# NUTRIENT MAPS OF ZEMGALE REGION, LATVIA

## WP T2., D3.1.

LATVIAN STATE ENVIRONMENTAL SERVICES

28.02.2022.

SUSTAINABLE BIOGAS

Interreg Central Baltic

European Union
European Regional Development Fund

# CONTENTS

# 1. INTRODUCTION

This report is the result of the project WP T2., Deliverable 3.1. activities under Sustainable Biogas project, which aims to promote the sustainability of biogas production. Biogas production can lead to nutrient leakages in watercourses if raw material, digestate and wastewater management is not carefully planned. Sustainable Biogas project is sponsored by the EU Interreg Central Baltic program. The project is implemented by John Nurminen Foundation, ELY Centre in Southwestern Finland, Finnish Biocycle and Biogas Association, Latvian State Environmental Service and Latvian Biogas Association.

The objective of this report is to investigate nutrients load in agricultural areas in Zemgale region, Latvia, an environmentally sensitive area. The main sources of plant nutrients leaching in groundwaters is diffuse pollution from agricultural land caused by overfertilization with phosphorus or nitrogen in organic and/or mineral fertilisers. To achieve this objective the maps on plant nutrients content in soil for the Zemgale region will be made. Although legislative limitation exists for nitrogen annual input with organic fertiliser (170 kg/ha), there no limits for phosphorus to be applied in soil with fertilisers, so special attention is put on investigating phosphorus content in agricultural soils.

The nutrient maps are divided in 5X5 km squares, providing data on average nutrients (N, $P_2O_5$ and $K_2O$) content in the soil in each square, as well as nutrient load from local sources such as biogas plants, livestock manure and wastewater sludge.

Nutrient mapping is the one of the first steps in reducing the nutrient pollution of watercourses and the Baltic Sea. The maps will be used for spatial planning, including optimization of the location of biogas plants, and for rough forecasting of fertilization plans, and to gather data to assess historical changes in soil nutrient content in the future.

# 2. SOIL DATA INFORMATION IN LATVIA

At this moment, due to the lack of a unified (nationwide) soil information system in Latvia, the challenges in Latvia in future are related to systematization and harmonization of the existing information (soil and agrochemical survey materials and analytical data, etc.), for creation of a national soil database, as well as adaptation of the information to the European Union Standards.

## 2.1 Soil survey of Latvia

Soil survey in Latvia historically was carried out in three stages during 1959-1992 (Table 1). It includes soil mapping according to genetic approach (including different classifications due its development) and agricultural land evaluation in the large-scale (1:10 000). Soil spatial information includes soil types, subtypes and textural classes as well as descriptions of soil profiles. Forest soils and soils in other non-agricultural use have not yet been mapped on a scale of 1:10 000 in Latvia.

Table 1. Large scale (1:10,000) soil mapping and agricultural land evaluation in Latvia (Karklins, 2005)

| Administrative region | Soil mapping (field activities) | | | Renewal of Maps |
|---|---|---|---|---|
| | 1st cycle | 2nd cycle | 3rd cycle | |
| *Aizkraukles | 1964-1966 | 1977 | 1989 | - |
| Aluksnes | 1960-1961 | 1977-1978 | 1985 | 1996 |
| Balvu | 1960-1961 | 1971; 1978 | 1987 | 1996-1997 |
| *Bauskas | 1960; 1962; 1965 | 1976 | 1991 | 1999 |
| Cesu | 1966-1967 | 1978 | 1981-1983 | 1995-1996 |
| Daugavpils | 1962; 1966 | 1976-1978 | 1988 | - |
| *Dobeles | 1965 | 1976 | 1990 | - |
| Gulbenes | 1959-1961 | 1979 | 1986 | 1996-1997 |
| *Jelgavas | 1961-1967 | 1971; 1978 | 1990 | - |
| Jekabpils | 1965-1967; 1961 | 1975; 1978 | 1988 | - |
| Kraslavas | 1966-1969;1960 | 1977 | - | 1994 |
| Kuldigas | 1959-1960; 1964 | 1976 | - | 2001 |
| Liepajas | 1961; 1963-1964 | 1978 | - | 2001 |
| Limbazu | 1961-1962; 1966 | 1975; 1978 | - | 1995-1996 |
| Ludzas | 1961;1963;1968; 1972 | 1977 | - | 1995 |
| Madonas | 1963-1965 | 1976-1978 | 1989 | 1997-1999 |
| Ogres | 1964 | 1975-1976; 1978 | - | 1997 |
| Preilu | 1962; 1965-1966 | 1978 | 1986 | 1997-1998 |
| Rezeknes | 1959-1960; 1965-1966 | 1977 | - | 1994-1994 |
| Rigas | 1961-1963; 1966-1967 | 1978 | - | 1995-1996 |
| Saldus | 1960-1961; 1964 | 1972-1973; 1978 | - | 1999 |
| Talsu | 1964-1965 | 1975-1976 | - | 2000 |
| Tukuma | 1963-1964 | 1976 | - | 1999 |
| Valkas | 1961-1863 | 1974; 1978 | 1983-1984 | 1996 |
| Valmieras | 1961-1963 | 1973-1974; 1977 | 1987 | 1997 |
| Ventspils | 1961 | 1979 | - | - |

Notes: *-Former administrative regions that corresponds to nowadays Zemgale region in Latvia

Georeferencing and digitalization of manual maps (including soil subtype, textural classes and land evaluation mapping units, as well as soil profile information) by integration of mapping units with orthophotomaps on a scale of 1:10 000, as well as harmonization of older soil units in the current Latvia Soil Classification System were done during 2014-2016. Cover of digitalized former agricultural soil maps in Latvia on scale 1:10 000 covers 38 787 km2 or 60% from area of Latvia.

In this report, the above mentioned digitalised soil database were used as a basis for preparation of nutrient maps of Zemgale region, Latvia.

## 2.2 Geochemical survey of Latvia

A geochemical survey of the country was performed by the State Geological Survey of Latvia at the scale of 1:500,000 in 1996-2000. Soil samples were collected from 10m × 10m areas located in the centre of 5km × 5km grids. Soil samples at each of 2,547 sampling points were taken from A (H, O) and C horizons.

Thirty seven chemical elements (Ag, Al, As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, K, La, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sc, Se, Sr, Te, Th, Ti, Tl, U, V, W, Zn) were determined by ICP-ES using extraction with hot (95°C) HNO3+HCl+H2O solution (24h digestion). Field activities, laboratory analysis and data processing has been completed but not yet published.

Geochemical mapping data have not been used as it is old information and out of date. It is mentioned for information that such mapping has taken place in the past.

## 2.3 History of the Agricultural Land Monitoring in Latvia

The Agricultural Land Monitoring programme in Latvia is designed as a three-level integrated system, with different levels going on simultaneously. It has the following structure (Vucans et al., 1996, Karklins et al., 1998, Livmanis et al., 2002).

1st monitoring level: Long-term observations carried out since 1992 on the research plots set up permanently on the most representative soils, farming profile and climatic conditions of Latvia. The objective is to obtain reliable and integrated information about soil parameters (physical, chemical and biological properties, erosion, pollution), soil productivity and yield quality depending on soil management, fertilizer use, and farming profile for making recommendations to control anthropogenic impact on agricultural land. Observations were carried out on separate 12 research units covering 20 soil variations of Latvia.

2nd monitoring level: Agricultural land monitoring on sample farms. It is expected that the sample farms represent more common farming systems, soil and climatic conditions of Latvia. They were selected in cooperation with State Land Service, Department of Agriculture and Agricultural Advisory Centre. The monitoring activities are carried out by agreement between farm owner/operator and the State Land Service. The State Land Service has the responsibility for land evaluation, renewal of soil maps and periodic soil testing (every 3 years for intensive production farms and every 6 years for others).

3rd monitoring level: Land use monitoring at the rural municipality level. These activities started in 1995 in all 512 rural municipalities of Latvia. This includes monitoring how land users are following state and municipality rules and regulations regarding land use and conservation. All agricultural land, including small holders' land, is designated under the auspices of the monitoring programme. The main issues to be monitored are as follows:

- Land use according to the title;
- Weed control by land user. Evaluation of weed invasion;
- Controlling whether one land user is diminishing another user's land quality and thereby restricting land use rights and interests;
- Controlling actions which might lead to land pollution with chemicals, household and production wastes;
- Controlling water management according to local regulations and interests of society;
- Soil conservation. Protection of soil humus when undertaking construction works;
- Dynamics of agricultural land acreage, soil quality and other changes with time and human activities.

Detailed monitoring is done on at least one third of agricultural land acreage in every municipality annually. Therefore, a full set of information is obtained within a 3-year period. The local rural municipality has responsibility to make decisions and to take measures against persons not following land use legislation.

This programme was started in 1992 and continued until 2001.

## 2.4 Nowadays agricultural land soil monitoring in Latvia

Soil monitoring is one of the components of the Environmental Monitoring Earth Monitoring Program in Latvia. State Plant Protection Service provides soil monitoring according to the Order No 130 of the Cabinet of Ministers of March 26, 2014 "On the Environmental Policy Guidelines 2014-2020. Year".

In agricultural soil monitoring is included following soil properties: organic matter content (%), pHKCl value, plant available phosphorus and potassium, degree of cultivation and soil texture.

Soil mineral nitrogen monitoring in Latvia is according to Regulation No. 834 “Requirements for the Protection of Water, Soil and Air from Agricultural Activities pollution." This monitoring area cover specific sensitive areas in Latvia in 47 monitoring points.

In this report, the above mentioned soil properties data (organic matter content, plant available phosphorus and potassium, mineral nitrogen) were used as a basis for preparation of nutrient maps of Zemgale region, Latvia.

# 3. STUDY AREA AND RESULTS OF EXTRAPOLATED DATA FROM AGRICULTURAL LAND SOIL MONITORING

The Republic of Latvia lies on the eastern coast of the Baltic Sea between 58° 05' - 55° 40' N in NS (extension: 210 km) and 20° 58' E - 28° 14' E WE (extension: 450 km) direction. The total area of Latvia is 64589 km2 of which 62046km2 are land and 2543km2 inland-water. The length of the State boundary is 1900km, of which 1400km is on land, including 343 km with Estonia in the north, 282 km with the Russian Federation in the east, 167 km with Belarus in the southeast and 567 km with Lithuania in the south. The length of the coastline is 494 km.

Latvia is located on the north-west edge of the East European Plain that is characterized by slight variations in elevation. Relief of Latvia is characterized by low hypsography (0-312 m above sea level - a.s.l.). About 44 % of Latvia is at or below 80 m a.s.l., 76 % up to 120 m and 24 % above 120 m a.s.l. Only 1.6 % of the territory is located above 200 m a.s.l. The average elevation is 87 m a.s.l. The highest point is Gaizinkalns (312 m a.s.l). The present day topography was mainly formed as a result of the Pleistocene glaciation, particularly the last Baltic (Weichselian) event. Despite the low hypsography, some parts of the uplands have remarkable relief.

In this report, the mapping of soil properties in agricultural lands in Zemgale region is presented by 5 x 5 km grid cells (25 km2 per cell) (Figure 1). There are 350 cells in the study area, covering 8750 km2. Forests and agriculture are the most common types of land use in the study area, however, it is predominantly covered by agricultural lands. Therefore, relatively high density is characterized by the distribution of livestock holdings in the study area (Figure 2).

Soils of this region is characterized by relatively high soil fertility that is impacted by higher silt and clay content, however lower soil fertility is characterized by sandy soils – distributed in northern and eastern part of the study area region.

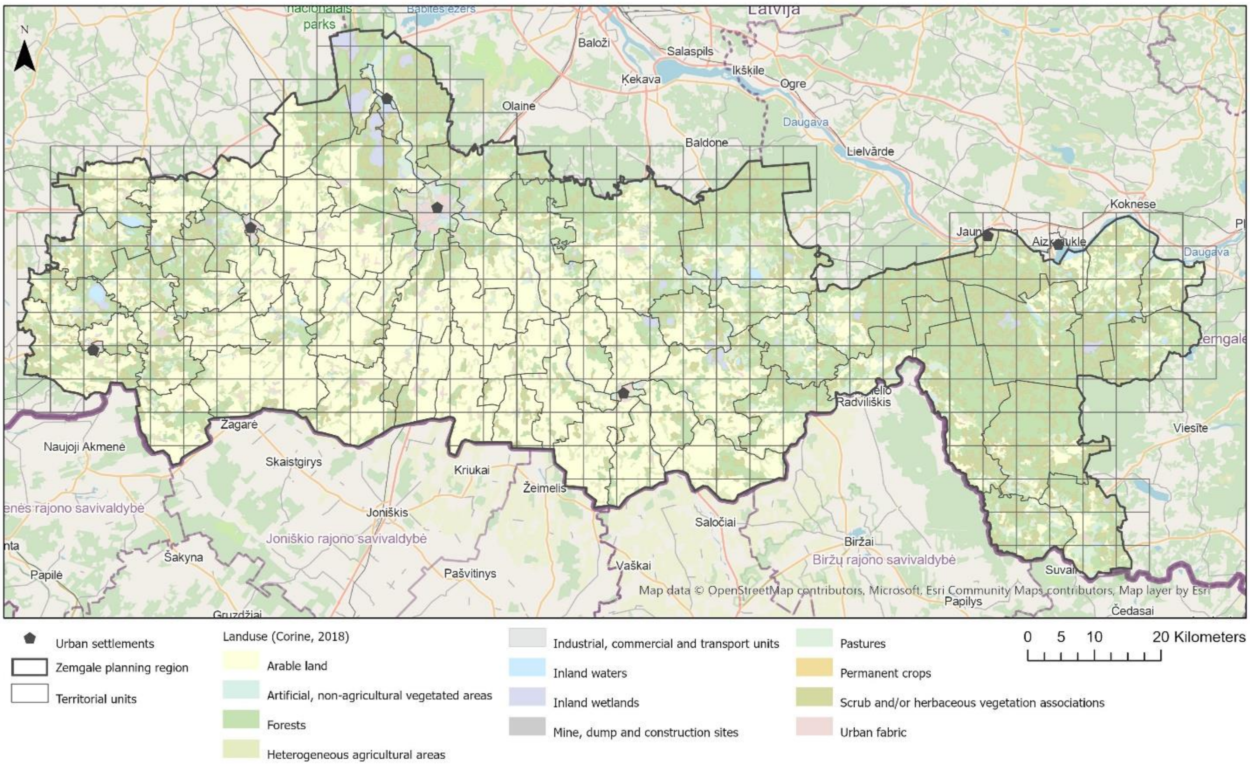


Figure 1. The distribution of grid cells in the study area

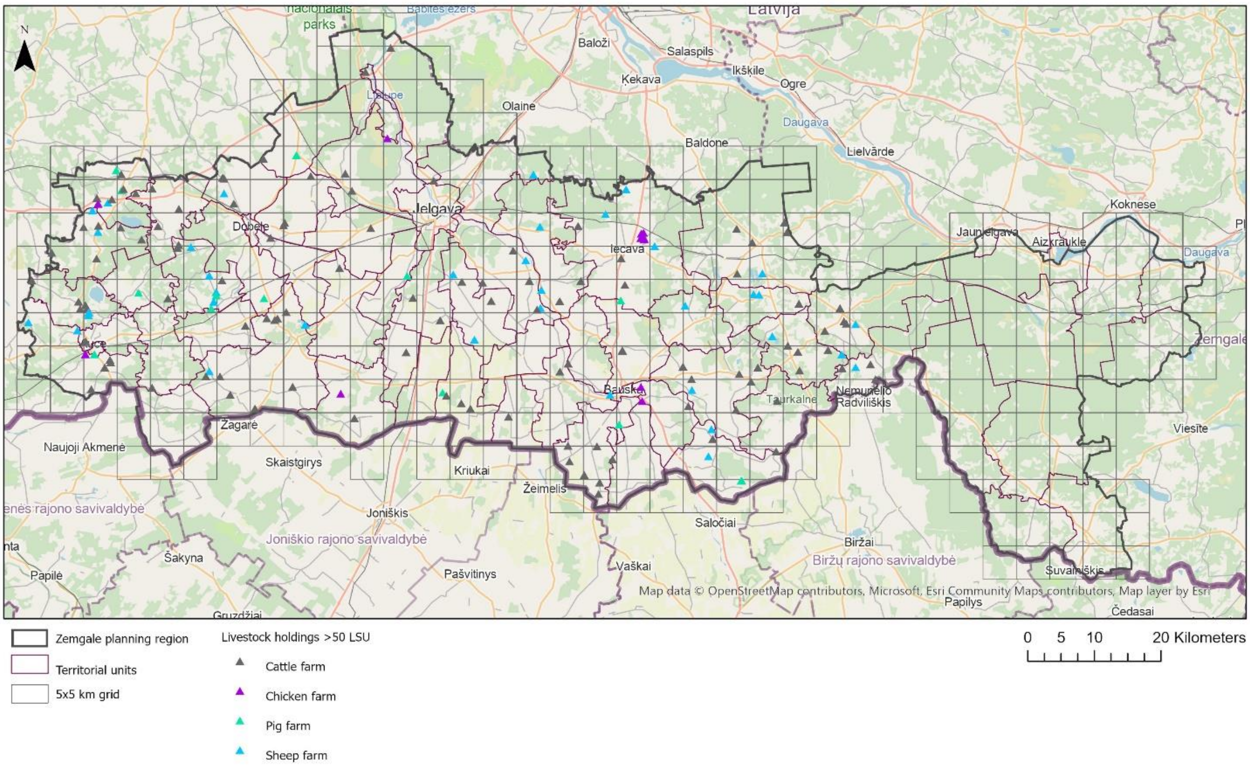


Figure 2. The distribution of livestock holdings in the study area

## 3.1 Soil mineral nitrogen

There are 47 soil mineral nitrogen monitoring plots in Zemgale region (Figure 3, Table 2). Relatively low soil mineral nitrogen median values is related to soils, characterized by lower fertility in sands (23,52), however mineral nitrogen values increases by increase of soil fertility, associated with increase in silt and clay content, reaching highest mineral nitrogen median value in clay (35,52) (Table 2). Based on this correlation, data of soil texture in grid cells were used for preparation and extrapolation of soil mineral nitrogen (Figure 4).

Table 2. Soil mineral nitrogen median values according to soil texture in monitoring sampling plots (47)

| **Soil texture** | **Number of sampling plots** | **Soil mineral nitrogen** (Median values) |
|---|---|---|
| Sand | 5 | 23,52 |
| Loamy sand | 20 | 26,60 |
| Loam | 21 | 33,60 |
| Clay | 1 | 35,52 |

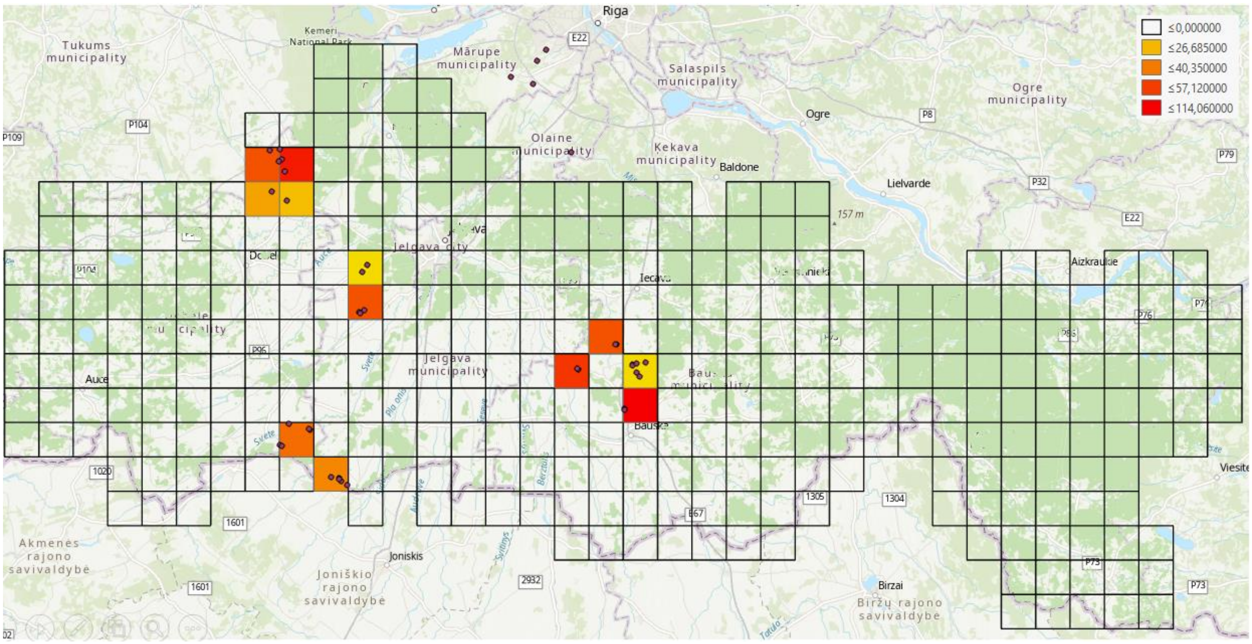


Figure 3. The soil mineral nitrogen monitoring plots distribution on grid cells of nitrogen median values in agricultural lands in the study area

It could be concluded, that relatively lower soil mineral nitrogen values is associated by extensively used poor sandy soils, located in northern part of the study area. Slightly increase of nitrogen is observed in loamy sand, located in eastern part, however higher nitrogen values is related to loam and clay soils, distributed in intensive agriculture areas in western part and southern part of the study area (Figure 4).

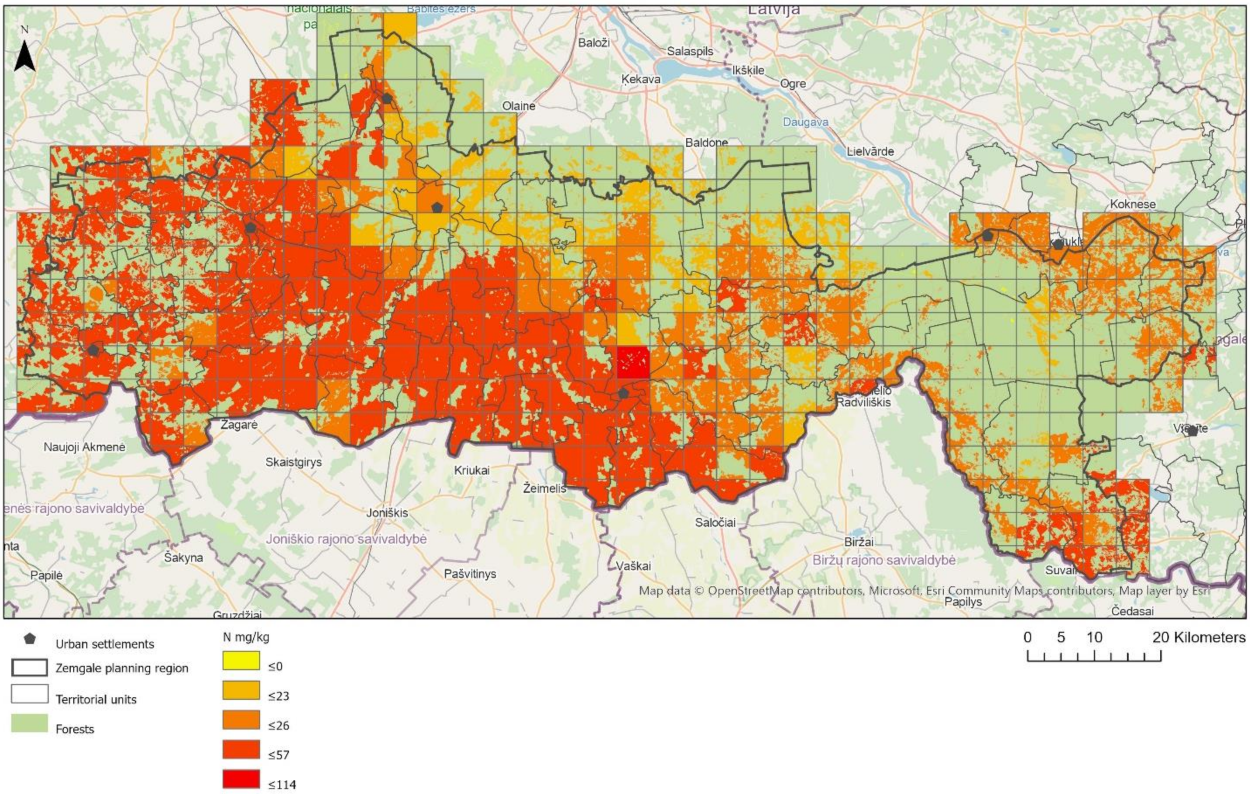


Figure 4. Extrapolated median values of soil mineral nitrogen in relation to soil texture in agricultural lands in the study area

## 3.2 Organic matter, plant available phosphorus and potassium

There are 3671 monitoring plots in Zemgale region (Figure 5), representing organic matter, plant available phosphorus and potassium.

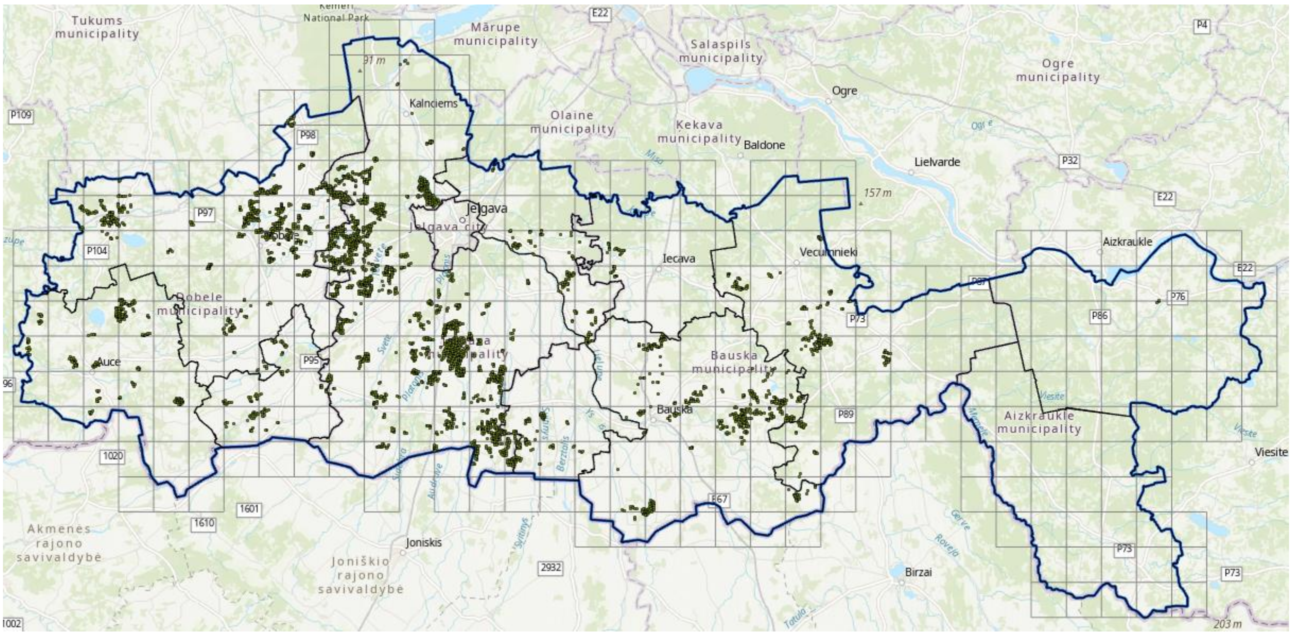


Figure 5. The study area and the coverage of grid cells in the study area and distribution of agricultural land soil monitoring sampling plots (organic matter, plant available phosphorus and potassium)

Table 3. Soil properties median values according to soil texture in monitoring sampling plots (3671)

| Soil texture | Organic matter | Plant available potassium | Plant available phosphorus |
|---|---|---|---|
| Sand | 2,8 | 101 | 126 |
| Loamy sand | 3,0 | 108 | 103 |
| Loam | 3,1 | 147 | 108 |
| Clay | 3,4 | 228 | 102 |

Relation is observed between soil fertility, soil texture and organic matter content, as well as plant available potassium is approved by Table 3. However plant available phosphorus concentrations are not unequivocally appreciated.

Median value of organic matter content is between 2,8 in poor sandy soils, reaching 3,4 in clay soils, characterized by high fertility and relatively intensive agricultural activities. Median value of plant available potassium variates is from 101 in sands and highest value is in clay – 228 (Table 3).

However plant available phosphorus variates between 102 in clay, reaching 126 in sandy soils.

Therefore based on above mentioned, extrapolation to grid cells were done for analysed soil properties in relation to soil texture distribution in study area (Figure 6, 7 and 8).

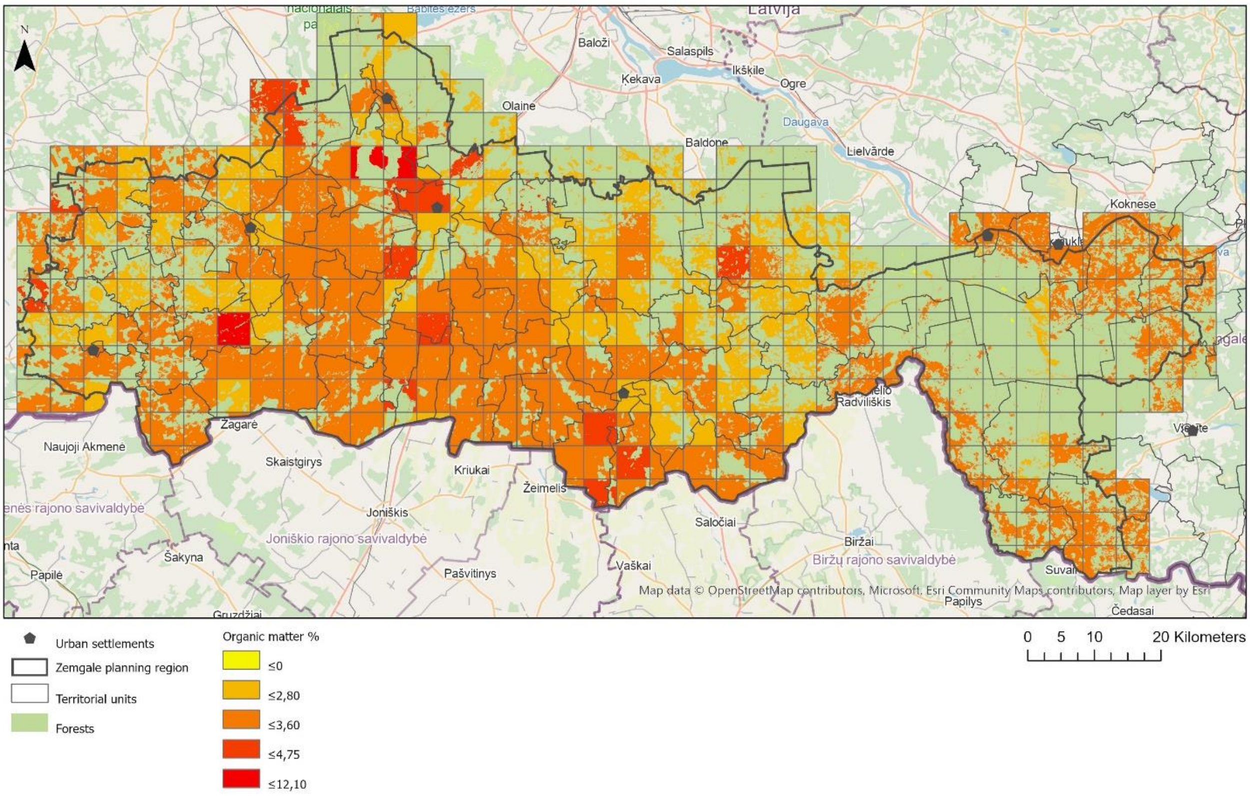


Figure 6. Extrapolated median values of organic matter in relation to soil texture in agricultural lands in the study area

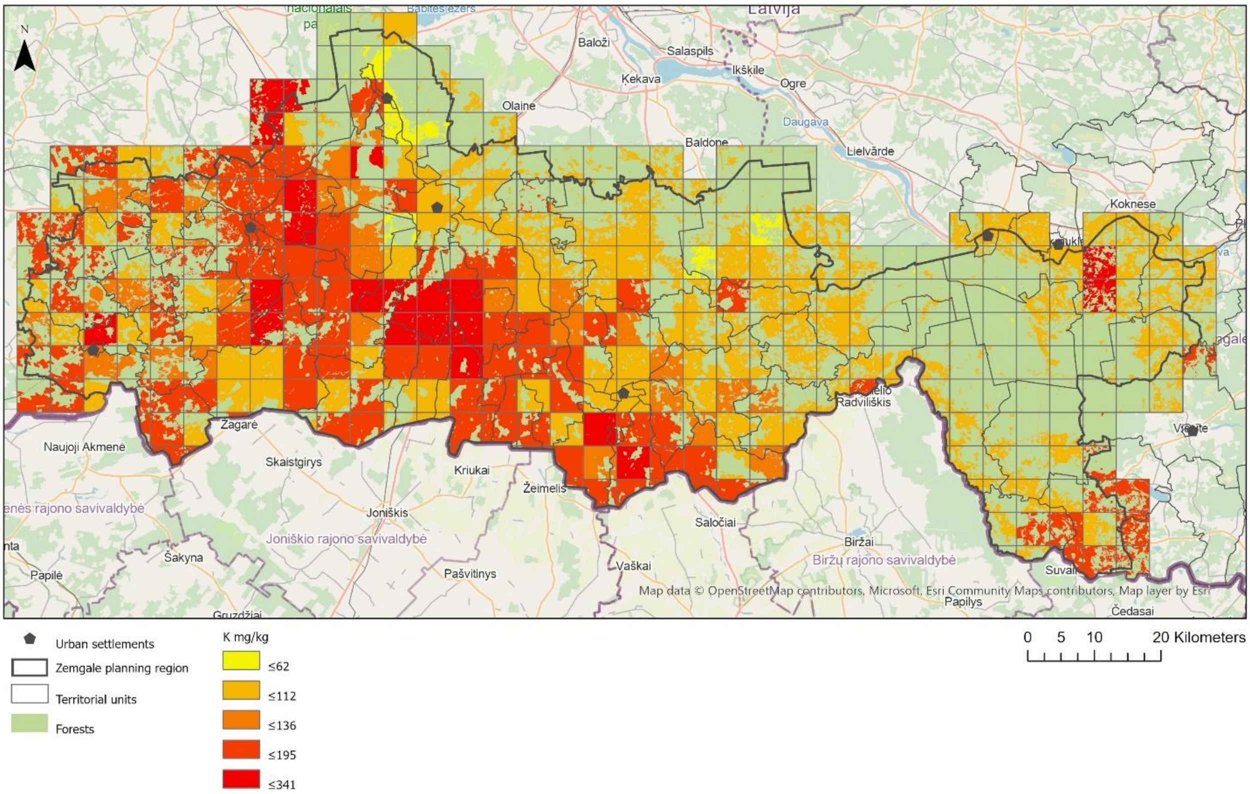


Figure 7. Extrapolated median values of plant available potassium in relation to soil texture in agricultural lands in the study area

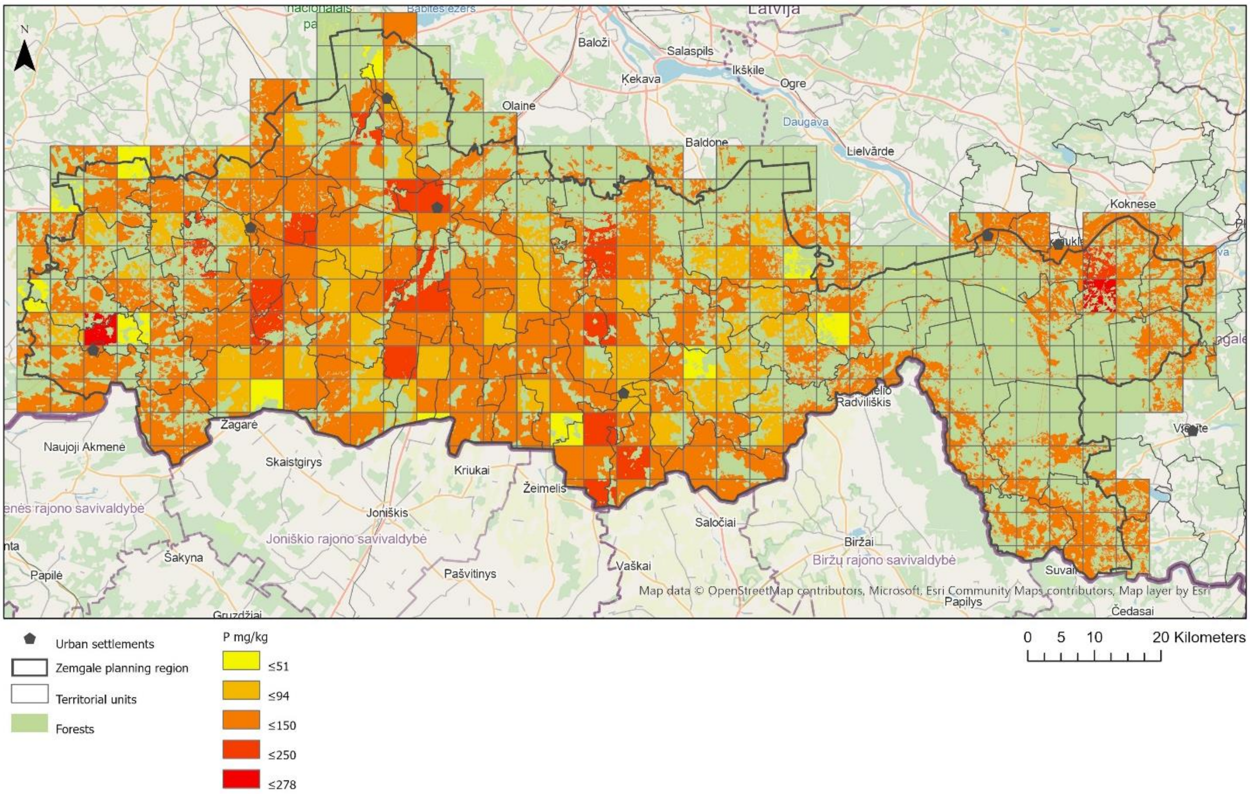


Figure 8. Extrapolated median values of plant available phosphorus in relation to soil texture in agricultural lands in the study area

# 4. NUTRIENT PRODUCTION

## 4.1 Biogas plants

The biogas plants data is provided by the State Environmental Service, The Republic of Latvia. There are 15 known biogas plants in study area of Zemgale region (Figure 9, 10 and 11).

Total biomass input by biogas plants varies from 7582 to 135322 t/year (Figure 9), total phosphorus input varies from 10 to 253 t/year (Figure 10), furthermore total phosphorus output by biogas plants varies from 3 to 340 t/year (Figure 11). However, total biomass input by biogas plants does not corresponds correlation to content of organic matter and plant available phosphorus in agricultural soils of the study area.

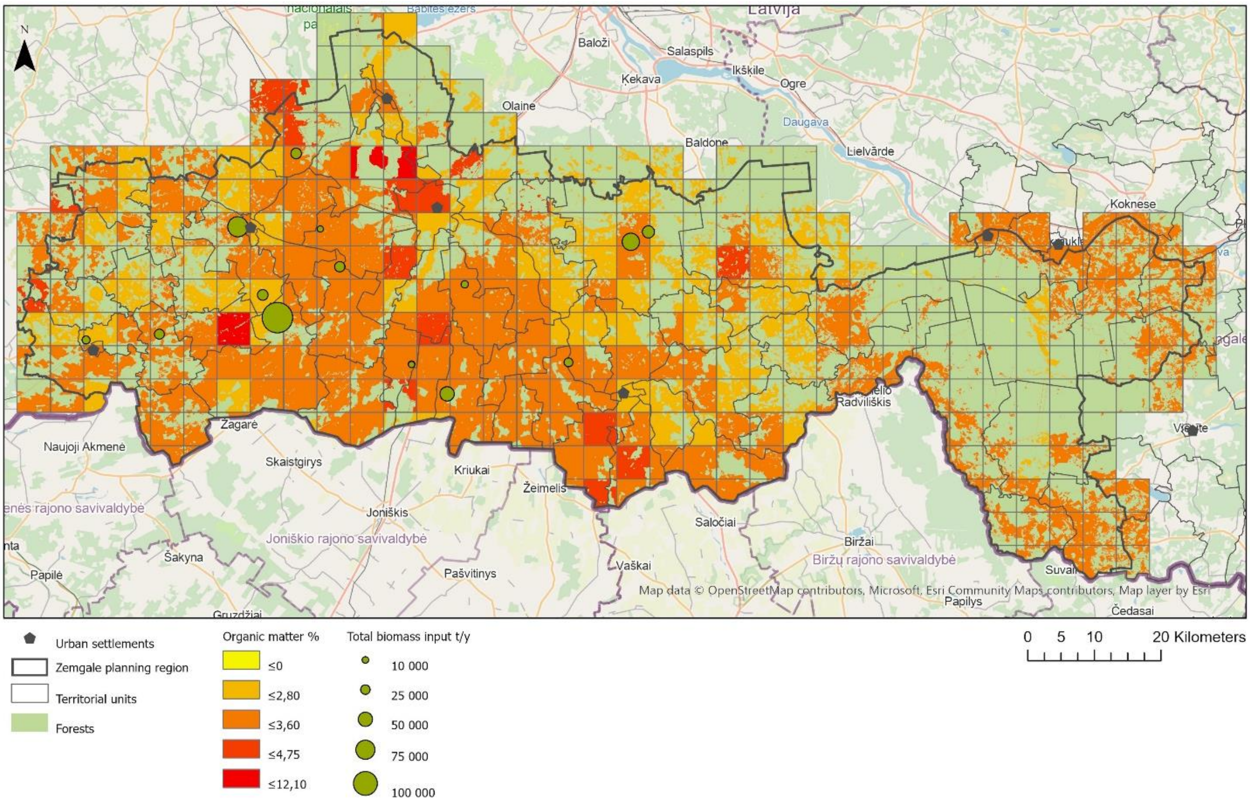


Figure 9. Total biomass input by biogas plants and extrapolated median values of organic matter in relation to soil texture in agricultural lands in the study area

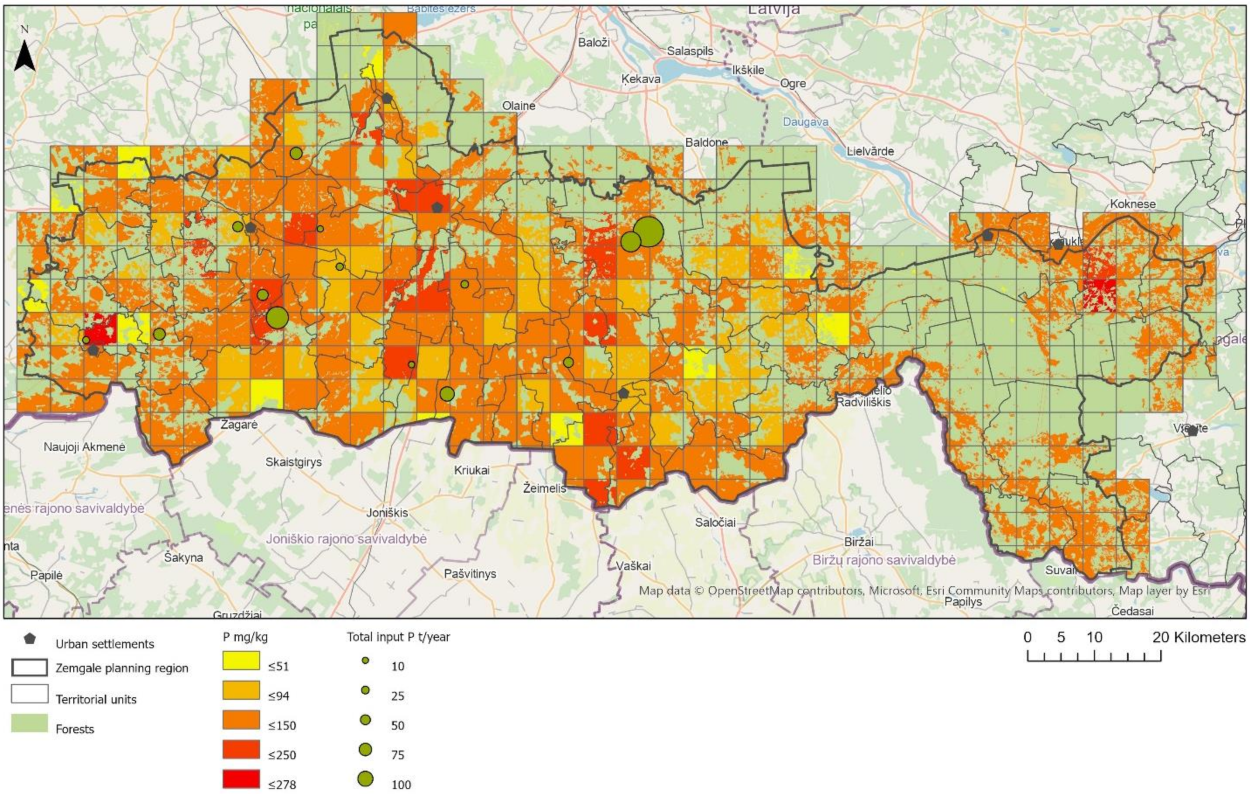


Figure 10. Total phosphorus input by biogas plants and extrapolated median values of plant available phosphorus in relation to soil texture in agricultural lands in the study

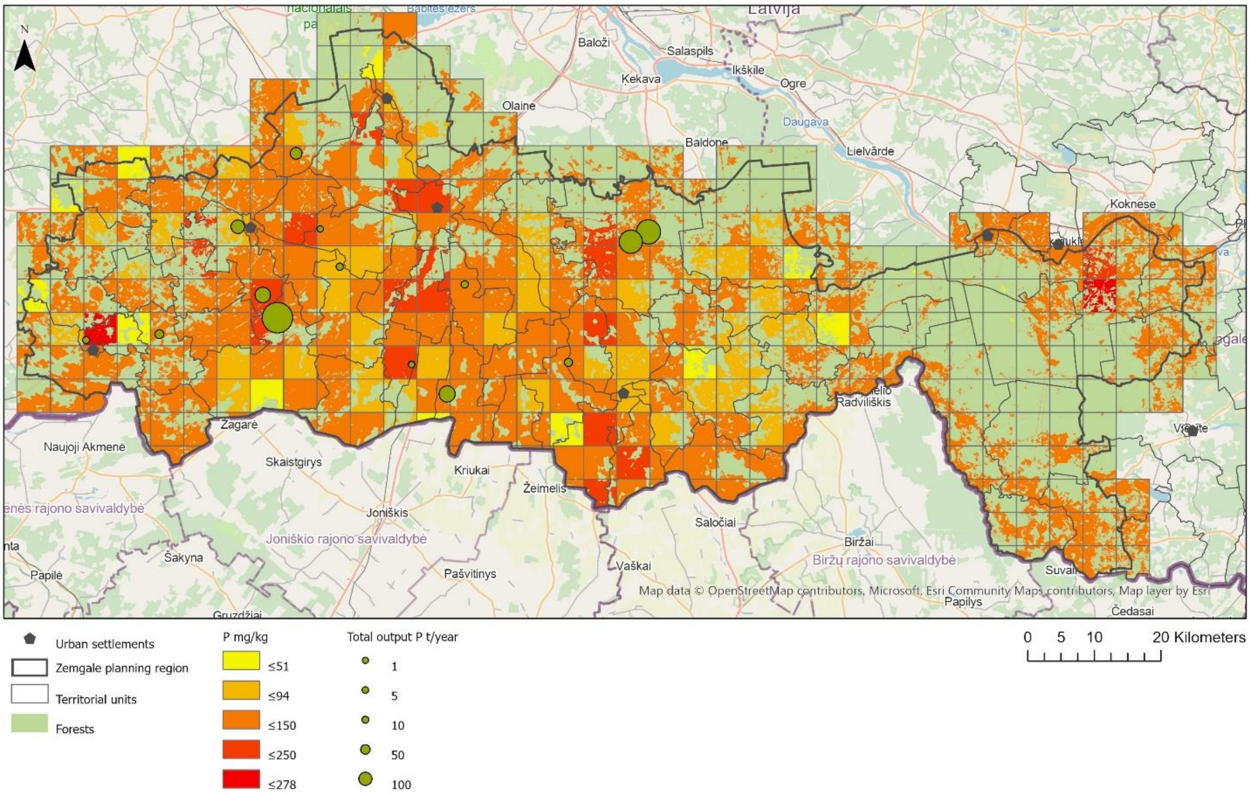


Figure 11. Total phosphorus output by biogas plants and extrapolated median values of plant available phosphorus in relation to soil texture in agricultural lands in the study

## 4.2 Animal manure

The livestock data is provided by the Agricultural Data Center, The Republic of Latvia.

The spatial distribution of livestock holdings is relatively regular (Figure 12, 13 and 14) and shows pressure areas. The number of livestock is approximately 434615 in livestock holdings in the study area. The number consists of 27 200 cattle, 100 200 pigs, 2 975 00 poultry, 7 800 sheep, 1 040 goats, 875 equidae. The manure output and amount of nutrients in the manure were determined according to the Regulations of the Cabinet of Ministers No. 834 “Requirements for the protection of water, soil and air against pollution caused by agricultural activities”.

There is 329 167 kg of nitrogen and 201 616 kg of phosphorus in the manure that animals produce annually in study area.

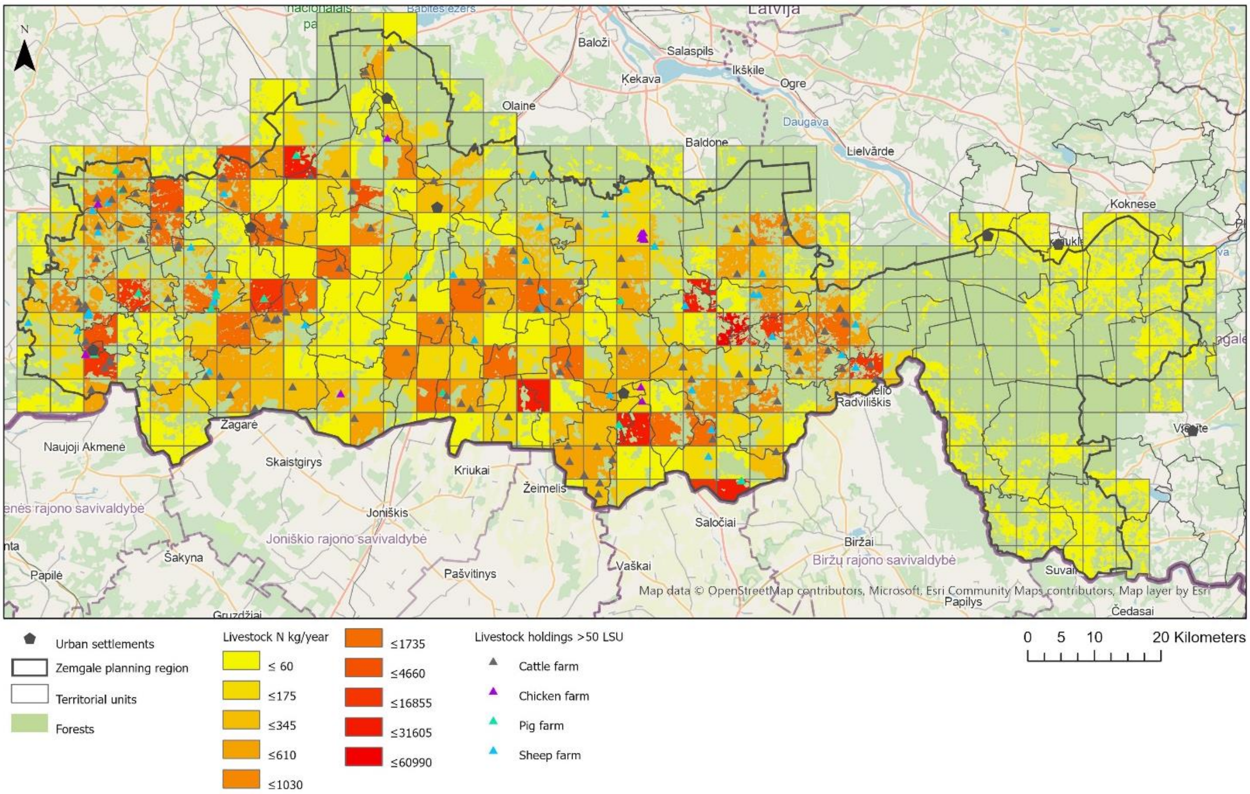


Figure 12. Extrapolated nitrogen production by livestock from animal manure in agricultural lands in the study area

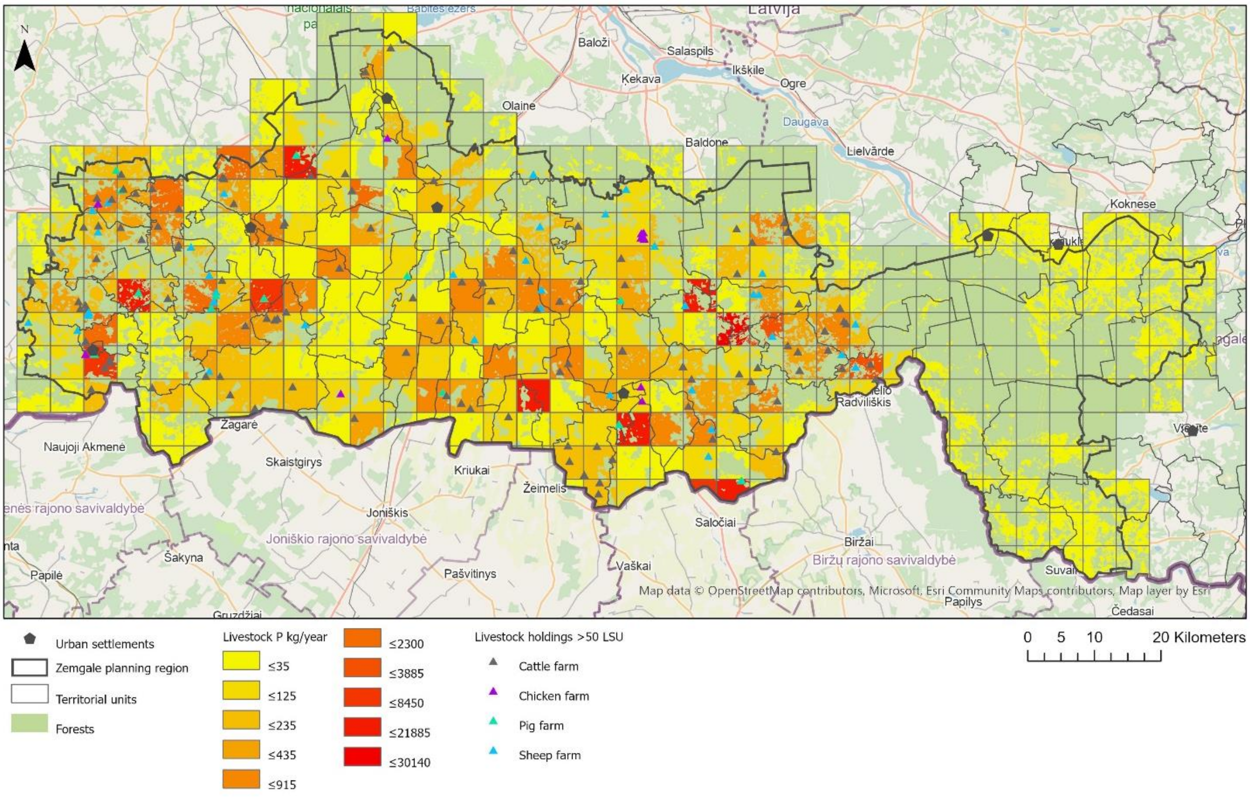


Figure 13. Extrapolated phosphorus production by livestock from animal manure in agricultural lands in the study area

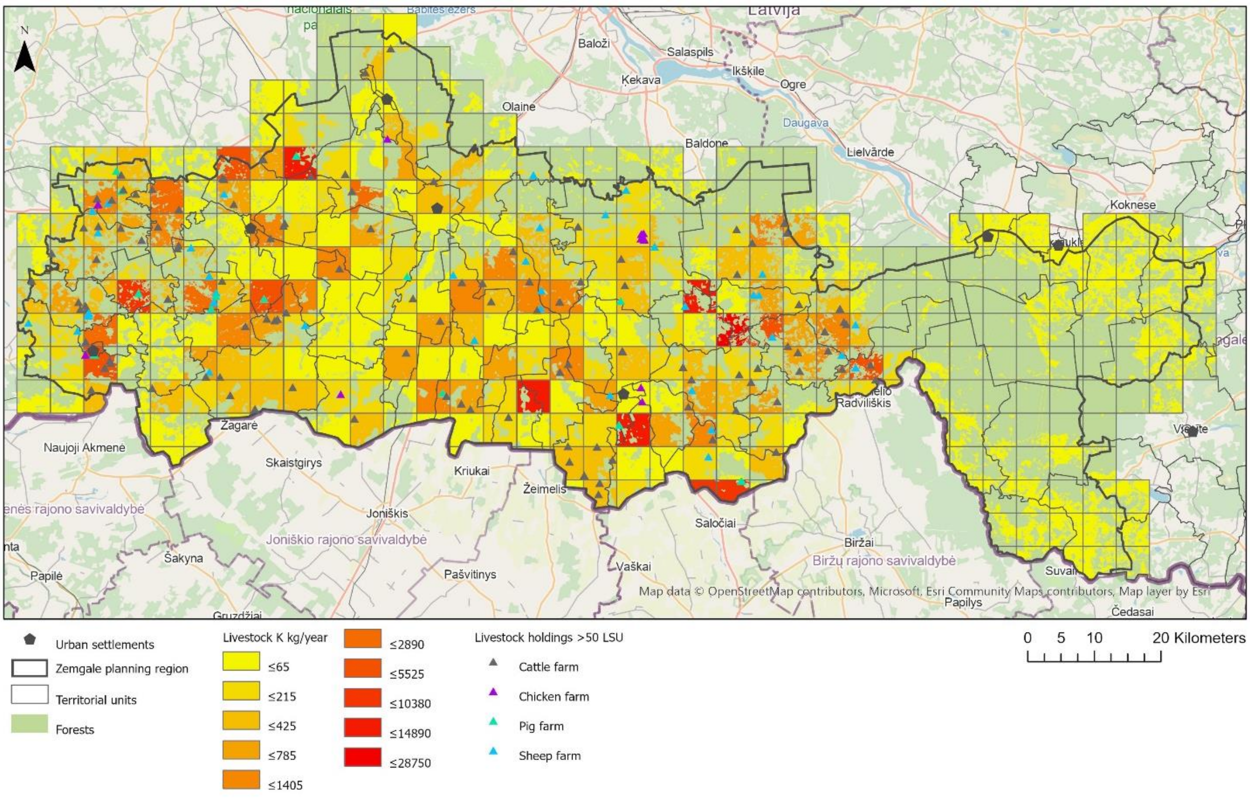


Figure 14. Extrapolated potassium production by livestock from animal manure in agricultural lands in the study area

## 4.3 Municipal sludge

Sources of municipal sludge consist of all active wastewater treatment plants in the study area. There are 97 active wastewater treatment plants in the study area (Figure 15 and 16). Treatment plant locations and data for sludge volume, dry matter content, nitrogen content and phosphorus content were acquired from Latvian Environmental, Geology and Meteorology Center.

The sludge from wastewater treatment plants contains approximately 7,75 tons of phosphorus annually and approximately 23,6 tons of nitrogen annually.

However, nitrogen and phosphorus input by sewage-treatment plants does not corresponds correlation to extrapolated median values of soil mineral nitrogen in relation to soil texture in agricultural lands of the study area.

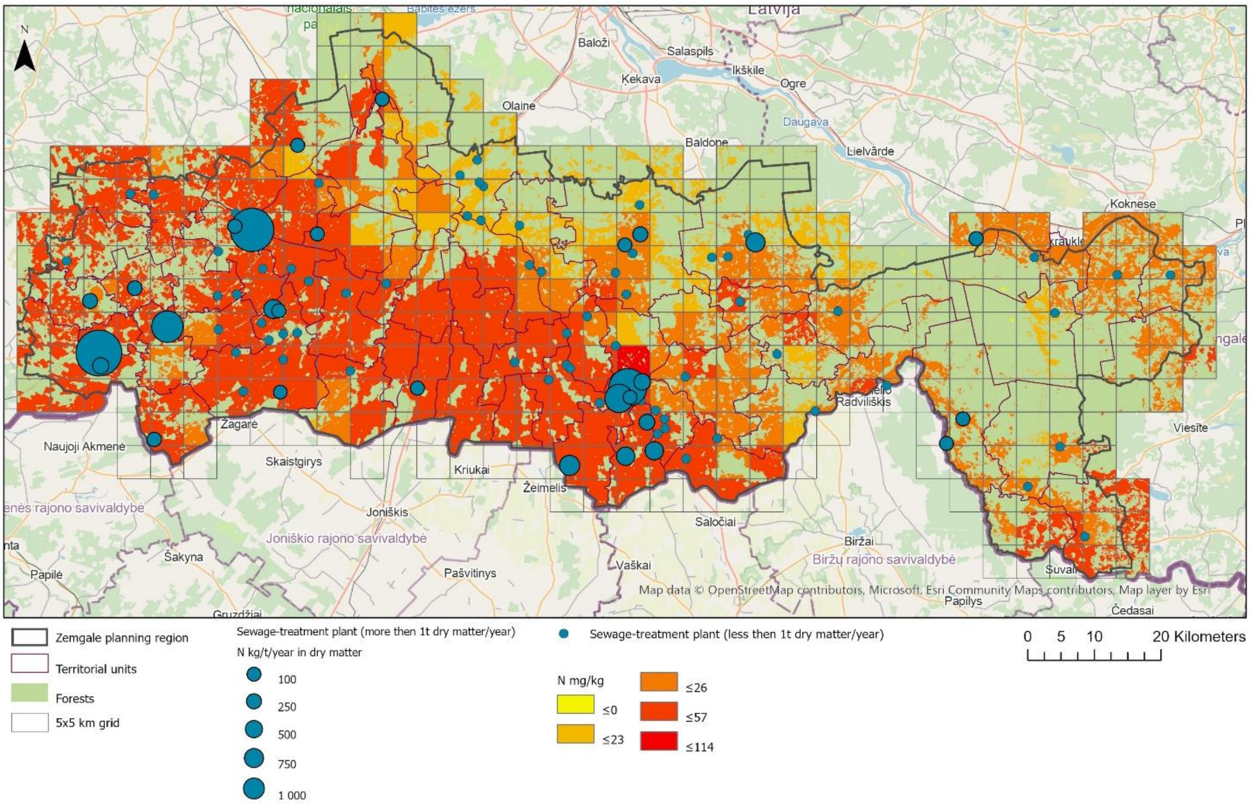


Figure 15. Nitrogen input by sewage-treatment plants and extrapolated median values of soil mineral nitrogen in relation to soil texture in agricultural lands of the study area

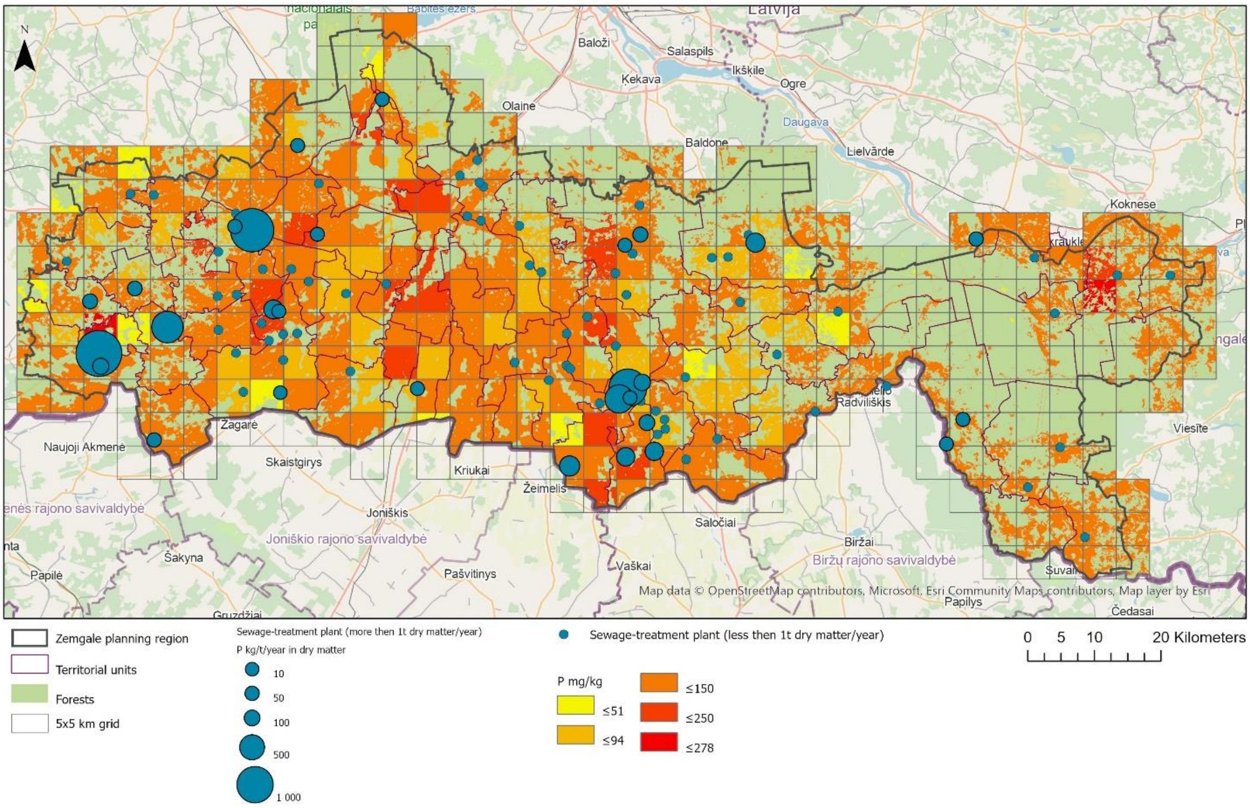


Figure 16. Phosphorus input by sewage-treatment plants and extrapolated median values of plant available phosphorus in relation to soil texture in agricultural lands of the study area

## 4.4 Phosphorus uptake potential in fields

Determination of the phosphorus uptake potential in fields in the study area was based on “Methodology for developing a crop fertilization plan” developed by Latvian Rural Consultation and Education Center, Ministry of Agriculture of the Republic of Latvia.

Extrapolated plant available phosphorus input amount and extrapolated phosphorus surplus/deficit (plant need coefficient) and phosphorus total output in agricultural lands of the study area could be spatially characterized by soil properties and soil fertility that is determined mainly by soil texture as well as anthropogenic impact of agricultural activities (Figure 17 and 18).

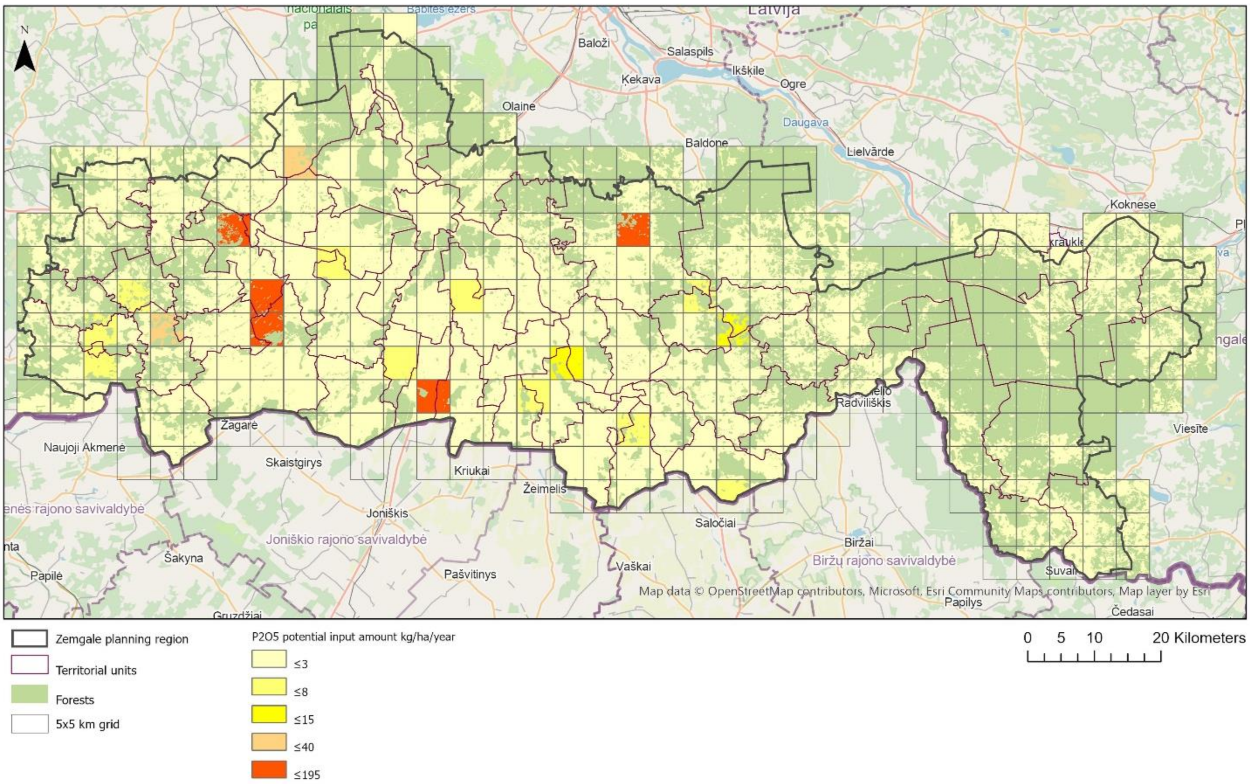


Figure 17. Extrapolated plant available phosphorus input amount in agricultural lands of the study area

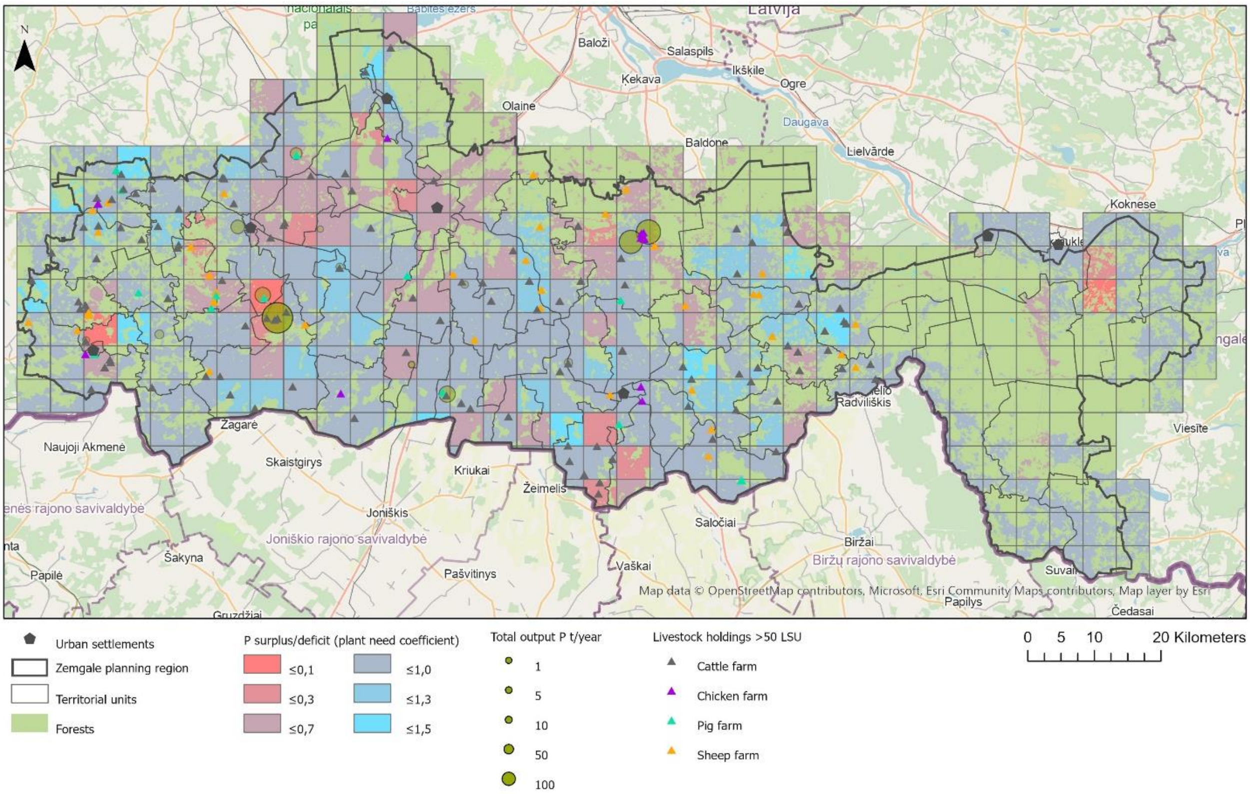


Figure 18. Extrapolated phosphorus surplus/deficit (plant need coefficient) and phosphorus total output in agricultural lands of the study area

# 5. SUMMARY

At this moment, due to the lack of a unified (nationwide) soil information system in Latvia, the challenges in Latvia in future are related to systematization and harmonization of the existing information (soil and agrochemical survey materials and analytical data, etc.), for creation of a national soil database.

The location of soil monitoring plots in Latvia is not regular. In Zemgale region there are 47 soil mineral nitrogen monitoring plots in comparison to 3671 soil monitoring plots for organic matter, plant available phosphorus and potassium.

Therefore, large scale (1:10,000) agricultural land soil mapping historical data (soil texture) were used for preparation of nutrient maps for Zemgale region.

Study results shows that relation exists between soil fertility, soil texture and soil mineral nitrogen, organic matter content, as well as plant available potassium. However plant available phosphorus concentrations are not unequivocally appreciated to soil texture.

It could be concluded, that relatively lower nutrient values are related to poor sandy soils, located in northern part of the study area, however it increases in loamy sand, located in eastern part, furthermore, relatively highest values is related to loam and clay soils, distributed in intensive agriculture areas in western part and southern part of the Zemgale region.

Total biomass input by biogas plants varies from 7582 to 135322 t/year, total phosphorus input varies from 10 to 253 t/year, furthermore total phosphorus output by biogas plants varies from 3 to 340 t/year. However, total biomass input by biogas plants does not corresponds correlation to content of organic matter and plant available phosphorus in agricultural soils of the study area.

The spatial distribution of livestock holdings is relatively regular and shows pressure areas. However, nitrogen and phosphorus input by sewage-treatment plants does not corresponds correlation to extrapolated median values of soil mineral nitrogen in relation to soil texture in agricultural lands of the study area.

Extrapolated plant available phosphorus input amount and extrapolated phosphorus surplus/deficit (plant need coefficient) and phosphorus total output in agricultural lands of the study area could be spatially characterized by soil properties and soil fertility that is determined mainly by soil texture as well as anthropogenic impact of agricultural activities.

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*Climate-friendly biogas may lead to nutrients entering the watercourses if the treatment of digestates and wastewater from biogas plants is not carefully planned.*
*The goal of the Sustainable Biogas project, funded by the EU's Interreg Central Baltic programme, is to promote the sustainability of biogas from a water protection perspective.*
*The project is implemented by the John Nurminen Foundation, the ELY Centre for Southwest Finland, the Finnish Biocycle and Biogas Association, Latvian State Environmental Services, and the Latvian Biogas Association.*