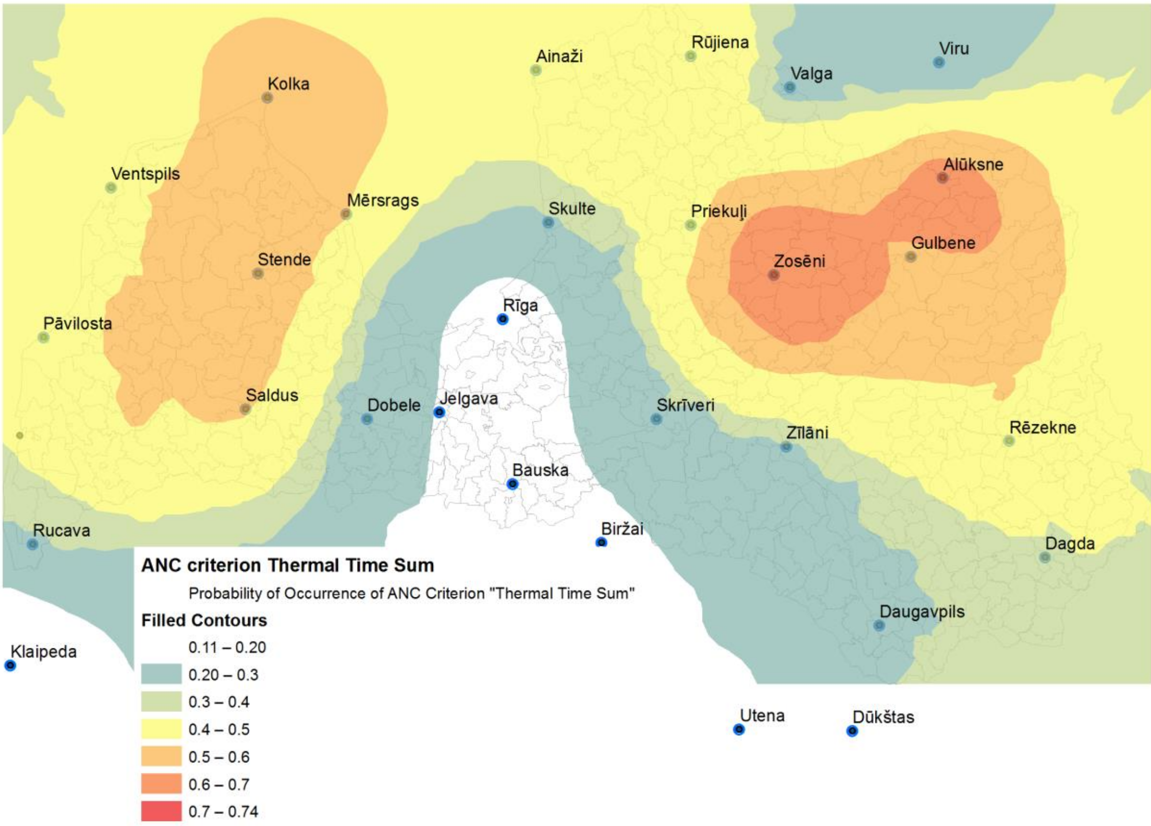



**Figure 3.1-11: Refined delineation of ANC territories where the Thermal Time Sum criterion occurrence probability exceeds 20% (8 measurement method, period 1968-2008) using co-kriging interpolation method**

The co-kriging interpolation method has been selected and applied for the ANC delineation (see table 3.1-6. and figure 3.1-12). The results of the delineation show only areas in a narrow stretch from Riga Gulf southwards accross the Zemgale Lowlands are not compliant to ANC criterion Low temperature - thermal time sum.

**Table 3.1-6: Model characteristics of interpolation method used in delineation of ANC territories**

| Interpolation method | Parameters | | | Interpolated territory area | |
|---|---|---|---|---|---|
| | Mean Standard Error | Root Mean Square Error | Correlation, significance level | thousand km$^2$ | percentage of country area |
| Co-kriging using secondary variable – relief elevation | -0.017 | 0.021 | Pearson r=0.992, $r^2$=0.984, p = 0.027 | 60.09 | 93.08% |

Since local administrative units (pagasts) was applied as main layer for ANC borders defining on the map, the final deliniation of ANC criterion 1 "Low temperature" was deliniated at the border og pagast therefore having the interpolation of the results overlayed with borders of administrative units.

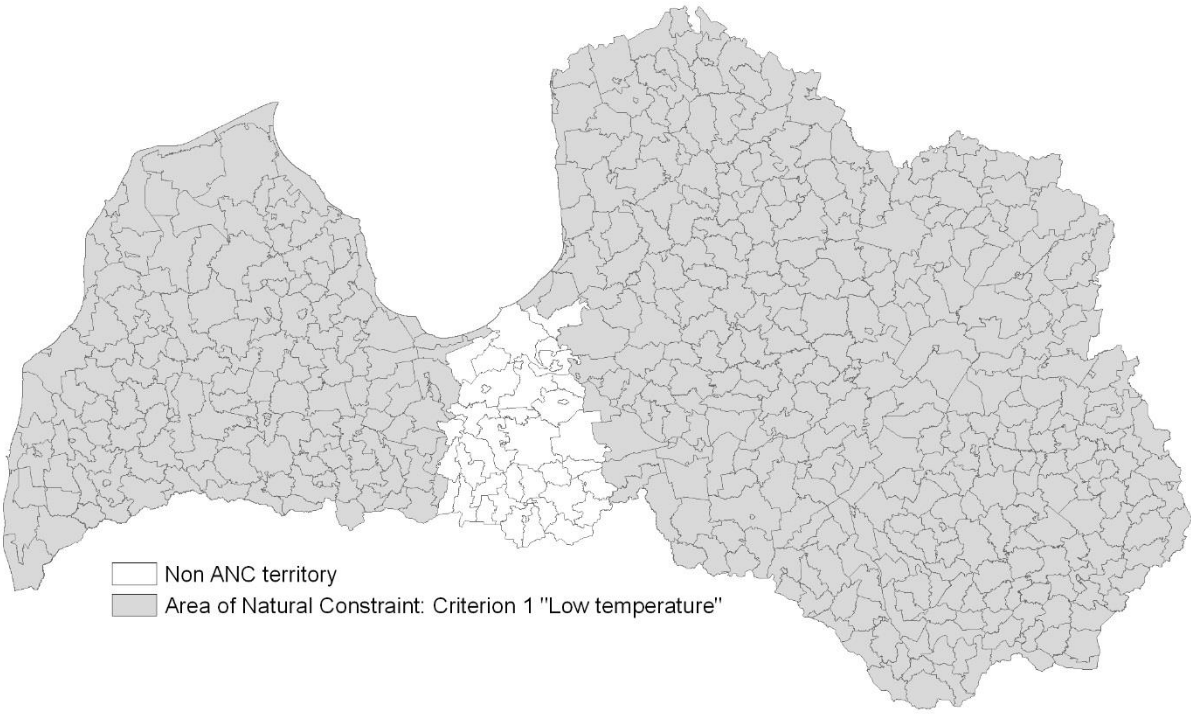



**Figure 3.1-12: Delineation of ANC territories where the Thermal Time Sum ANC criterion occurrence probability exceeds 20% (8 measurement method, period 1968-2008) using co-krco-kriging interpolation method with elevation as a secondary input variable. ANC size – 60.09 thousand km$^2$ or 93.08% of the total country area.**

## 3.2 Heat stress

The criterion has not been tested in Latvia / is not relevant for Latvia.

## 3.3 Criteria: Soil Drainage

### *3.3.1 THRESHOLD*

The thresholds identify land areas that are waterlogged for significant periods during the normal growing season, thus affecting normal farming operations or crop yields.

Soil drainage is said to be severe limiting if with regard to drainage the soil is classified as poorly or very poorly drained[6].

The definition of poorly drained soils.

Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity of nearly continuous rainfall, or of a combination of these.

The definition of very poorly drained soils.

Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater[7].

Value for severe threshold

According to the Guidelines, the thresholds are set to identify land areas that are waterlogged for significant periods during the normal growing season and thus affect normal farming operations or crop yields. The severe threshold is designed to identify soils on which farming operations for adapted crops are possible, but with severe yield reductions due to late planting or poor tillage, crop damage by transient anoxic conditions or plant pathogens resulting from poor drainage, or a substantial risk of crop damage[7]

Therefore, soil drainage is said to be severely limiting if with regard to drainage the soil is classified as:

- wet within 80cm (from the surface) for over 6 months, or wet within 40cm for over 11 months; OR
- classified as poorly drained (soils are commonly wet for considerable periods - ground water table commonly within 40cm from the surface, or classified as very poorly drained (wet at shallow depths for long periods - ground water table is commonly within 15cm from the surface; OR
- the soil has Gleyic colour pattern within 40cm from the surface;

Fine tuning with regard to artificially drained areas is required. Therefore if drainage systems are permanent and functioning the drained soil units should be evaluated as if they were better drained than without the installed drainage systems[8].

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[6] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions „*Towards a better targeting of the aid to farmers in areas with natural handicaps*" COM (2009)161 final version (21 April, 2009);

[7] Updated Common Bio-physical Criteria to Define Natural Constraints for Agriculture in Europe. EUR 23412 EN – 2013;

[8] TECHNICAL ANNEX of Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions „*Towards a better targeting of the aid to farmers in areas with natural handicaps*" COM (2009)161 final version;

### 3.3.2 DELINEATION OF THE INTERMEDIATE AREAS WITH NATURAL HANDICAPS FOR AGRICULTURE

The use of quantitative water-regime evaluation methods ([9], [10]) for the assessment of the Criterion 3: "DRAINAGE" currently is not possible due to lack of data (information and data are not available or it may require time and resources to collect them). The simulation of this criterion is based on Taxonomy of Latvia Soils ([11]), which is genetic classification of soils including also water-regime related parameters. The approach used is in line with recommendations set by the Technical Appendix of EC Communication ([12]).

Presence of periodic water, as well as shallow groundwater and/or surface water develops soil gleyzation (reduction) processes, which are the most characteristic soil formation processes in Latvia. Above mentioned feature is the indicator used for soil classification in Latvia[13] after which semi-hydromorphic soils are divided into several types and subtypes. Saturated moisture and anaerobic conditions in upper soil layer stimulates with stimulates formation of peat and is the second specific soil formation process for soils with poor drainage - hydromorphic or marsh peat soils in Latvia.

In Latvian circumstances some semi-hydromorphic subtypes of soils with dense, greenish-blue-grey gley soil horizon formed under long influence of groundwater or surface water (refer – Appendix 1), particularly can be addressed to poorly and very poorly drained soils.

Correlation of poorly drained soils to WRB/Soil Taxonomy

WRB defines several soil properties directly related to poor drainage, namely *gleyic* and *stagnic* features that are based on soil colour variations. Dominance of reductimorphic features is identified in the soil pit/profile wall by "Gleyic colour pattern"according to WRB, 2006. These features are used to define Reference Groups (*Gleysols* and *Stagnosols*). Other reference groups are associated with poor internal drainage: the *Planosols*, *Solonetz* and *Vertisols*.

In addition to soil taxonomic properties that are directly related to moisture regime, classes of soil moisture regime as per WRB, 2006 can be used to correlate the Latvia soil classification system to WRB. Classes of soil moisture regimes characteristic to Latvia conditions according to Soil Taxonomy are *Aquic*, *Peraquic*, *Udic* and *Aridic*. Soils with *Aquic* and *Udic* soil moisture regime are characteristic to most of soils in Latvia being formed in humid and cool climate conditions.[15]

*Aquic* soil moisture class relates to such soil moisture regime where reducing conditions are dominating in the upper part of the soil profile, i.e. the soil is fully saturated with oxygen depleted water. *Aquic* properties are said to be forming if soil is saturated with water for several days and soil temperature is above 5°C. *Aquic* soil moisture regime is characteristic to all hydromorphic soils and partly to semi-hydromorphic soils that are not artificially drained [15].

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[9] Kravchenko A. N., Bollero G. A., Omonode R. A., and Bullock D. G. *Quantitative Mapping of Soil Drainage Classes Using Topographical Data and Soil Electrical Conductivity*. Soil Science Society of America Journal 66:235-243 (2002);

[10] Campling P., Gobin A. and Feyen J. *Logistic Modeling to Spatially Predict the Probability of Soil Drainage Classes*. Soil Science Society of America Journal 66:1390-1401 (2002);

[11] Karklins A., Gemste I., Mezals H., Nikodemus O., Skujans R. *Taxanomy of Latvian Soils*. Jelgava. LLU. 2009. 240 p. (in Latvian - Latvijas augšņu noteicējs);

[12] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions „*Towards a better targeting of the aid to farmers in areas with natural handicaps*" COM (2009)161 final version (21 April, 2009);

[13] Karklins A., Gemste I., Mezals H., Nikodemus O., Skujans R. *Taxanomy of Latvian Soils*. Jelgava. LLU. 2009. 240 p. (in Latvian - Latvijas augšņu noteicējs)

*Peraquic* soil moisture regime is characteristic to soils in relief depressions, flood plains, bogs and other territories having high water table.

*Udic* soil moisture class is characteristic to soils in humid climates with characteristic equal distribution of precipitation during the summer and soil moisture balance with precipitation equals or exceeds the summary evapotranspiration. *Udic* soil moisture regime is characteristic to most of automorphic and semi-hydromorphic class soils according to Latvian soil classification system. Hydromorphic soils with installed and well operational artificial drainage system can also be considered *Udic*.[15]

*Aridic* soil moisture regime is characteristic to dry (arid) climate zones but can be also observed in humid climate zones in soils with rapid water infiltration properties, soils in steep slopes, territories with rapid surface runoff, In Latvia soils with Aridic soil moisture regime is considered exclusively in isolated, local areas such as dunes, steep slopes etc. [15]

Poorly drained soils correspond to soils with *Aquic* soil moisture regime that are not artificially drained. Also semi-hydromoprhic soils with *Udic* properties that are not artificially drained are considered poorly drained soils.

## (a) Very poorly drained soils

In Latvia conditions hydromorphic soils can be addressed to very poorly drained soils. Hydromorphic soils develop in prolonged influence of surface waters or in conditions of high water table. Hydromorphic soils are associated with accumulation of poorly decomposed organic matter (peat) in anaerobic conditions. Normally hydromorphic soils are characterized with high water table and capillary water reaches the topsoil. According to soil classification system commonly used in Latvia very poorly drained soils correspond to the following soil types and subtypes:

- Fen peat humic soil (TZh);
- Fen peat mucky –humus soil (TZt);
- Fen peat humic gley soil (TZr);
- Fen peat mucky – humus gley soil (TZa);
- Typic transitional mire soil (TPt);
- Transitional mire mucky – humus soil (TPa);
- Transitional mire gley soil (TPi);
- Transitional mire mucky – humus gley soil (TPr);
- Typic raised bog peat soil (TAt);
- Raised bod gley peat soil (TAi).

Such selection is specifying also by the Guidelines[14], stating that several soil properties are directly related to poor drainage, namely *gleyic*[15] and *stagnic*[16] features.

The soils with gley horizon (Br and Cr) selected to set the main conditions for very poorly drained soil criterion is presented in Table 3.3.-1.

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14 Guidelines for Application of Common Criteria to Identify Agricultural Areas with Natural Handicaps. EUR 23795 EN – 2009;

15 Gleyic properties – soil material qualities acquired when soil is waterlogged for long period, when certain colour features of gleyic soil appear – *Soil diagnostics and description.* 2008;

16 Stagnic properties – soil has been affected by groundwater in a long period of time, in the result, acquiring stagnic soil colour features. – *Soil diagnostics and description.* 2008;

**Table 3.3.-1: List of soil subtypes classified as very poorly drained**

| List of soil subtypes according to soil types list from 1952 | List of soil subtypes according to soil types list from 1987 | List of soil subtypes according to soil types list from 2008 |
|---|---|---|
| Grass fen soil (Tz) | Fen peat soil (Tz) | Fen peat humic soil (TZh) or fen peat mucky–humus soil (TZt) |
| Shallow grass fen soil (TGz) | Fen peat gley soil (Tzg) | Fen peat humic gley soil (TZr) or fen peat mucky–humus gley soil (TZa) |
| Transitional mire soil (Tp) | Transitional mire peat soil (Tp) | Typic transitional mire soil (TPt) or transitional mire mucky–humus soil (TPa) |
| Shallow transitional mire soil (TGp) | Transitional mire peat gley soil (Tpg) | Transitional mire gley soil (TPi) or transitional mire mucky–humus gley soil (TPr) |
| Moss bog soil (Ts) | Raised bog peat soil (Ta) | Typic raised bog peat soil (TAt) |
| Shallow moss bog soil (TGs) | Raised bog peat gley soil (Tag) | Raised bod gley peat soil (TAi) |

Notes: The Taxonomy of Latvia Soils ([17]) is used to classify soils corresponding to given category

## (b) Poorly drained soils

In Latvian condition all hydromorphic and some semi-hydromorphic soil types comply with poor drainage threshold value. Semi-hydromorphic soils are developing in areas where stagnant surface waters are present for some period of time, in areas with medium-high water table level. Semi-hydromorphic soils are present in relief depressions and undulated plains with poor surface runoff. Semi-hydromorphic soils are subject to constant or periodic influence of water.
In accordance with existing soil classification semi-hydromorphic soils contain following soil types:

- Gley soils;
- Podzolic – gley soils;
- Alluvial soils.

The subtypes of semi-hydromorphic and hydromorphic soils with gley horizon (Br or Cr) selected to set the main conditions for poorly drained soil criterion are presented in Table 3.3.-2.

**Table 3.3.-2. List of soil subtypes classified as poorly drained**

| List of soil subtypes according to soil types list from 1952 | List of soil subtypes according to soil types list from 1987 | List of soil subtypes according to soil types list from 2008 |
|---|---|---|
| Sod-gley soil (VG) | Sod-gley soil (VG) | Sod-gley soil (GLv) |
| Sod gleyic humi-soil (VGt) | Humi-sod gley soil (VGt) | Humi-gley soil (GLr) |
| Sod gley mucky soil (VGT) | Humus – mucky sod gley soil (VGT) | Mucky-humus gley soil (GLa) |
| Sod podzolic gley soil (PG) | Sod podsolic gley soil(PG) | Sod-podzolic gley soil (PGv) |
| Sod podzolic gley humi- soil (PGt) | Humi-sod podzolic gley soils (PGt) | Humi-podzolic gley soil (PGr) |
| Sod podzolic gley mucky soil (PGT) | Humus–mucky sod podzolic gley soil (PGT) | Mucky-humus podzolic gley soil (PGa) or mucky-podzolic gley soil (PGi) |
| Transitional alluvial soil (Ap) | Alluvial sod gley soil (AG) | Alluvial sod-gley soil (ALv) |
| Alluvial peat soil (AT) | Alluvial peat soil (AT) | Alluvial humic-gley soil (ALh) or alluvial muck soil (ALi) |

[17] Karklins A., Gemste I., Mezals H., Nikodemus O., Skujans R. *Taxanomy of Latvian Soils*. Jelgava. LLU. 2009. 240 lpp. (in Latvian - Latvijas augšņu noteicējs)

| List of soil subtypes according to soil types list from 1952 | List of soil subtypes according to soil types list from 1987 | List of soil subtypes according to soil types list from 2008 |
|---|---|---|
| Grass fen soil (Tz) | Fen peat soil (Tz) | Fen peat humic soil (TZh) or fen peat mucky–humus soil (TZt) |
| Shallow grass fen soil (TGz) | Fen peat gley soil (Tzg) | Fen peat humic gley soil (TZr) or fen peat mucky–humus gley soil (TZa) |
| Transitional mire soil (Tp) | Transitional mire peat soil (Tp) | Typic transitional mire soil (TPt) or transitional mire mucky–humus soil (TPa) |
| Shallow transitional mire soil (TGp) | Transitional mire peat gley soil (Tpg) | Transitional mire gley soil (TPi) or transitional mire mucky–humus gley soil (TPr) |
| Moss bog soil (Ts) | Raised bog peat soil (Ta) | Typic raised bog peat soil (TAt) |
| Shallow moss bog soil (TGs) | Raised bog peat gley soil (Tag) | Raised bod gley peat soil (TAi) |

Notes: The Taxonomy of Latvia Soils ([18]) is used to classify soils corresponding to given category ([19])

Description of soil subtypes addressed to very poorly and poorly drained soils is provided in Appendix 1.
The share of very poorly and poorly drained soils within agricultural lands in selected administrative units is summarized in Figure 3.3.-3.

Taking into account that the soil drainage criterion is referable only to natural soils the artificially drained areas should be systematically excluded during the simulation of criteria.

The basic information on related soil subtypes (source: Data Sheets of Land Evaluation Summary Compendium) originally are presented separately for drained and non-drained (natural areas without drainage systems) areas. Therefore the fine tuning of area delimitation should not be necessary.

Humid climate conditions stimulates artificial drainage of agricultural lands in Latvia. Soils have been artificially drained in considerable amounts (refer Figure 3.3.-2.) during the last century. However, taking into account that the largest land drainage works were carried out at least some decades ago (1967 - 1989) and afterwards not appropriately maintained, only part of drained areas currently can be considered as areas with improved water regime complying with good drainage conditions[20]. Referring to the evaluation of drainage experts reconstruction or renovation of drainage systems in Latvian conditions must be done at least once per 7 - 10 years in order to secure drainage during high water flows in spring and autumn time and also to drain extremes of precipitation.

According to the priorities set by Strategic Documents of the Ministry of Agriculture and the Instruction of the Ministry of Agriculture ([21]) Methodology for Inventory of the Drainage Systems was developed. The methodology provides guidance on how to evaluate water regime in drained areas, condition of drainage systems and to identify the renovation needs. The inventory of melioration systems currently has been carried out only in few pilot areas though ([22]).

[18] Karklins A., Gemste I., Mezals H., Nikodemus O., Skujans R. *Taxanomy of Latvian Soils*. Jelgava. LLU. 2009. 240 p. (in Latvian - Latvijas augšņu noteicējs);

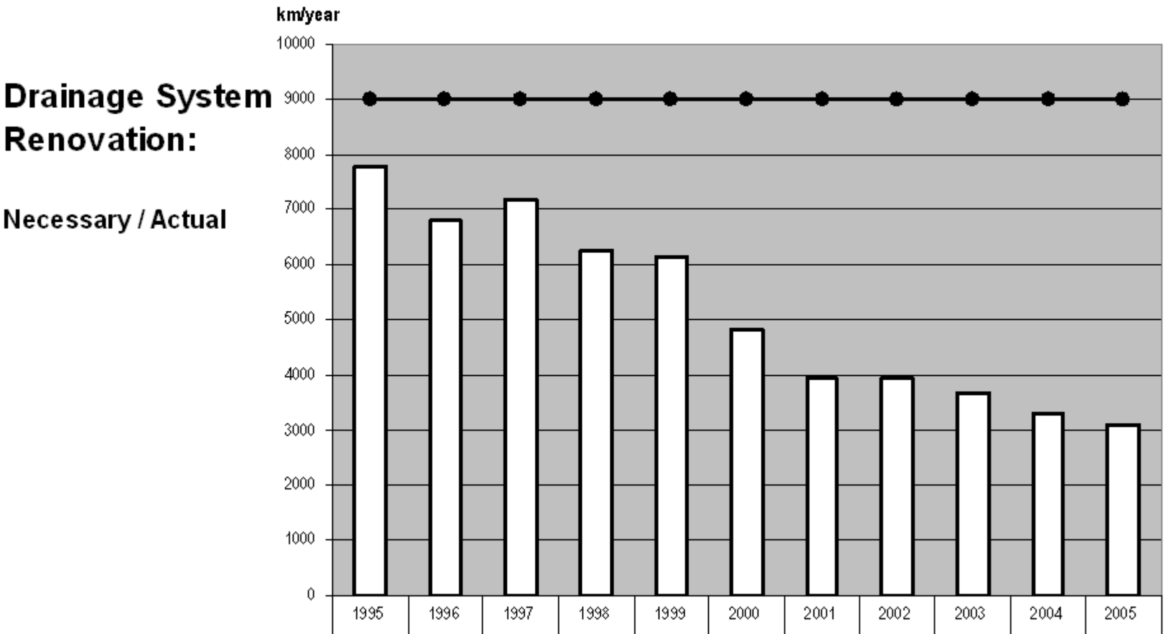
[19] Karklins A., Gemste I., Mezals H., Nikodemus O., Skujans R. *Taxanomy of Latvian Soils*. Jelgava. LLU. 2009. 240 p. (in Latvian - Latvijas augšņu noteicējs)

[20] Boruks A. Nature Conditions and Their Influence on Agricultural Environment in Latvia. State Land service of the Republic of Latvia. 2004. 166.p. (in latvian - Dabas apstākļi un to ietekme uz agrovidi Latvijā)

[21] The Order of Ministry of Agriculture No.15 „On development of Working Group"; 25.01.2007

[22] The inventory of drainage systems in Tukuma region Semes parish . Ltd. Melioracija'". 2007. 667 p. (in Latvian - Meliorācijas sistēmu un meliorēto zemju inventarizācija Tukuma rajona Sēmes pagastā. SIA '"Meliorācija" . 2007. 667 lpp. )

In order to ensure functioning of drainage systems in Latvia 9000 km of water drains have to be renovated and/or maintained annually. It is stated that actual renovation scope is considerably smaller (refer Figure 3.3.-1). During the last 10 year period funding for drainage system maintenance and renovation has been maintained at the same level (approx. 1 million Latvian Lats/year). In reality the scope of practical renovation activities has decreased for more than 50 per cent (Source: Land Use Division of Rural Support Service).




| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Actual (km/year) | 7800 | 6800 | 7170 | 6268 | 6143 | 4835 | 3923 | 3924 | 3689 | 3305 | 3114 |
| Necessary (km/year) | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 |

**Figure 3.3-1: Renovation of drainage systems – Actual status and necessity within 10 years period (1995 - 2005).**

The investments used for renovation of drainage systems and actual amount of renovation works clearly demonstrate that only part of drained areas are in compliance with good drainage condition. Nevertheless there are not statistical data available to argue amount of drained areas to be classified as poorly or very poorly drained. The fine tuning of drained areas to be classified as poorly drained is based on the opinion of the experts ([23]) and is calculated according to the adjustment coefficient - $R_{kor}$.
The simulation results of Criterion: “DRAINAGE” is presented in the Figures 3.3.-3 and 3.3.-4. Areas designated as affected by significant natural handicaps with 60% compliance is presented in Figure 3.3.-5.

### *3.3.3 CRITERIA CALCULATION AND MAPPING METHODS*

The principal sources of information used for simulation and mapping of the ANC Criterion : “DRAINAGE” are Soil Mapping and Land Evaluation Files. Each of such File consists of Soil Maps (in scale 1:10 000) and Soil Mapping Compendiums where soil survey data are summarized.

[23] Boruks A. Nature Conditions and Their Influence on Agricultural Environment in Latvia. Latvijas Republikas Valsts Zemes dienests. 2004. 166.lpp. (in Latvian - Dabas apstākļi un to ietekme uz agrovidi Latvijā)

Basic soil survey data were obtained during Soil Mapping and Land Evaluation Campaign when soil agricultural survey was carried out at the former collective farm level by using approved methodology ([24], [25],[26], [27]).
The scale of data unit is <9 ha of agricultural land. Soil Mapping Compendiums data is based on sampling data representing 1- 9 ha area plots with similar soil characteristics (soil acidity, fertilizing intensity, drainage conditions etc.) and land use.

The following information from the Soil Mapping Compendiums is used to mapping this criterion:

- General information on soil mapping and land evaluation file – overall information on collective farm and details on agricultural land being used by the collective farm
- Explication of data on soil types and soil texture.

To simulate the ANC Criterion : "DRAINAGE" in total 767 Soil Mapping Files were used.

Two approaches have been used to calculate and determine the ANC according to the drainage criteria. In the first approach soil drainage has been evaluated for non-drained soils only. A correction factor for drained territories has been applied to compensate the effect of non-functioning drainage systems. In the second approach we combined drained soils with non-drained as recommended by the Commission guidelines document (Common bio-physical criteria to define natural constraints for agriculture in the Europe).

### *FIRST APPROACH*

## (a) Poorly drained soils

The selection of poorly drained soils is based on genetic Typology of Latvian Soils. The semi-hydromorphic soil types and subtypes are related with more or less periodic or permanent presence of the moisture in upper soil layers that cause reducing processes in the soil and are classified as poorly drained.

The basic information on related soil subtypes (source: Data Sheets of Land Evaluation Summary Compendium) originally are presented separately for drained and non-drained areas.

Non-drained soil area at collective farm level is calculated as following:

$$S_{NEDREN} = S_{LIZ} - S_{DREN}$$

where:
$S_{NEDREN}$ – total area of non-drained soils in a collective farm (ha)
$S_{LIZ}$ – total area of agriculture land in a collective farm (ha)
$S_{DREN}$ – total area of drained area in a collective farm (ha).

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24 Technical Standart for Soil Mapping and Land Evaluation . 1962 (in Latvian - Tehniskie norādījumi zemes vērtēšanas lauku darbu izpildei);

25 Metodology for Soil Mapping and Land Evaluation in Latvia. 1983 (in Latvian - Metodika augsnes kartēšanai un saimniecības iekšējai zemes vērtēšanai Latvijas PSR);

26 Metodological and technical guide for agro-chemical soil mapping (6th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1991

27 Metodological and technical guide for agro-chemical soil mapping (5th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1985

Referring to the evaluation of drainage experts ([28]), at least 24,85% of drained areas do not comply with good drainage conditions (areas where drainage systems are not functioning appropriately). The fine-tuning was used to calculate poorly drained soils.

The adjustment coefficient - $R_{kor}$, describing the functionality of drainage systems is calculated as follows:

$$S_{NEDREN}=S_{NEDREN} \times 1.25$$

The proportion of poorly drained soils for each of collective farm is calculated by summing up all non-drained gleyic soil areas and relating those to the all agriculture land area of the collective farm.

Poorly drained soil proportion in a collective farm ($R_{DREN}$) is calculated as follows:

$$R_{DREN} = \frac{S_{AG} + S_{AT} + S_{DG} + S_{DGt} + S_{PG} + S_{Pg-PG} + S_{PGT} + S_{PGt} + S_{VG} + S_{VGt} + S_{VGT} + S_{Vg-VG}}{S_{LIZ}} \times 100\%$$

where:
$S_{AG}$ – total area of the non-drained alluvial sod-gley soil of agricultural land in a collective farm (ha);
$S_{AT}$ – total area of the non-drained alluvial peat soil of agricultural land in a collective farm (ha);
$S_{DG}$ – total area of the non-drained deluvial gley soil of agricultural land in a collective farm (ha);
$S_{DGt}$ – total area of the non-drained deluvial gley mucky soil of agricultural land in a collective farm (ha);
$S_{PG}$ – total area of the non-drained sod-podzolic gley soil of agricultural land in a collective farm (ha);
$S_{Pg-PG}$ – total area of the non-drained sod podzolic gley and gley soil of agricultural land in a collective farm (ha);
$S_{PGT}$ – total area of the non-drained mucky-humus sod-podzolic gley soil of agricultural land in a collective farm (ha);
$S_{PGt}$ – total area of the non-drained humi-sod podzolic gley soil of agricultural land in a collective farm (ha);
$S_{VG}$ – total area of the non-drained sod-gley soil area of agricultural land in a collective farm (ha);
$S_{VGt}$ – total area of the non-drained humi-sod gley soil of agricultural land in a collective farm (ha);
$S_{VGT}$ – total area of the agriculture non-drained humus-mucky- sod-gley soil of agricultural land in a collective farm (ha);
$S_{Vg-VG}$ – total area of the non-drained sod-gley and gley soil of agricultural land in a collective farm (ha);
$S_{LIZ}$ – total area of the agriculture land in a collective farm (ha).

## (b) Very poorly drained soils

Non-drained soils of hydromorphic class are considered to be classified as soils with very poor drainage.

The proportion of very poorly drained soils for each collective farm is calculated by summing up all non-drained soils of hydromorphic class with gley horizon (Br and Cr) and relating those to the all agriculture land area of the farm.

Very poorly drained soil proportion in a collective farm ($R_{DREN1}$) is calculated as follows:

$$R_{DREN1} = \frac{S_{Ta} + S_{Tag} + S_{Tp} + S_{Tpg} + S_{Tz} + S_{Tzg}}{S_{LIZ}} \times 100\%$$

$\{S_{Ta}, S_{Tag}, S_{Tp}, S_{Tpg}, S_{Tz}, S_{Tzg}\} \in S_{NEDREN}$

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[28] Boruks A. Nature Conditions and Their Influence on Agricultural Environment in Latvia. Latvijas Republikas Valsts Zemes dienests. 2004. 166.lpp. (in Latvian - Dabas apstākļi un to ietekme uz agrovidi Latvijā)

where:
$S_{Ta}$ – total area of the non-drained raised bog peat soil of agricultural land in a collective farm (ha);
$S_{Tag}$ – total area of the non-drained raised bog peat gley soil of agricultural land in a collective farm (ha);
$S_{Tp}$ - total area of the non-drained transitional mire peat soil of agricultural land in a collective farm (ha);
$S_{Tpg}$ – total area of the non-drained transitional mire peat gley of agricultural land in a collective farm (ha);
$S_{Tz}$ – total area of the non-drained fen peat soil of agricultural land in a collective farm (ha);
$S_{Tzg}$ – total area of the non-drained fen peat gley soil of agricultural land in a collective farm (ha);
$S_{LIZ}$ – total area of the agriculture land in a collective farm (ha).

ANC are selected accordingly:

Soil drainage is said to be severely limiting if with regard to drainage the soil is classified as poorly and very poorly drained. Therefore both areas of poorly drained and very poorly drained soils are summed up and normalized for the size of total agricultural area in the collective farm in order to obtain the drainage criteria final value.

An administrative unit is designated as area affected by natural handicaps for agriculture if a large part of its utilized agricultural land meets criteria. Minimum level of threshold is used to designate ANC:

- 60% compliance: $R_{DREN}$ >60% (threshold level defined by EC).

### *SECOND APPROACH (TAKING INTO CONSIDERATION DRAINAGE)*

Since most of the agricultural land in Latvia is artificially drained, this has to be taken into consideration upon evaluating the soil drainage. Drainage works are considered now as a part of the landscape and the drained soil units should be evaluated as if they were better drained than without the installed drainage systems. It is stipulated by the guidelines that artificial drainage systems normally improve the water regime by at least one class and thus shall be ranked higher by one class.

The most notable constraint of this approach is the condition of the drainage systems. It is assumed drainage systems are functioning satisfactory and delivering the drainage to the soil systems. However this is far from reality and therefore can be considered the most optimistic scenario.

This approach requires information on drainage of relevant territories and soil types.
Drained hydromorphic soils (very poorly drained soil class) are evaluated as one class higher – poorly drained soils and drained semi-hydromorphic gleysols are excluded from the poorly drained soil class.

Based on this approach following classes of drainage conditions and their respective soil types are delineated:

- Very poorly drained soils – hydromorphic soils without artificial drainage systems;
- Poorly drained soils – drained hydromorphic soils and non-drained gleysols.

## (a) Very poorly drained soils

Very poorly drained soils are considered all hydromorphic soils without drainage systems installed. The area of non-drained hydromorphic soils ($S_{HM}$) in the collective farm agricultural land is calculated as follows:

$$S_{HM} = S_{Ta} + S_{Tag} + S_{Tp} + S_{Tpg} + S_{Tz} + S_{Tzg}$$

where:
$S_{Ta}$ – total area of the non-drained raised bog peat soil of agricultural land in a farm (ha);
$S_{Tag}$ – total area of the non-drained raised bog peat gley soil of agricultural land in a farm (ha);
$S_{Tp}$ - total area of the non-drained transitional mire peat soil of agricultural land in a farm (ha);
$S_{Tpg}$ – total area of the non-drained transitional mire peat gley of agricultural land in a farm (ha);
$S_{Tz}$ – total area of the non-drained fen peat soil of agricultural land in a farm (ha);
$S_{Tzg}$ – total area of the non-drained fen peat gley soil of agricultural land in a farm (ha)

## (b) Poorly drained soils

Poorly drained soils include semi-hydromorphic soils (gleysols) that are not drained and hydromorphic soils with drainage that are considered better drained than hydromorphic soils without drainage.

The total area of non-drained gleysols are derived as follows:

$$S_{GLEY} = (S_{AG} + S_{AT} + S_{DG} + S_{DGt} + S_{PG} + S_{Pg-PG} + S_{PGT} + S_{PGt} + S_{VG} + S_{VGt} + S_{VGT} + S_{Vg-VG})$$

where:
$S_{AG}$ – total area of the non-drained alluvial sod-gley soil of agricultural land in a farm (ha);
$S_{AT}$ – total area of the non-drained alluvial peat soil of agricultural land in a farm (ha);
$S_{DG}$ – total area of the non-drained deluvial gley soil of agricultural land in a farm (ha);
$S_{DGt}$ – total area of the non-drained deluvial gley mucky soil of agricultural land in a farm (ha);
$S_{PG}$ – total area of the non-drained sod-podzolic gley soil of agricultural land in a farm (ha);
$S_{Pg-PG}$ – total area of the non-drained sod podzolic gley and gley soil of agricultural land in a farm (ha);
$S_{PGT}$ – total area of the non-drained mucky-humus sod-podzolic gley soil of agricultural land in a farm (ha);
$S_{PGt}$ – total area of the non-drained humi-sod podzolic gley soil of agricultural land in a farm (ha);
$S_{VG}$ – total area of the non-drained sod-gley soil area of agricultural land in a farm (ha);
$S_{VGt}$ – total area of the non-drained humi-sod gley soil of agricultural land in a farm (ha);

The area of drained hydromorphic soils ($S_{HM-DREN}$) is calculated as follows:

$$S_{HM-DREN} = S_{Ta-D} + S_{Tag-D} + S_{Tp-D} + S_{Tpg-D} + S_{Tz-D} + S_{Tzg-D}$$

where:
$S_{Ta-D}$ – total area of the drained raised bog peat soil of agricultural land in a farm (ha);
$S_{Tag-D}$ – total area of the drained raised bog peat gley soil of agricultural land in a farm (ha);
$S_{Tp-D}$ - total area of the drained transitional mire peat soil of agricultural land in a farm (ha);
$S_{Tpg-D}$ – total area of the drained transitional mire peat gley of agricultural land in a farm (ha);
$S_{Tz-D}$ – total area of the drained fen peat soil of agricultural land in a farm (ha);
$S_{Tzg-D}$ – total area of the drained fen peat gley soil of agricultural land in a farm (ha)

Resulting sum of both gleysols ($S_{GLEY}$) and drained hydromorphic soils ($S_{HM-DREN}$) provides the area of poorly drained soils in the collective farm. Drainage ratio ($R_{DREN}$) is calculated as follows:

$$R_{DREN} = \frac{S_{GLEY} + S_{HM}}{S_{LIZ}} \times 100\%$$

where:
$S_{GLEY}$ - total area of gleysols without drainage (ha);
$S_{HM}$ - area of drained hydromorphic soils (ha);
$S_{LIZ}$ – total area of the agriculture land in a farm (ha).

ANC according to the second approach is determined as a sum of very poorly drained soils (a) and poorly drained soils (b) in the agricultural land of the collective farm.

$$R_{DREN} = \frac{S_{GLEY} + S_{HM-DREN} + S_{HM}}{S_{LIZ}} \times 100\%$$

An administrative unit is designated as area affected by natural handicaps for agriculture if a large part of its utilised agricultural land meets criteria. A minimum level of threshold used to designate ANH is:

- 60% compliance: $R_{DREN}$>60% (threshold level defined by EC);

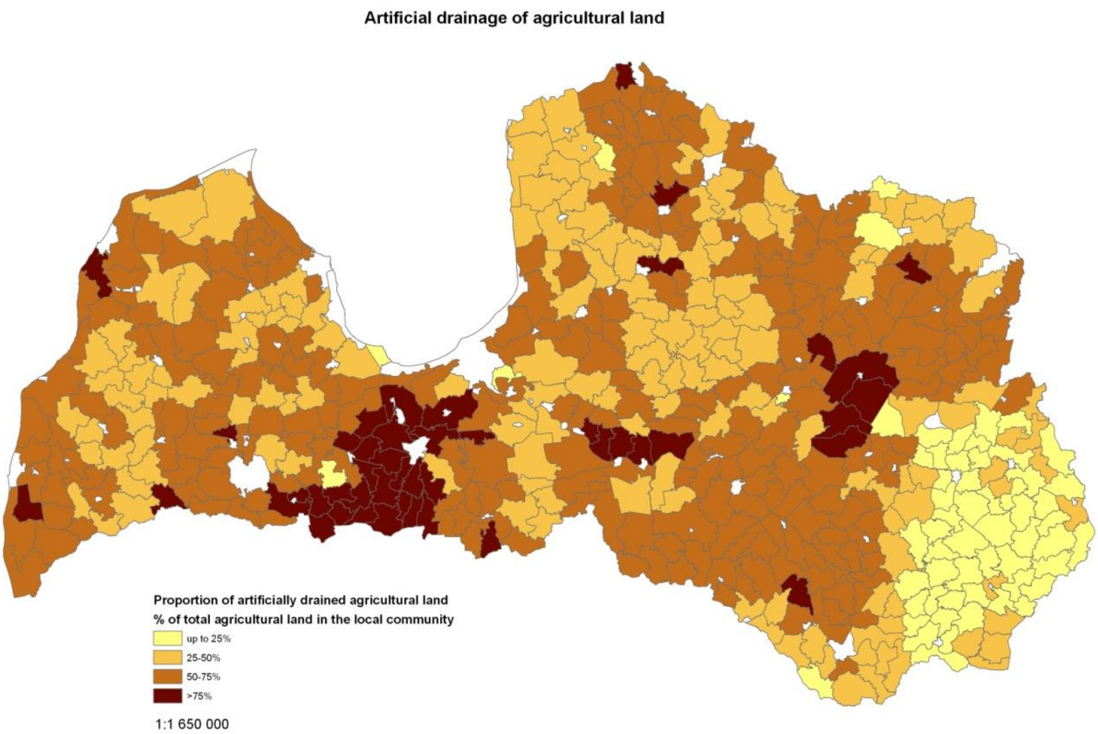


**Figure 3.3-2:** ***Artificial drainage of agricultural land in Latvia***

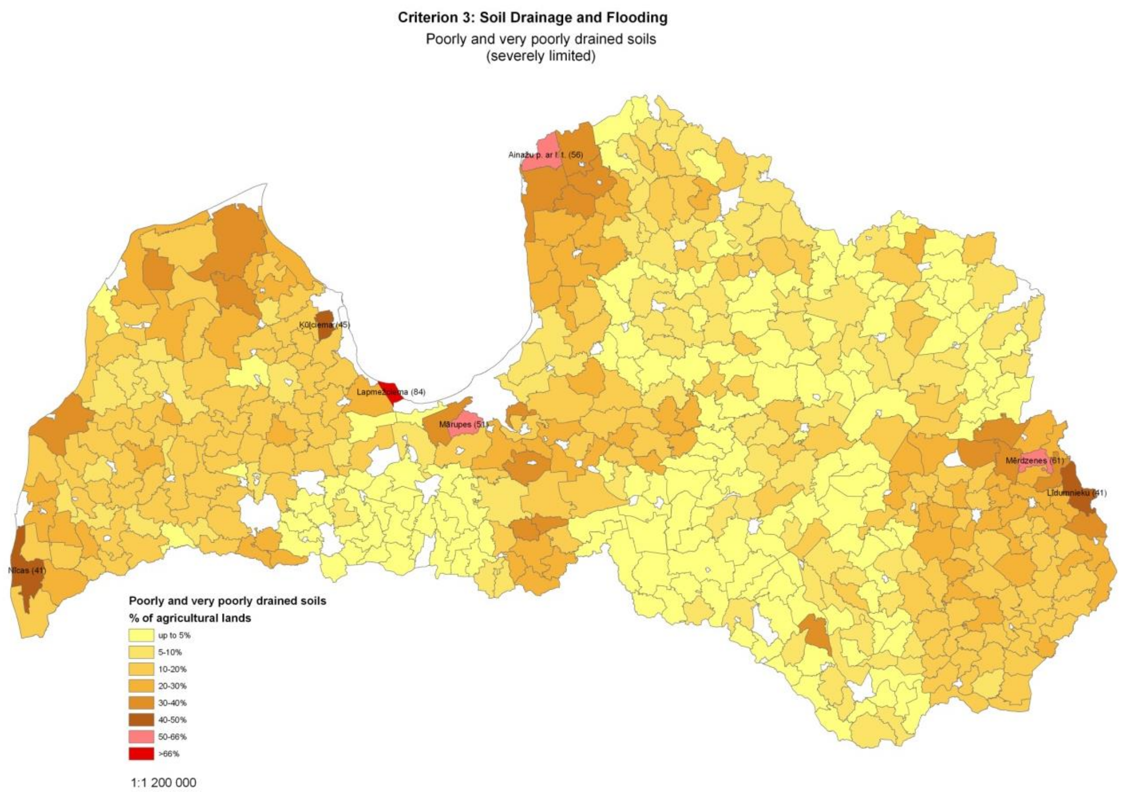


**Figure 3.3-3: Overall situation in Latvia: Simulation results of the Criterion "DRAINAGE" – Poorly and very poorly drained soils**

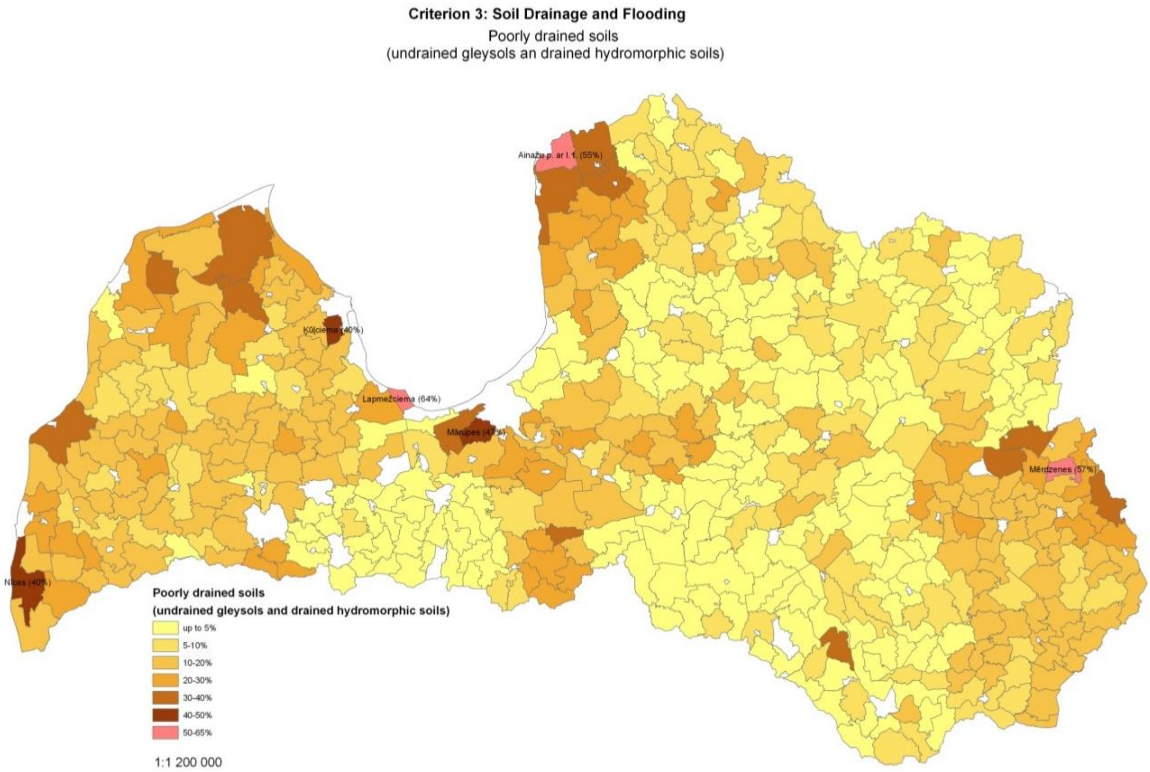


**Figure 3.3-4: Overall situation in Latvia: Simulation results of the Criterion "DRAINAGE" – Poorly drained soils**

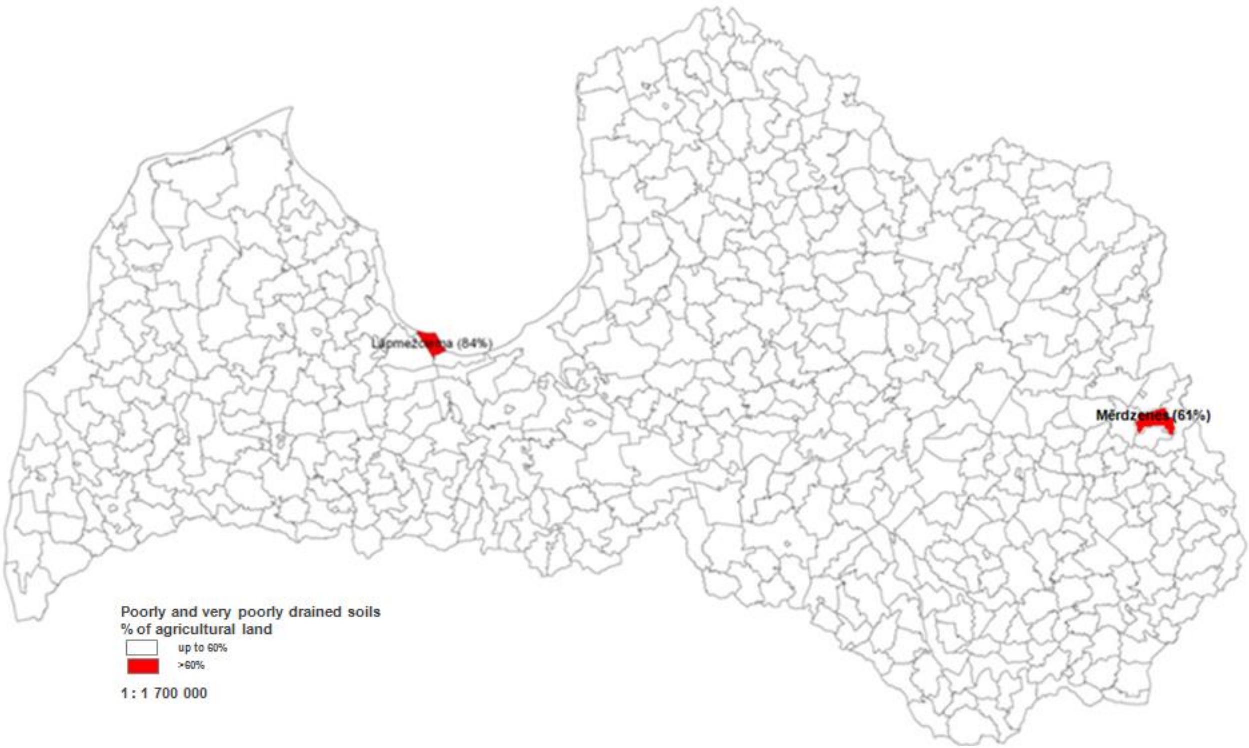


**Figure 3.3-5: Criterion "DRAINAGE". Poorly drained and very poorly drained soils – Areas considered as affected by significant natural handicaps with >60% compliance**

## 3.4 Criteria 4: Unfavourable Soil Texture and Stoniness

### Background: soil texture data in national data set

Soil texture in Latvian soil database inventory has been determined based on two fold approach, i.e. abundance and relation of physical clay (particles smaller in size than 0.01 mm) and sand particles. Silty till fraction (till sediments, including fluvioglacial and limnoglacial material – clay, heavy, medium and light silty loam and silty sandy loam) ) have been determined in addition to clay and sand particle fractions, if present. In fact this can be considered as an intermediate between two step (clay/sand) and triangular (FAO/USDA) soil texture classification methods utilized in soil texture classification as silty till and silty glacial sediment fractions were distinguished separately in addition to clay and sand fractions.

Soil texture has been differentiated depending on the genesis of the parent material: stony and silty loam and sandy loam depending on the genesis of glacial sediments: stony, unsorted till (fluvioglacial) sediments - unsorted, stony, lithic moraine material; and silty sorted (limnoglacial) sediments - characterized with sorted silt sediments with substantial amount of silt particle fraction (0.001-0.05 mm).

Soil texture in both upper and lower parts of the soil profile has been determined during the soil survey. Resulting soil texture is determined by soil layer with heavier texture in general or taking into consideration relation of nearby, similar soil texture classes. According to the soil mapping methodology soil texture is determined for both upper soil profile – within a rooting depth of vegetation (up to 40cm) and in lower part of the soil profile – down to soil parent material. In case soil texture is different within 40cm, then the texture class of heavier texture (except sand) was applied as a resulting soil profile texture. In situation when depth of uniform soil texture exceeds 40cm, upper soil profile texture is applied as a resulting soil texture. Other options for delineation of resulting soil texture class are provided for special cases of upper and lower soil layer texture combinations. See table 3.4-1 for soil texture classes used in national soil classification system.

The soil texture groups used in Latvia soil database (N. Kachinsky classification system) differs from the FAO classification system. According to N. Kachinsky soil classification system the selection of soil texture group is based on percentage ratio proportions of physical clay (particles < 0.01 mm) and physical sand (> 0.01 mm), while according to FAO classification - selection of soil texture group is based on a relative mass proportion of sand (0.063-2.0 mm), silt (0.002-0.063 mm) and clay (< 0.002 mm).

Soil granulometric properties are distinguished depending from their genesis:

- Moraine (till) sediments, mainly consisting of clayey sand and sandly loam; and
- Rewashed silty glacial material: limnoglacial (clay, loam) and fluvioglacial (gravel, coherent sand, loose sand, loam) sediments; alluvial sediments and organic sediments.

**Table 3.4.-1: Soil texture classes according to Latvian soil classification system**

| Granulometry | Proportion physical clay (<0.01mm), % | Nomenclature | |
|---|---|---|---|
| | | Symbol | Numerical symbol |
| Medium and heavy clay | >66 | M1 | 1 |
| Light clay | 65-51 | M2 | 2 |
| Heavy till loam | 50-41 | sM1 | $2^2$ |
| Heavy silty till loam | 50-41 | sMp1 | $2^1$ |
| Medium till loam | 40-31 | sM2 | 3 |
| Medium silty till loam | 40-31 | sMp2 | $3^1$ |
| Light till loam | 30-21 | sM3 | 4 |
| Light till loam | 30-21 | sMp3 | $4^1$ |
| Sandy loam | 20-11 | mS | 5 |
| Silty sandy loam | 20-11 | mSp | $5^1$ |
| Coherent sand | 10-6 | sS | 6 |
| Loose sand | <5 | iS | 7 |
| Gravel | <10 | Gr | 8 |
| Clayey gravel | 30-11 | mGr | $8^1$ |
| Peat | - | T | 9 |
| Dolomite | - | D | 0 |

### 3.4.1 THRESHOLD

The texture of a soil refers to the relative proportions of different-sized soil particles in the bulk soil. Conventionally it is divided into two parts: coarse fragments > 2 mm effective diameter, and the fine soil.

Soil texture is said to be severely limiting if any of the following condition are present:

- (1) Volume of coarse fragments of any kind in topsoil is 15% or more, including rock outcrops, boulders or large boulders; OR
- (2) Texture class (fine earth particle < 2mm) in half or more (cumulatively) of the 100 cm soil surface is sand, loamy sand (defined as *Silt% + 2×Clay% ≤30%*); OR
- (3) Dominant texture class (fine earth particle < 2mm) of topsoil is heavy clay (≥60% clay); OR
- (4) Organic soil as defined with organic matter (≥30%) of 40 cm or more, either extending down from the surface or taken cumulatively within the upper 100 cm of the soil (*Histic* horizon, IUSS Working Group WRB (2006), Soil Survey Staff (2010, 1999)); OR
- (5) Topsoil constraints 30% or more clay, combined with presence of soil layer with *vertic* properties within 100 cm of the soil surface as defined by the WRB (FAO-IUSS-ISRIC, 2006).

### 3.4.2 DELINEATION OF THE INTERMEDIATE AREAS OF NATURAL HANDICAPS FOR AGRICULTURE

Data from national soil data set available from Soil survey summary compendiums collected during soil survey and land evaluation campaigns in 70ties and 80ties are used in delineation of ANC Criteria 4: Unfavorable soil texture and stoniness.

In 2014 it is planned to launch a project funded by European Economic Area Financial Instrument (2009-2014) under the program "National Climate Policy" project "Improvement of the system of national greenhouse gas inventory and reporting on policies and measures and projections". The project will be implemented by Ministry of Environment and Regional Development, Ministry of Agriculture being a project partner. Duration of the project - April 30, 2016.
The main focus of project will be to carry out a study "Sustainable management of land resources in promoting the creation of a digital soil database ". Within the project a contemporary soil maps and soil database for agricultural land prepared during previous soil mapping and land evaluation campaigns and accompanying text information will be transferred into electronic format. Thus it is planned to expand the availability of existing data and enhance the spatial analysis of soil data that is currently not available.

#### (a) Volume of coarse fragments of any kind in topsoil is 15% or more, including rock outcrops, boulders or large boulders

The national dataset contain stoniness data, which is obtained during Soil Mapping and Land Evaluation Campaign. The stoniness data presented in the Soil Mapping and Land Evaluation Compendiums (2nd and 3rd soil mapping round) are summarized according to stoniness classes. The numbers of classes in Compendiums of stoniness class 2nd and 3rd Soil Mapping Round are different such as the stoniness assessment method has been improved in beginning of 80-ties.

During the 2nd Soil Mapping Round stoniness was divided into 3 classes (weak, medium, strong) while during the 3rd Soil Mapping Round the soils were divided into 5 stoniness classes (refer Table 3.4.-2.). The following criteria are used for the identification of stoniness classes:

- Stone volume ($m^3$/ha);
- Number of stones on 100$m^2$ in the area of visible topsoil;
- Estimated stone number (in 100$m^2$);
- Stoniness description after stone size.

**Table 3.4.-2.: Characterization of stoniness classes according to methodology of III mapping round**

| Stoniness class | Degree of Stoniness | Definition |
|---|---|---|
| Class 1 | Weak | Stones are few, mostly small |
| Class 2 | Under medium | Small, mostly medium, rarely large stones |
| Class 3 | Medium | Various size stones, large stones are few, no boulders |
| Class 4 | Above medium | Many small, medium and large stones, no boulders |

| | | |
|---|---|---|
| Class 5 | Strong | Many various size stones, possible presence of boulders |

The following data is used to simulate the ANC criterion:

- 4th class (stoniness above medium) and 5th class (strong stoniness) data defined in 3rd Soil Mapping Round;
- 3rd class (strong stoniness) data defined in 2nd Soil Mapping Round.

The simulation results of Criterion: “SOIL TEXTURE AND STONINESS” - Soils where any proportion of rock outcrops, boulders within 15 cm of the surface, are presented in the Figure 3.4.-7. Areas designated as affected by significant natural handicaps with 60% compliance is presented in Figures 3.4.-8.

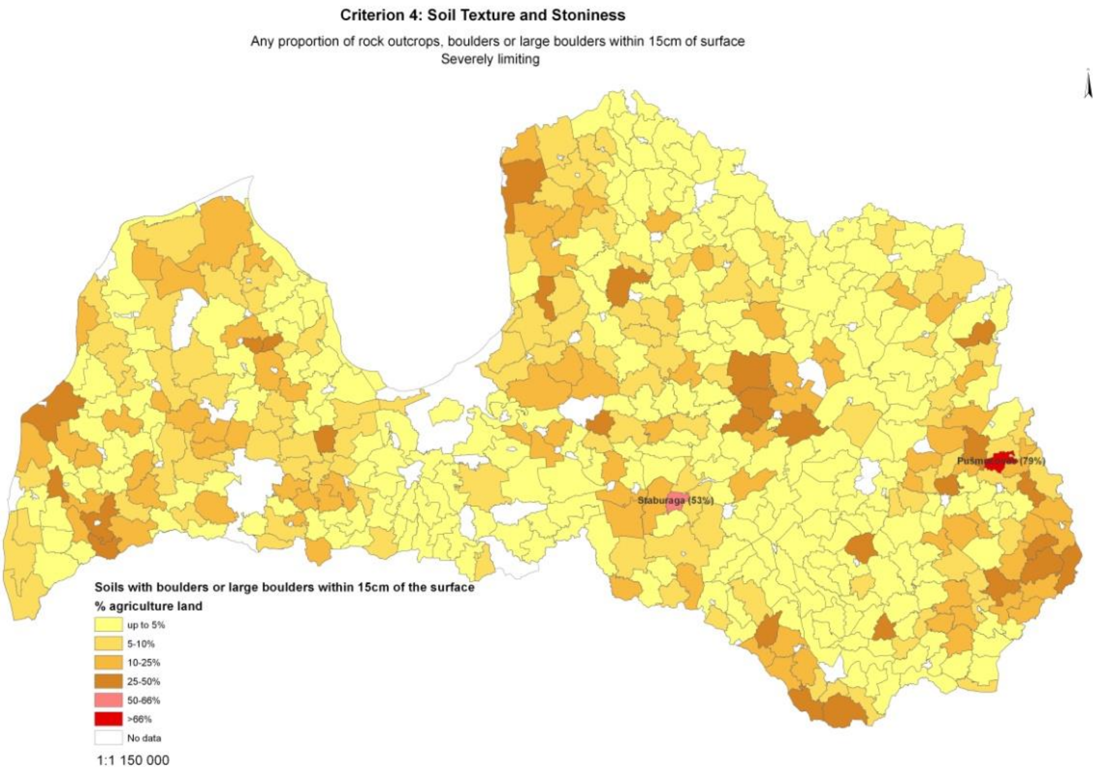


**Figure 3.4-1: Overall situation in Latvia: Simulation results of the Criterion “SOIL TEXTURE AND STONINESS” - Soils where any proportion of rock outcrops, boulders within 15 cm of the surface**

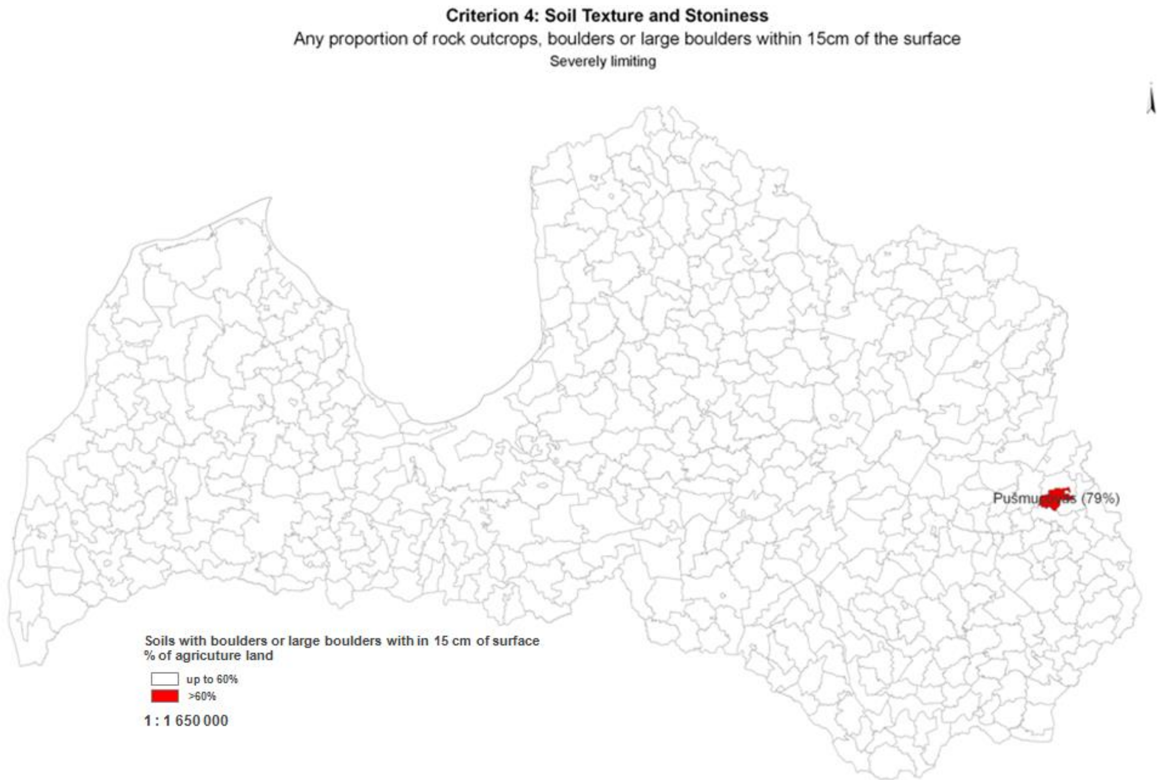


Figure 3.4-2: Criterion “SOIL TEXTURE AND STONINESS” - Soils where any proportion of rock outcrops, boulders within 15 cm of the surface. Areas considered as affected by significant natural handicaps with >60% compliance

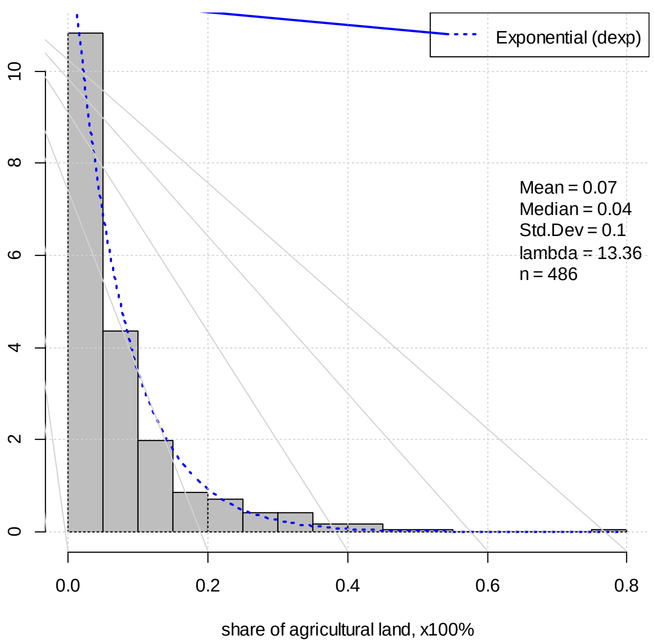


Figure 3.4-3: Criterion “SOIL TEXTURE AND STONINESS”: the share of soils with coarse fragments in topsoil in agricultural lands in Latvia.

## (b) Organic soils: organic soil as defined with organic matter (≥30%) of 40 cm or more, either extending down from the surface or taken cumulatively within the upper 100 cm of the soil (*Histic* horizon, IUSS Working Group WRB (2006), Soil Survey Staff (2010, 1999))

The national dataset contain information on organic soils (source: Agrochemical Research Centre). This information have been collected during Soil Agrochemical Survey carried out from 1985 to 1990. The scale of data unit is 3-6 ha of agricultural land. The dataset does not contain information on the thickness.

The organic matter content < 15% is analysed by photo-colorimetric dichromate oxidation method (Tjurin's method - OST. 4647-76) which is recommended by World Soil Information Centre (ISRIC). Soils with organic matter content > 15% are determined by furnace combustion at the temperature 525°C ± 25°C. The inter- calibration of results done demonstrate the high level of accuracy (r=0.96) with standard method ISO 10694:1995 *Soil quality - Determination of organic and total carbon after dry combustion (elementary analysis)*.

The Soil Agrochemical Mapping data according to content of organic matter are summarised in 11 groups as follows:

- Group 1: Content of organic matter in soil is < 1,1%;
- Group 2: Content of organic matter in soil is 1,1 - 1,5%;
- Group 3: Content of organic matter in soil is 1,6 - 2,0%;
- Group 4: Content of organic matter in soil is 2,1 - 3,0%;
- Group 5: Content of organic matter in soil is 3,1 – 5.0,0%;
- Group 6: Content of organic matter in soil is 5,1 - 10,0%;
- Group 7: Content of organic matter in soil is 10,1 - 20,0%;
- Group 8: Content of organic matter in soil is 20,1 - 30,0%;
- Group 9: Content of organic matter in soil is 30,1 - 40,0%;
- Group 10: Content of organic matter in soil is 40,1 - 50,0%;
- Group 11: Content of organic matter in soil is > 50,0%.

The data of groups 9 - 11 (content of organic matter in soil is >30,1%) is used to simulate the ANC Criterion: "SOIL TEXTURE AND STONINESS" – organic soils.

The simulation results of Criterion 4: "SOIL TEXTURE AND STONINESS" – organic soils, are presented in the Figure 3.4.-4. Areas designated as affected by significant natural handicaps with 60% compliance are presented in Figures 3.4.-5.

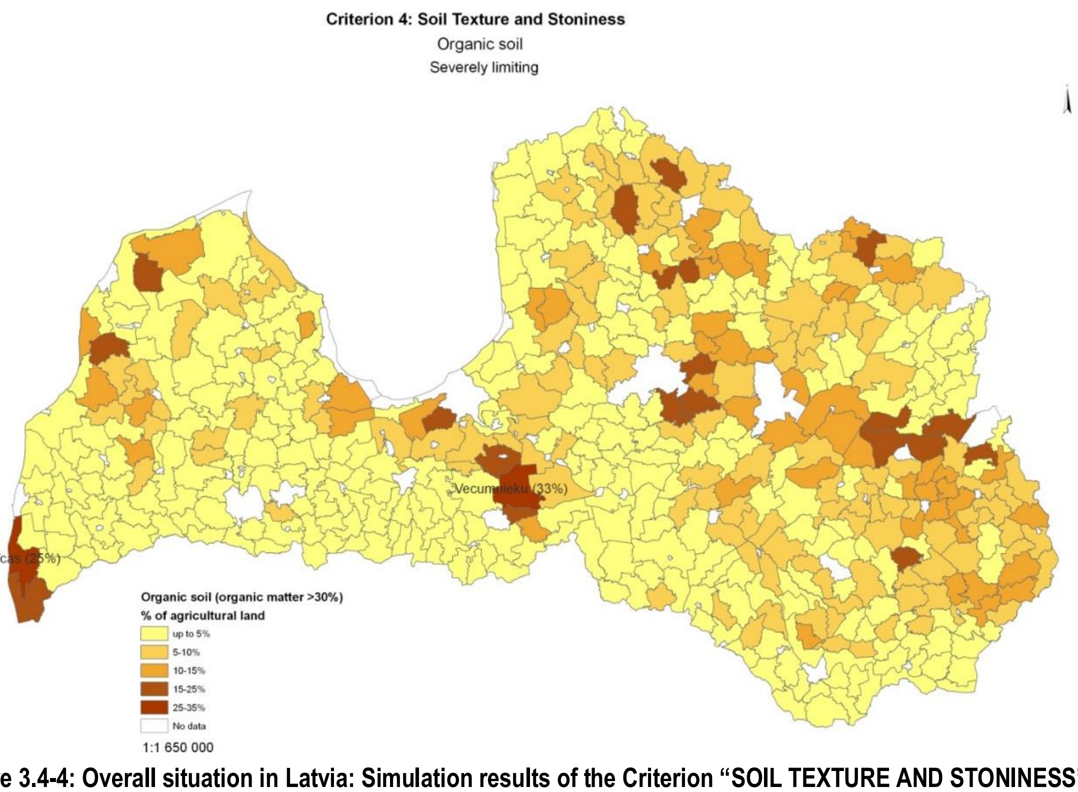


**Figure 3.4-4: Overall situation in Latvia: Simulation results of the Criterion "SOIL TEXTURE AND STONINESS" – organic soils**

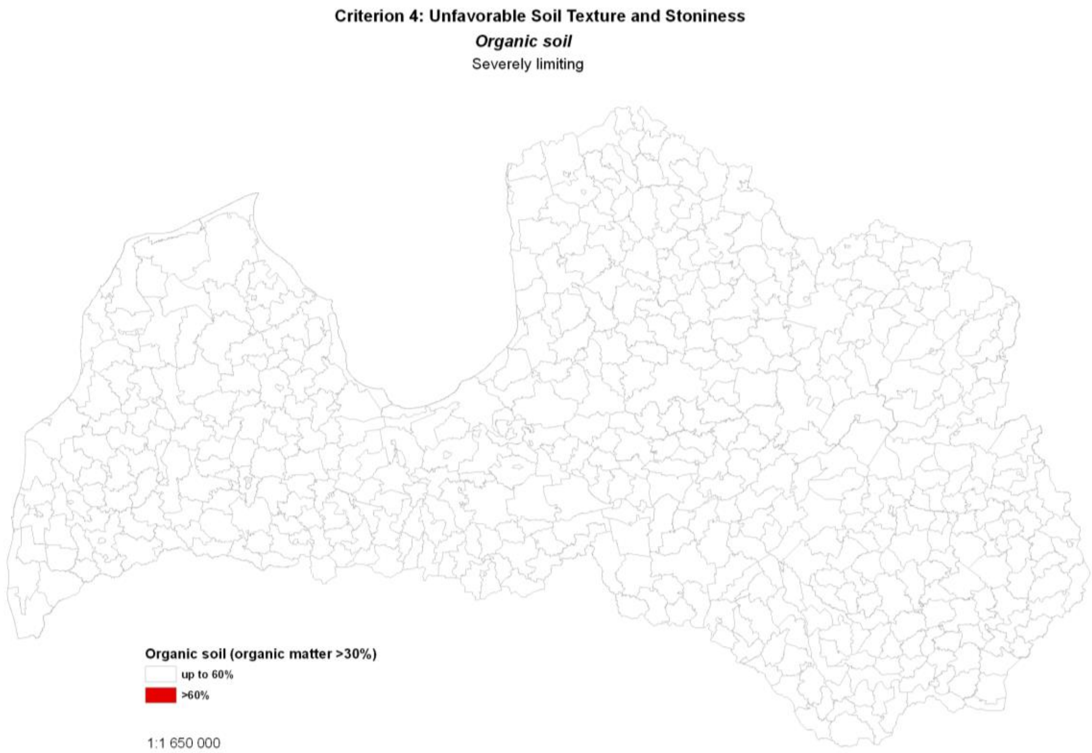


**Figure 3.4-5: Criterion "SOIL TEXTURE AND STONINESS" – organic soils. Areas considered as affected by significant natural handicaps with >60% compliance**

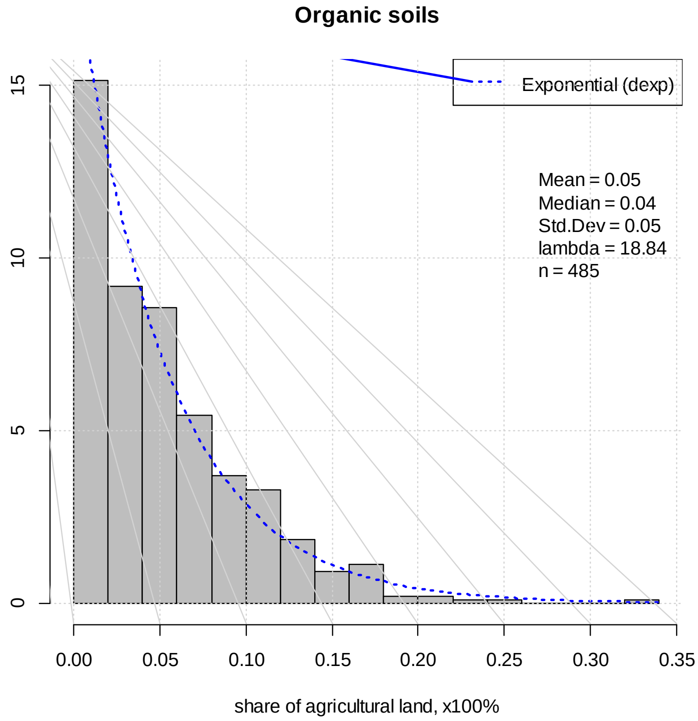


**Figure 3.4-6: Criterion "SOIL TEXTURE AND STONINESS: organic soils" the share of organic soils in agricultural lands in Latvia.**

## (c) Very heavy clay soils: dominant texture class (fine earth particle < 2mm) of topsoil is heavy clay (≥ 60% clay)

According to FAO classification system soil consisting of over 60% clay particles with the size below **0.002 mm**, 40% and less sand particles and less than 40% silt particles is referred to as "very heavy clay" and considered severely limiting.

The soil granulometric data summarized in the national dataset - Soil Mapping and Land Evaluation Files have been obtained by using N. Kachinsky Soil Granulometric Classification System. To correlate the data from the national dataset to this ANC criteria, heavy clay and medium clay texture soils (soils having texture class – heavy clay (M1), with abundance of clay particles exceeding 66% according to N. Kachinsky classification) has been attributed to this ANC criteria. Available soil data from national dataset does not allow addressing criteria directly due to differences in granulometry classification systems. In Kachinsky system clay particle threshold values is **0.01** mm. See table 3.4-1.

Additional difficulty related to addressing of this criteria lies in the fact that different soil texture classification approaches have been used during soil surveying and mapping campaigns. In earlier soil mapping campaigns no texture class of heavy clay has been distinguished as a separate texture class. Therefore both soils with dominant texture class of light and medium-heavy clay are also included. This can be distinguished in the map which shows higher proportion of clay texture soils in territories where earlier soil surveying and land evaluation campaigns have been carried out. See Figure 2.2 1: Soil mapping in Latvia – territory covered

Relationship of share of soils with clay texture class in agriculture land is provided in figure 3.4-9.

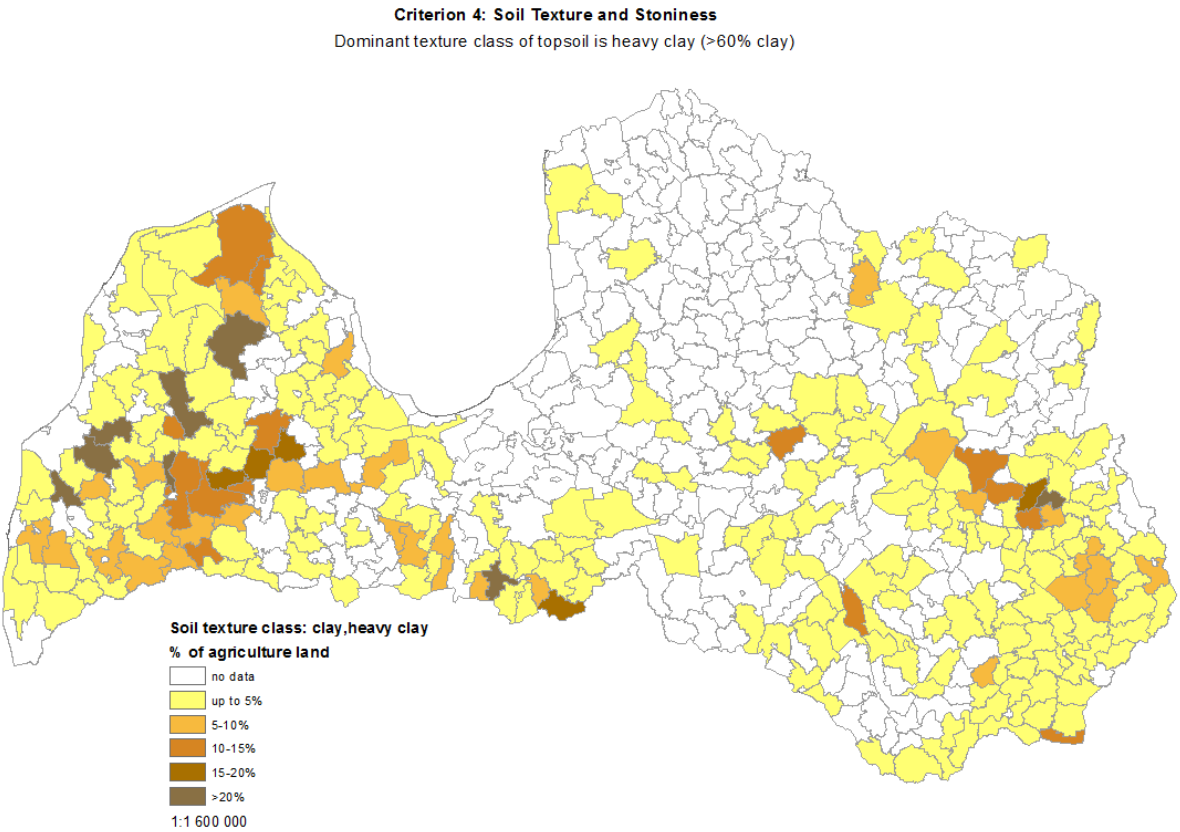


**Figure 3.4-7: Overall situation in Latvia: Simulation results of the Criterion "SOIL TEXTURE AND STONINESS" – organic soils**

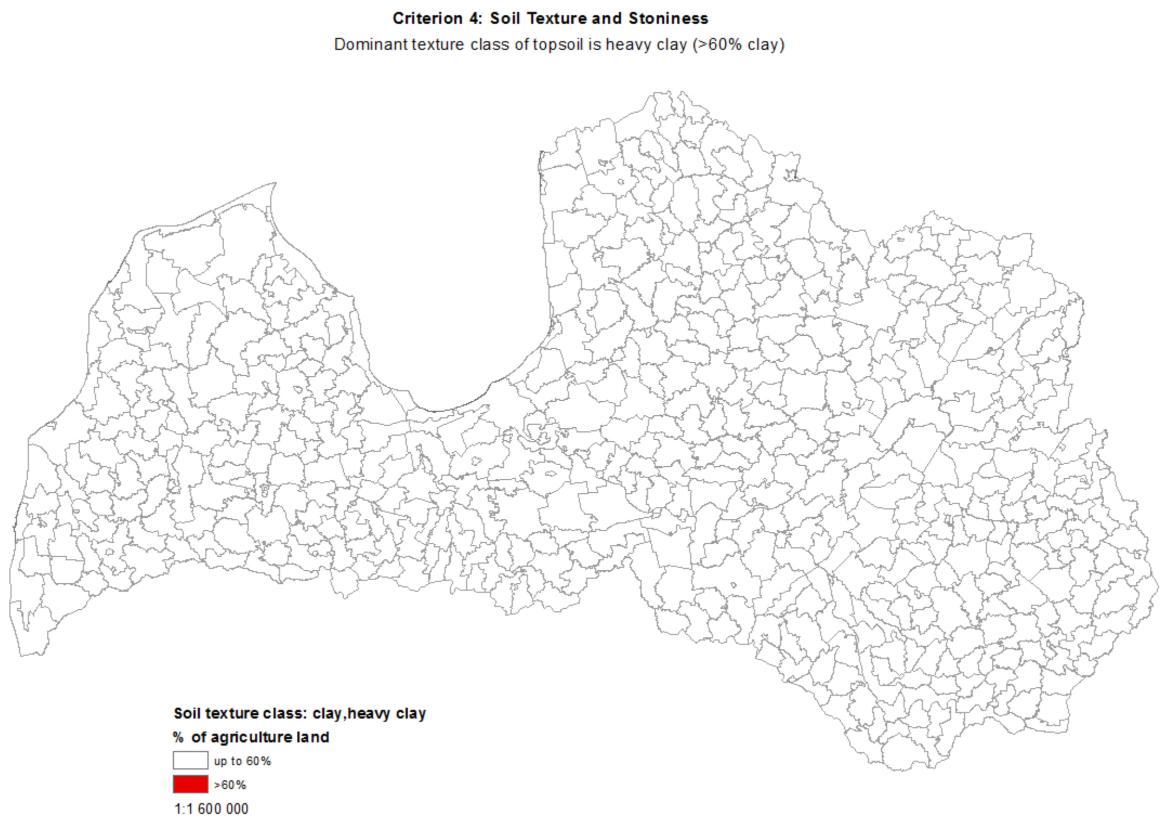


**Figure 3.4-8: Criterion "SOIL TEXTURE AND STONINESS" – organic soils. Areas considered as affected by significant natural handicaps with >60% compliance**

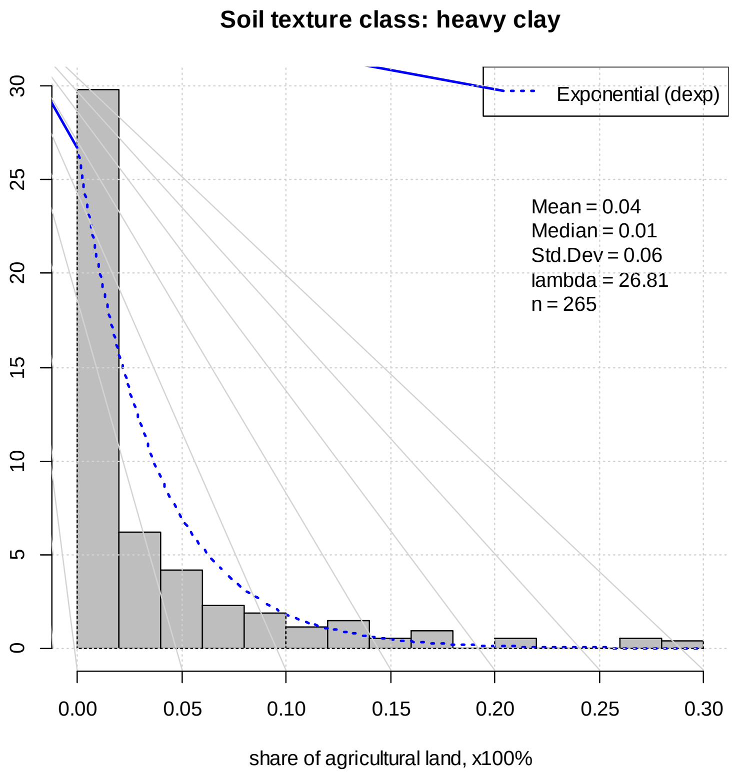


**Figure 3.4-9: Criterion "SOIL TEXTURE AND STONINESS": the share of soils with dominant texture class of clay and heavy clay in agricultural lands in Latvia.**

### (d) Topsoil constraints 30% or more clay, combined with presence of soil layer with vertic properties within 100 cm of the soil surface as defined by the WRB (FAO-IUSS-ISRIC, 2006).

The soils with heavy, heavy silt clay soil in topsoil with *Vertic* properties within 100cm of soil surface are not represented in Latvia. Thus the criterion is not relevant for Latvia.

## *3.4.3 CRITERIA CALCULATION AND MAPPING METHODS*

The principal sources of information used for simulation and mapping of the ANC Criterion : "SOIL TEXTURE AND STONINESS" are Soil Mapping and Land Evaluation Files. Each of such Files consists of Soil Maps (in scale 1:10 000) and Soil Mapping Compendiums where soil survey data are summarized.
Basic soil survey data were obtained during Soil Mapping and Land Evaluation Campaign when soil agricultural survey was carried out at the former collective farm level by using approved methodology ([29], [30],[31], [32]).
The scale of data unit is <9 ha of agricultural land. Soil Mapping Compendiums data is based on sampling data representing 1- 9 ha area plots with similar soil characteristics (soil acidity, fertilizing intensity, drainage conditions etc.) and land use.

The following information from the Soil Mapping Compendiums is used to simulate criterion:

- General information on soil mapping and land evaluation file – overall information on collective farm and details on agricultural land being used by the collective farm
- Explication of data on soil types and soil texture.

To simulate the ANC Criterion: "SOIL TEXTURE AND STONINESS" 767 Soil Mapping Files were used all together.

### (a) Organic soils

The principal sources of information used for simulation and mapping of the ANC Criterion: "DRAINAGE" – Organic soils, are Soil Agrochemical Mapping data (source: State Ltd. Agrochemical Research Centre).

The organic matter content (%) describing data presented in the Summaries of are Soil Agrochemical Mapping data Soil are summarized in following classes:

- Class 1: <1%;
- Class 2: 1.0-1.5%;
- Class 3: 1.5-2.0%;
- Class 4: 2.0-3.0%;
- Class 5: 3.0-4.0%;
- Class 6: 4.0-10%;
- Class 7: 10-20%;

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[29] Technical Standart for Soil Mapping and Land Evaluation . 1962 (in Latvian - Tehniskie norādījumi zemes vērtēšanas lauku darbu izpildei);

[30] Metodology for Soil Mapping and Land Evaluation in Latvia. 1983 (in Latvian - Metodika augsnes kartēšanai un saimniecības iekšējai zemes vērtēšanai Latvijas PSR);

[31] Metodological and technical guide for agro-chemical soil mapping (6th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1991

[32] Metodological and technical guide for agro-chemical soil mapping (5th mapping round) . Ministry of Agriculture of Latvian Republic. Riga. 1985

- Class 8: 20-30%;
- Class 9: 30-40%;
- Class 10: 40-50%;
- Class 11: >50%.

The proportion of area with organic soils ($R_{ORG}$) at collective farm level is calculated as follows:

$$R_{ORG} = \frac{S_{30} + S_{40} + S_{50}}{S_{LIZ}} \times 100\%$$

where:
$S_{30}$ – total area of the soils with organic matter content 30-40% in collective farm (ha);
$S_{40}$ – total area of the soils with organic matter content 40-50% in collective farm (ha);
$S_{50}$ – total of the soils with organic matter content more than 50% in collective farm (ha);
$S_{LIZ}$ – total area of the agriculture land in collective farm (ha)

An administrative unit is designated as area affected by natural handicaps for agriculture if a large part of its utilised agricultural land meets criteria.

Two different minimum levels of thresholds were used to designate ANC:

- 60% compliance: $R_{ORG}$ >60% (threshold level defined by EC).

### (b) Soils where 15% of top layer volume consists of coarse material

The principal sources of information used for mapping of the ANC criterion are Soil Mapping and Land Evaluation Files of 2nd and 3rd mapping round.

Proportion of agriculture lands characterized as soils with strong stoniness - $R_{AKM}$ (3 th class from summaries of 2nd mapping round) is calculated as follows:

$$R_{AKM} = \frac{S_{3KL}}{S_{LIZ}} \times 100\%$$

where:
$S_{3KL}$ – total area of soils with strong stoniness (ha);
$S_{LIZ}$ – total area of the agriculture land in a collective farm (ha).

Proportion of agriculture lands characterized as soils with medium and strong stoniness - $R_{AKM}$ (4 th and 5 th class from summaries of 3rd mapping round) is calculated as follows:

$$R_{AKM} = \frac{S_{4KL} + S_{5KL}}{S_{LIZ}} \times 100\%$$

where:
$S_{4KL}$ – total area of soils with medium strong stoniness (ha);
$S_{5KL}$ – total area of soils with strong stoniness area (ha);
$S_{LIZ}$ – total area of the agriculture land in a collective farm (ha).

An administrative unit is designated as area affected by natural handicaps for agriculture if a large part of its utilised agricultural land meets criteria.

Two different minimum levels of thresholds were used to designate ANC:

- 60% compliance: $R_{AKM}$ >60% (threshold level defined by EC);

## 3.5 Criteria: Soil Rooting depth

The criterion has not been tested in Latvia

## 3.6 Criteria 6: Poor chemical properties –Soil Acidity

The podsolic (podzolaugsnes) soils, soils that naturally have acidic soil reaction (pH ≤5,5), low content of calcium and base saturation, forms the biggest areas of agricultural land in Latvia (> 50%). These soils are developed during natural succession of forest within areas where forest formations were replaced with meadow vegetation thus increasing humus content and developing the humus horizon (A horizon - according to FAO classification). Podsolic soils are developing mainly on low-carbon or non-carbon loamy sand, sandy loam or clay parent materials. The acidity of podsolic soils formed on loamy sand or sand parent materials are higher as for soils that are formed on sandy loam and clay parent material. These soils are usually characterized with low base saturation, high water permeability, low water holding capacity and low soil capillarity.

The leaching processes are predominant soils forming factor in Latvia due to humid climate characterized by mean annual rainfall 700 mm, and with evaporation only 50-60% from total rainfall amount. The leaching processes also are leading the reduction of exchangeable bases amount in topsoil and soil acidification. Most of cultivated plants in Latvia are growing poorly in acidic soils (pH KCl <5.5).

Soil acidity impact also biological, physical and agrochemical qualities of the soil. The soil structure of acid soils decline and the compaction of soils is resulting with reducing of moisture and air conditions.

High soil acidity reduces activity of nitrificators and nitrogen fixing bacteria, resulting with reduced nitrogen supply and availability of nitrogen, phosphorus, potassium, calcium, magnesium and molybdenum. Well - soluble and mobile compounds of different microelements (manganese, boron, copper and zinc) well available for plants are forming in acid soils. However there are also high loses of compounds of microelements recorded due to the leaching of acid soils. The high concentrations of manganese recorded in acid soils in Latvia are toxic for cultivated plants. The concentrations of heavy metals and another dangerous substances increase in plants that are growing in acidic soils.

According to Guidelines the acidic soils with **pH reaction below 5.0** can be classify as ANC as those are characterized with low soil productivity and where maintaining extensive farming activity (liming) is important for the management of the land.

The simulation results of Criterion "SOIL ACIDITY" are presented in the Figure 3.6.-1. Areas designated as affected by significant natural handicaps with 60% compliance are presented in Figures 3.6.-2.

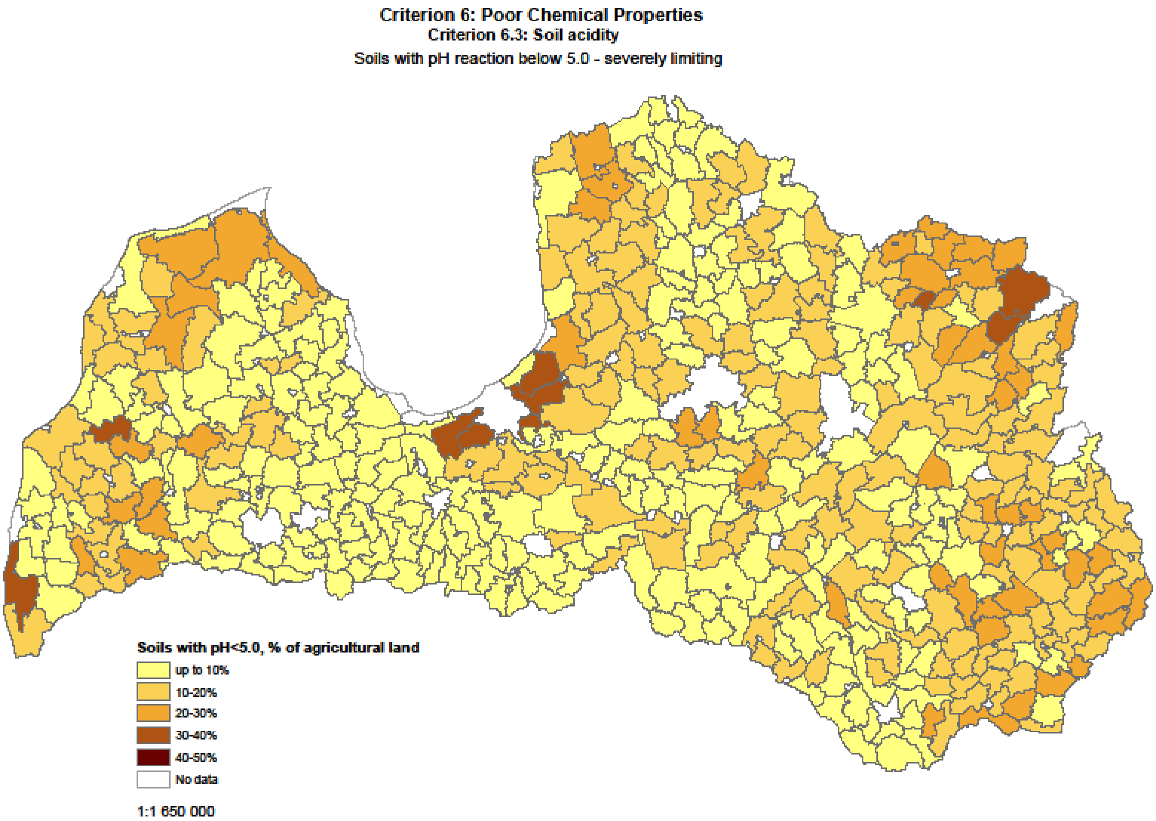



**Figure 3.6-1: Simulation results of the Criteria 6: Poor chemical properties – Soil Acidity**

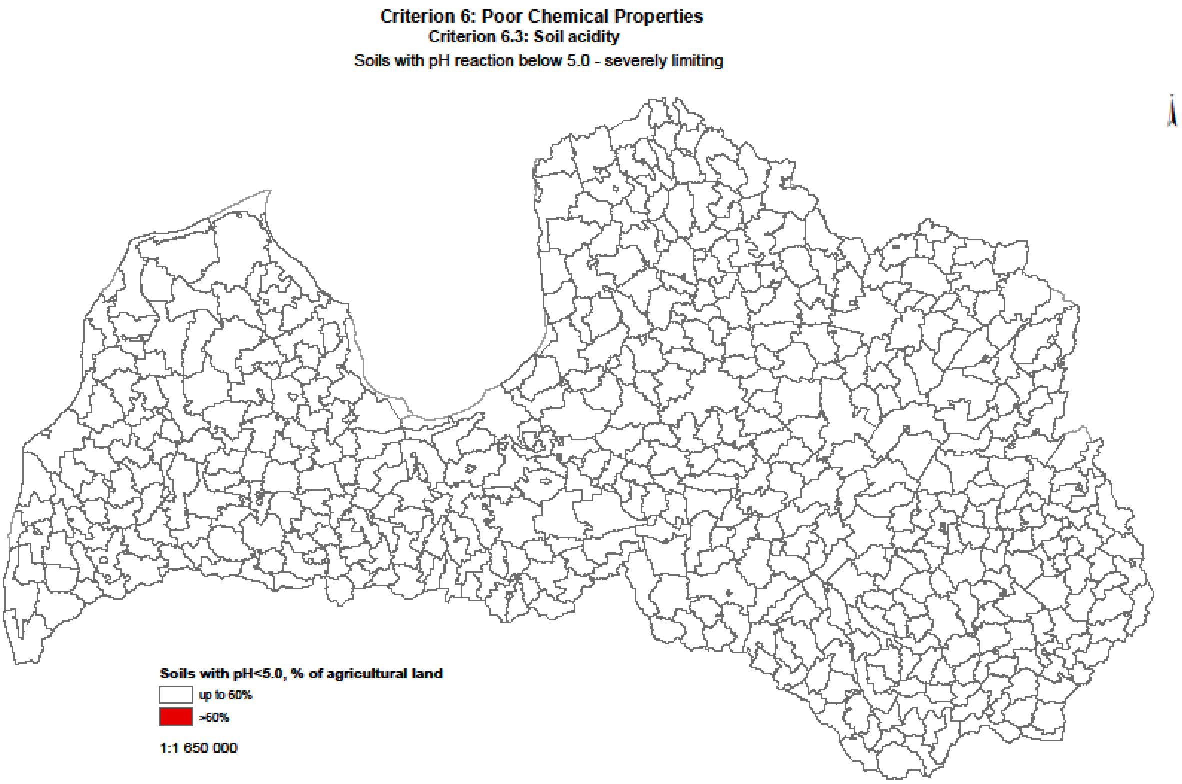



**Figure 3.6-2: Criterion 6 “Poor chemical properties”, Soil acidity – Areas considered as affected by significant natural handicaps with >60% compliance**

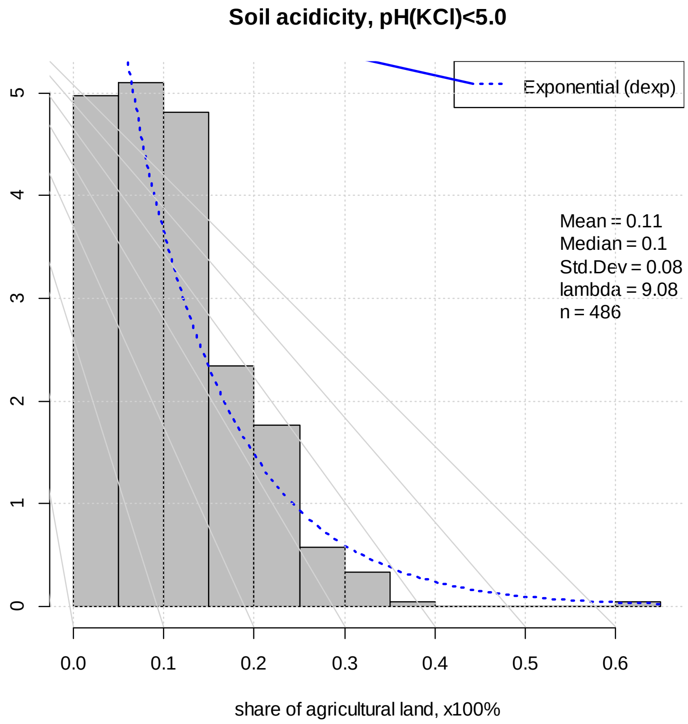



**Figure 3.6-3: Criterion “6. Poor chemical properties: 6.3 Soil acidicity”: the share of soils with pH<5.0 in agricultural lands in Latvia.**

## 3.7 Criteria: Soil Moisture Balance

The criterion has not been tested in Latvia.

## 3.8 Criteria: Slope

### *3.8.1 THRESHOLD*

Slope is the angle the soil surface makes with the horizontal. It can be expressed in degrees or as a percentage (45° corresponds 100%). The form of the slope may be important and influence the moisture status of the underlying soils, as happens in concave or convex slopes. A particular important characteristic for agricultures is the aspect (direction of exposure) of the slope that may result in significant higher temperatures on south-exposed slopes as compared to northern exposed ones, at least in the northern hemisphere.

Slope as such has little or no direct influence on the yield of cultivated plants. However, the steeper the slope the more difficult it becomes to manage the land to grow cultivated plants. In particular mechanization is hampered and may require specific equipment, while access to land and all agricultural operations become more time consuming. Steeper slopes are also associated with shallower soils in general and with a higher risk for soil erosion and landslides.

The threshold aims at identifying locations currently under agricultural usage having limiting factors for farming production and requires special farming equipment and machinery.

High slope threshold

Slope angle is said to be severely constrain factor if:

- Slope angle is larger than >15%.

### The digital elevation model approach

The slope angle can be calculated using absolute territory's elevation above sea level, based on algorithms and acquired results should be corrected for larger area in order to get sufficient indicator. Slope angle can be calculated using digital elevation model method.

The delineation of ANC criterion "Slope" was carried out based on digital elevation model. Results are provided in Figure 3.8-1. Results obtained show that ANC criterion is relevant in highland areas and territories with expressed river valleys, such as Gauja, Daugava, Abava rivers. Results show that in few highland areas ANC criterion "Slope" reaches up to 10% of agricultural land.

The analysis of results shows that use of digital elevation model for simulation of ANC in Latvia is not practical. The digital elevation model has relatively low vertical resolution (5m). The resolution of digital relief model does not allow to detect small fragmented relief forms characteristic to highland areas of Latvia and river valleys, where occurrence of ANC criterion "Slope" is most probable. The results obtained are rather general and represent only most pronounced terrain forms.

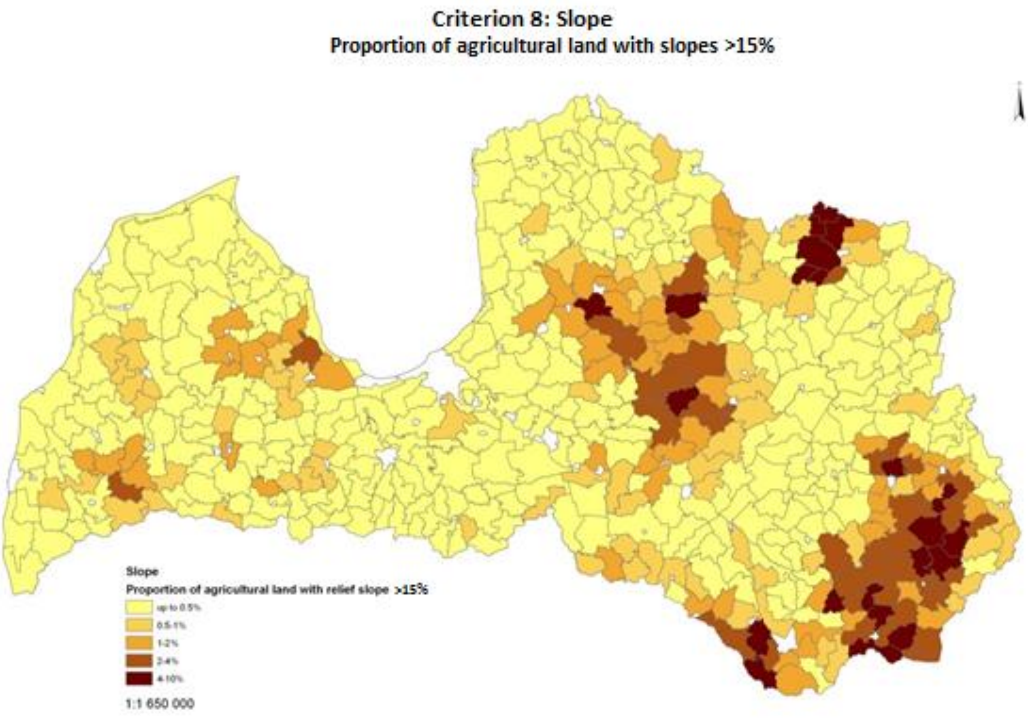



**Figure 3.8-1: Simulation results of the Criterion “Slope” (based on digital elevation model)**

# 4 SPATIAL AGGREGATION OF THE CRITERIA USED FOR DELINEATION

Soil criteria have been individually tested at 60% level of administrative unit, while it should be all aggregated criteria area (non-overlapping) which should be tested for the 60% level. The source data used in ANC assignment – summaries of soil compendiums or soil summary data does not allow aggregating individual criteria due to the fact that aggregated data are used and the data does not have spatial dimension. Each criterion has been developed from soil summaries and consequently, if applied aggregated it would result in criteria overlapping. The criteria cannot be aggregated without soil maps and subsequent spatial analysis of soil attribute data. Testing of soil criteria aggregation in few municipalities/parishes where digital soil maps is available showed that aggregated soil criteria can exceed 60% (soil texture and soil moisture criteria, for instance) while individual criteria does not exceed the threshold. Thus it is reasonable to consider that some administrative units are not passing the 60% threshold when criteria are applied alone, but when combining all relevant criteria, the constrained agricultural area of that administrative unit may be over 60%.

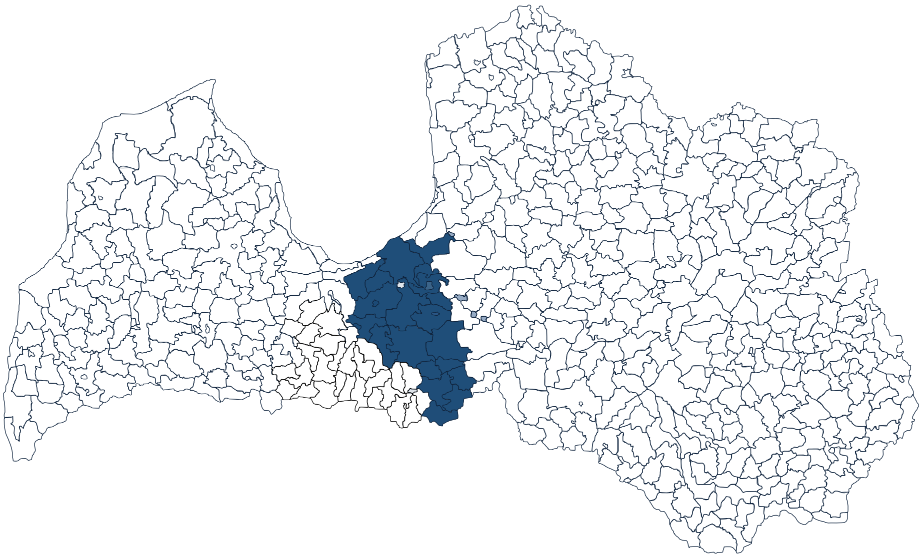
# 5 SPATIAL IMPACT ASSESSMENT

| Criterion | Total area constrained by the criterion | Agricultural area constrained by criterion | Number of administrative units constrained by the criterion | Biophysical criteria compared to the current LFA delimitation for Art.19: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Areas under Art.19 and constrained by criterion | | | Areas under Art.19 but not constrained by criterion | | | Areas constrained by criterion but not under Art.19 | | |
| | | | | Agricultural Areas | Number of Administrative units | Ares of Administrative units | Agricultural Areas | Number of Administrative units | Ares of Administrative units | Agricultural Areas | Number of Administrative units | Ares of Administrative units |
| Art.19 | 4 805 722,1 | 1 766 421,3 | 419 | | | | | | | | | |
| LOW TEMPERATURE | 6 020 111,1 | 2 239 528,8 | 551 | 1 749 421,5 | 416 | 4 760 961,4 | 16 999,8 | 3 | 44 760,7 | 490 107 | 135 | 1 275 012,2 |
| DRAINAGE | 13 818 | 9 873 | 2 | 5 238 | 1 | 8 921 | 1 761 183,3 | 418 | 4 796 801,1 | 4 897 | 1 | 310 |
| SOIL TEXTURE AND STONINESS | 7280 | 3600 | 1 | 3600 | 1 | 7280 | 1 762821,3 | 418 | 4 798442,1 | 33 236,1 | 12 | 135 231,7 |
| SLOPE | 21 409 | 8 551 | 2 | 8 551 | 2 | 21 409 | 1 757 870,3 | 417 | 4 784 313,1 | - | - | - |
| SOIL ACIDITY | 0 | 0 | 0 | 0 | 0 | 0 | 1 774545,9 | 417 | 4 805722,1 | 0 | 0 | 0 |

# 6 CRITERIA FOR SPECIFIC CONSTRAINTS

In defining *Specific constraints*, Latvia has used the *Cultivated agricultural Areas* indicator. The conformity threshold of 85% has been determined. No spatial modelling was used for the determination of specific constraints.

The source of data used to identify areas affected by the criterion is the State Land Service (Payment Agency) which, according to its functions, carries out annual physical control in all the Agricultural area.



As a result, in the identified areas which comply with ANC, the amount of Agricultural areas is 4% of the total amount of Agricultural areas or 1.6% of the territory of Latvia.

Information in details are provided in Report “Areas with Natural Constraints (ANC) Part 3: Specific constraints”.

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# Appendix1: Description of soil types and subtypes used for simulation of ANC

Poorly and very poorly drained soil category summary is based on Soil Determiner of Latvia ([33]).

Semi-hydromorphic soil class. Gley soils.

Gleyic soils are in all the territory of Latvia, mostly in meadows and pasture lands, rarely in tillage fields. Gleyic soils formed on carbonic parent material from sod carbonic soils or well-tillage sod-podsolic soils when water regimen worsens. Soil sodding[34] and gleying[35] processes are dominant. Parent material rich in plant nutrients and strong grass plant vegetation strongly influence forming of gley soils. Live organism remnants due to moisture in the ground accumulate typical humus layer with high organic content. Anaerobe conditions decrease decomposing process of organic substances. Soil reaction is from acid to neutral (pH KCl from 4,6 till 6,5).

Soil profile contains gley horizon, which is dense, amorphous formation with low water penetrability and contains many reduced combinations, thus affecting root system and micro organism development.

Soil subtypes for ES criteria:

Sod-gley soil (GLv)
The soil is widespread on different parent material in tillage, meadows and pasture, lower parts of valleys and in plain ground with poor water drainage. The sod-gley soil was formed in difficult water drainage conditions, thus creating blue-greyish gleyic horizon layer under humus accumulation level. Humus accumulation layer is well-seen with high organic substance content up to 10%. Soil acidity is low acid to neutral (pH KCl 6,1 til 6,5).
Humi-gley soil (GLr)
This type of soil is widespread meadows and pasture fields, rarely in tillage, mostly in lower part of relief. In soil profile a strong gleyic horizon is observed. Soil organic substance content is 10 – 20%. Soil acidity reaction in low acid to neutral (pH KCl 6,1 till 6,5).
Mucky-humus gley soil (GLa)
This kind of soil is widespread in meadows and pastures, low marsh side are. The soil was formed during glacier process near shallow groundwater when organic substances accumulate on parent material with rich chemical content. Soil top layer has increased organic matter content (20 – 50%). Soil reaction is low acid till neutral (pH KCl 6,1 till 6,5).

Semi-hydromorphic soil class. Podsolic gley soil.

33 Latvijas augšņu noteicējs (Soil Determiner of Latvia). Kārkliņš A., Gemste I., Mežals H., Nikodemus O., Skujāns R. Jelgava. LLU. 2009. 240 lpp.

34 Sodding is soil forming process, where live organism decayed parts accumulate, decomposing of organic parts influenced by micro organisms.

35 Gleying - soils develop in anaerobic conditions of the poorly drained soil in the presence of constant water (either ground water or surface water).

Podsolic gley soils are widespread in the east of Latvia and on the coast of the Baltic Sea, in meadows and pastures, rarely in tillage fields. Podsolic gley soils are formed on parent material that is poor with plant nutrient substances, from podsolic to sod-podsolic soils when water regimen decreased. Sodding, podzolisation[36] and gleying processes dominate.

Although organic substance content is very high in podzolic gley soils, they are considered to be the poorest agriculture farming lands in Latvia, they are very poor in plant nutrients, soil reaction is acid and medium acid (pH KCl no 4,6 till 5,5), low saturation, bad physical qualities (poorly set structure, dense, high water saturation and inadequate air volume).

Soil subtypes for EC criteria:

Sod-podzolic gley soil (PGv)
This type is widespread in meadows and was formed from sod-podsolic gley soils, gradually worsening the water regimen and increase of reducing processes. Soil top layer contains organic matter up to 10%. Soil reaction – medium acid (pH KCl 5,1 till 5,5).
Humi-podzolic gley soil (PGr)
This type of soil is widespread in meliorated meadows and pastures. They are formed in podsolic and gleying processed in lower parts of relief on clay and loam parent material, affected by high ground water conditions. Humus accumulation horizon is well developed, organic matter content 10 – 20%. Soil reaction - acid (pH KCl 4,6 till 5,0).
Mucky-humus podzolic gley soil (PGa)
This soil is widespread in meadows and pastures, rarely in tillage. The soil is formed in gleying process influenced by shallow groundwater when organic matter accumulate on parent material with poor chemical content. Humus content on top layer 20 – 50%. Soil acidity - acid (pH KCl 4,6 till 5,0).
Mucky-podzolic gley soil (PGi)
It is widespread in farm land after low marsh drainage. During overly moisture conditions it forms on poor parent material. Peat accumulation and moving processes are dominant. Organic content exceeds 50% on the top layer of soil. Soil reaction - acidic (pH KCl 4,6 till 5,0).

Semi-hydromorphic soil class. Alluvial soils.

Alluvial soils are widespread in earlier and current river valleys, also in areas near the lakes where water overflows. From farm lands those soils are observed in meadows and pasture, very rarely in tillage. Alluvial soils are formed from melt waters accretion or on colluvial[37] material. Alluvial soil has various soil texture, amount of organic substances and chemical composition, which depends on melt waters, its speed and mass, relief etc.
Alluvial gleyic soils are dominated by gleyic and peat[38] forming processes. Collected material usually is of fine grains and contains much organic substance. Humus accumulation horizon can reach 1 meter and more. The soil has improved structure, more nitrogen and other nutrients, as well as moisture. Soil reaction is acidic to neutral (pH KCl 4,6 till 6,5).

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Podzolisation is a complex soil forming process (or number of sub-processes) in which organic material and soluble minerals (commonly iron and aluminium) are leached from the A and E horizons to the B horizon. Podzolisation process combines positive moisture balance, cool climate, poor base element soils, poor biologic substance turnover.

37 Colluvium is the name for loose bodies of sediment that have been deposited or built up at the bottom of a low-grade slope or against a barrier on that slope, transported by gravity.

38 **Peat** is an accumulation of partially decayed vegetation matter due to insufficient oxygen and too much moisture.

Soil subtypes for EC criteria:

Alluvial sod-gley soil (ALv)
It is widespread in river terrains that during spring melting do not get flooded and also on the gently sloping lake banks in all Latvia territory. Sodding and gleying processes are dominant; some places podsolic process takes place as well. Gleyic horizon level lays under humus accumulation horizon, which is mixed with alluvial silts. Organic substance content in the top layer is under 10%. Soil reaction is neutral (pH KCl 6,5).
Alluvial humic-gley soil (ALh)
It is widespread in river valleys non-flooded old river banks. Soil top layer organic substance mass is 10 – 50%, with alluvial silt and mixture of tiny dull and more coarse mineral material. Soils are mildly acid till neutral (pH KCl 6,1 till 6,5).
Alluvial muck soil (ALi)
It is widespread in river flood-land lower parts and old river areas where peat was formed. Peat contains large amount of alluvial mucky silt. In the lake flooded areas under peat some **sapropelis** silt. Gleyic horizons lay under peat level. Organic substance contains more than 50% in top layer. Soils are acid till low acid (pH KCl 4,6 till 6,0).
Hydromorphic soil class. Low marsh peat soil.

In farm land low marsh peat soils occur in meadows and pastures, rarely in tillage. The largest lower marsh areas are located in the eastern part of Latvia. Low marsh areas were formed in lower parts of relief, river valleys, banks of lakes, as well in the places with poor natural water drainage. Lower marsh peat forms in the areas rich in plant nutrient substances, positively influencing vegetation, including grass land development, activities of micro organisms etc.

Low marsh peat soils are dominant with peat forming process. Peat decomposing level is from 25 till 45% and more than 45%. Soils reaction is slightly acidic till neutral (pH KCl from 6,1 till 6,5).

Soil subtypes for EC criteria:

Low marsh gleyic humi- peat soil (TZr)
Peat layer is 30 till 50 cm thick, well decomposed (more than 45%). Under peat level there is ble-greyish gleyic mineral horizon.
Low marsh gleyic humus mucky soil (TZa)
Peat layer is 30 till 50 cm thick. Top layer is less decomposed (under 25%), but deeper – better decomposed (more than 45%). Under peat layer there is gleyic mineral horizon.
Low marsh humi- peat soil (TZh)
Peat layer is thicker than 50 cm and is well decomposed (more than 45%). Under peat level there is a gleyic mineral soil horizon.
Low marsh humus mucky soil (TZt)
Peat layer is thicker than 50 cm. Peat is quite well or well decomposed (25 till 45%).

Hydromorphic soil class. Transition marsh peat soils.

The largest transition marsh areas are located in the eastern part of Latvia and in the middle of Latvia with thick low marsh peat levels, the Baltic Sea coastline and poor parent material with slightly mineralized ground waters, as well on the side areas of high marsh fields. Transition marsh fields were formed from low marsh when peat layer thickness increased. Ground water rich in mineral do not reach top layer of peat soil, thus peat layer increases its acidity, it becomes poor in plant nutrient substances and is not so well decomposed.

Peat is well and quite well decomposed (25 till 45%). Soils reaction is sour till very sour (pH KCl from 4,6 till 5,0 and less than 4,6).

Soil subtypes for EC criteria:

Transition marsh gleyic humus mucky soil (TPr)
Peat layer is 30 till 50 cm thick, formed from low and high marsh vegetation. Peat is well decomposed (25 till 45%).

Transition marsh gleyic peat soil (TPi)

Peat layer is 30 till 50 cm thick, less decomposed than humus mucky soil. Under the peat layer usually there is overall gleyic mineral soil horizon.

Transition marsh humus mucky soil (TPa)

Peat layer is thicker than 50 cm, well decomposed (25 till 45%). Under peat layer usually there is overall gleyic mineral soil horizon.

Transition marsh typical peat soil (TPt)

Peat layer is thicker than 50 cm, it is formed from the grass, moss and tree remnants. Peat top layer is well decomposed (25 till 45%), but lower – less well decomposed (less than 25%).