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Investigation of Waterlogged Land Area – A Case of Lithuania

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ABSTRACT

The existing drainage infrastructure in Lithuania fails to ensure proper land drainage due to the inefficient or complete malfunctioning of drainage collectors and drains. In some areas, surface water runoff is inadequate, resulting in the inability to effectively utilize land, as land areas become waterlogged. This waterlogging leads to financial losses for farmers, as excess moisture reduces soil fertility. In some cases, the land becomes inaccessible or even abandoned due to these issues. This study analyzes waterlogged areas in Lithuania, with a focus on soil types, terrain features, and variations in the spatial extent of waterlogged regions. An analysis of orthophotographic maps from 1995 to 2023 was conducted to assess changes in waterlogging within the study sites. A forecast of future waterlogging trends was also developed. Additionally, field research was conducted during the 2020–2024 period, which involved evaluating waterlogged areas in selected locations. The findings suggest that soils most commonly become waterlogged due to a combination of factors, including granulometric composition (with clay and peat soils being the most susceptible), unsustainable human activities (such as topsoil compaction), excessive rainfall (as Lithuania is located in a region with a moisture surplus), the condition of drainage systems (72% of which are degraded), and land relief (with waterlogging primarily occurring in depressions, valleys, and saddles). Based on the research, a classification of waterlogged areas was created. Waterlogged land was grouped into three categories based on its suitability for agricultural use. Soils were also classified by their granulometric composition and likelihood of waterlogging.

Keywords: soil waterlogging, waterlogged land, land monitoring, drainage problems.

INTRODUCTION

The planning of rational land use, water resource management, and the global impact of climate change are critical issues worldwide, especially in the context of agricultural crop production [Cammerino et al., 2024; Hyandye et al., 2018; Kalfas et al., 2024]. Agriculture is one of the most vulnerable sectors to climate change, with regions facing the dual challenge of requiring irrigation during droughts and water regulation during periods of heavy rainfall [Jiang et al., 2024; Scatolini et al., 2024]. The distribution of water resources globally is uneven, with some regions experiencing abundance while others struggle with severe shortages [Li et al., 2020; Suvendran et al., 2024]. Droughts can significantly impact crop yields, with serious consequences for global and regional food security [Eslamifar et al., 2024; He et al., 2024; Novaes et al., 2024]. It is essential to recognize that atmospheric precipitation is a fundamental component of the hydrological cycle and a primary source of surface water [Yang et al., 2024; Zhu et al., 2024]. In agricultural regions with higher precipitation, such as Lithuania, well-functioning drainage systems provide considerable benefits. These include increasing the amount of arable land, facilitating access to fields with larger and more efficient machinery, and improving conditions necessary for plant growth, including moisture regulation and soil aeration. This enables the achievement of maximum crop yields [Hu et al., 2024; Li et al., 2024].

In Lithuania, there are 2.978 million hectares of drained land (47% of the country's territory or 87% of agricultural land). Lithuania, based on the drainage infrastructure in agricultural fields, is one of the countries with the most drained land in the world. The rapid development of Lithuania's drainage systems took place during the Soviet era, specifically between 1960 and 1990. As a result, the current drainage systems are now 70–80 years old. The drainage systems installed during the Soviet period in Lithuania are approaching the end of their operational life. Nowadays, most of these systems are worn out and no longer function effectively. It is estimated that €3 billion would be needed to repair and renew the entire drainage system. To maintain the proper functioning of drainage networks alone requires an annual investment of approximately €70 million [Adamonytė et al., 2013; Bastienė et al., 2020]. However, due to a lack of funding, Lithuania is currently facing a situation where drainage systems operate poorly, resulting in waterlogged soils [Grygelaitis, 2017; Juknevičienė et al., 2021].

Given the current situation, the research aims to determine the intensity and causes of waterlogging in Lithuanian territories. It seeks to assess how much waterlogging is due to malfunctioning drainage systems and how much is influenced by other factors.

MATERIALS AND METHODS

The research object was selected waterlogged agricultural land in different geographical regions of Lithuania. The study focused on three areas from different municipalities (Fig. 1), with the research on waterlogged areas conducted during the 2020–2024 period.

The studies were conducted in parts of the Kaunas District Municipality, Kalvarija Municipality, and Rokiškis District Municipality. Municipalities located in the Southeastern Lithuania and Žemaitija Highlands were not selected for the study, as they are classified as low-yield lands according to the General Plan of the Republic of Lithuania regarding the differentiation zones of agricultural territories.

Figure 1. Selected municipalities for the study in Lithuania

The tasks of this study are to determine the levels of waterlogging in selected areas by establishing criteria for identifying waterlogging levels, to analyze changes in waterlogged areas over a 30-year period using orthophotographic maps, and to identify the causes of waterlogging and assess factors for predicting future waterlogging.

This study is relevant because the drainage systems in Lithuania are worn out and no longer fulfill their functions. The amount of precipitation in Lithuania exceeds the amount of water evaporated by approximately 1.48 times, placing the country in a zone of moisture surplus. The average annual precipitation in Lithuania was 612 mm in 2019, 628 mm in 2020, 708 mm in 2021, 675 mm in 2022, and 722 mm in 2023. On average, excessively wet lands account for 52% of the country's territory. Due to varying amounts of precipitation, the soil's capacity to absorb and evaporate excess moisture, temperature variations, and the poor condition of both neglected and newly uninstalled drainage systems, waterlogging occurs unevenly across different areas. The extent of waterlogged lands varies, new areas emerge, and the waterlogging levels of existing areas change. Thus, it is crucial to frequently update existing data and take all possible actions to reduce or eliminate waterlogging of land surfaces. It is necessary to identify the causes of waterlogging in agricultural lands and provide recommendations on how to halt the waterlogging of these plots. The study is also relevant for neighboring geographical zones or states facing similar situations regarding the condition of drainage systems and/or similar granulometric composition of soils.

During the research, the analysis of waterlogged land areas utilized the following methodologies: spatial data analysis, field studies, analysis of orthophotographic maps data, data grouping. The field study was conducted from 2020 to 2024, in early spring, at a time when water excess prominently highlighted the negative factors of poor drainage. The study identified waterlogged areas, monitored changes during the analyzed period, and observed these areas again (in late spring) to assess how excessive surface water could have contributed to their waterlogging.

One factor that may influence water accumulation is soil structure. The granulometric composition of the waterlogged areas was evaluated. Soil composition was determined using the soil spatial data set Dir_DR10LT available at www.geoportal.lt. The prevailing surface granulometric composition was assessed according to Fere. A list of waterlogging coefficients for different soils was compiled. To create this list, the soil‘s granulometric composition and waterlogged level were evaluated, and the coefficients were coordinated with four experts in geology and agriculture in Lithuania. The projected saturation coefficients provided can be used to predict the likelihood of future waterlogging. In analyzing waterlogged land areas with poorly functioning drainage systems, the relief was also evaluated. The relief in orthophotographic maps was delineated using a relief mapping tool. Once the waterlogged areas were identified, all land areas were classified into three levels based on the degree of waterlogging. The criteria and examples for these levels are presented in the study: Level I indicates light waterlogging, Level II indicates moderate waterlogging, and Level III indicates severe waterlogging.

To further investigate changes in the areas of waterlogged land, the following orthophotographic maps were analyzed: ORT10LT (2021–2023), ORT10LT (2018–2020), ORT10LT (2015–2017), ORT10LT (2012–2013), ORT10LT (2009–2010), ORT10LT (2005–2006), ORT10LT (1995–1999) – digital raster orthophoto map of the Republic of Lithuania. The study utilized orthophotographic maps from 1995 to 2023 at a scale of 1:10,000. This detailed study allows for a deeper understanding of changes in land conditions and aids in identifying specific issues faced by the agricultural sector.

RESULTS AND DISCUSION

Causes and problems of land waterlogging

The preservation and appropriate use of arable land is a globally relevant task. Due to natural reasons, the use of some areas for agriculture is complex. One natural problem is the excess of water, and its solution involves draining areas suitable for agricultural activities. Globally, areas with heavy granulometric composition and high groundwater levels are often drained to improve agricultural operations. Scientific studies related to the installation of drainage systems in arable land emphasize that this impacts rational land use. The protection of arable land and the establishment of drainage systems are crucial for ensuring food security, social stability, and sustainable development [Zhou et al., 2021]. It is essential to regulate the amount of water in arable land to ensure rational land use [Vlotman et al., 2020; Sousa et al., 2022; Wu et al., 2022]. When considering land as a means of production, it is crucial to maintain the quality of land resources and environmental safety while meeting the land needs of the population [Adizovna et al., 2023; Yusupjonovich, 2020], as well as in the production of agricultural products and the supply of raw materials for industrial production [Adizova et al., 2021; Zatsepina et al., 2020]. Soil is a mixture of minerals, living and dead organisms (organic matter), water, and air. These four components interact remarkably, making soil one of our most important natural resources [Rahman et al., 2023]. However, the world faces soil depletion, or degradation [Klevinskas, 2018]. In Lithuania, soil has lost 50-60% of its humus since 1991 [Liakas, 2019].

Drainage systems aim to dry smaller, seasonally and temporarily flooded, swampy land areas. Waterlogging has a significant negative impact on grain production in all regions of the world with high precipitation and undeveloped drainage systems. For example, in Australia’s grain industry, waterlogging during rainy years can reduce wheat yields by as much as 40–50%. The establishment of drainage systems is particularly important for the most efficient use of farmland [Adizovna et al., 2022; Bhunia et al., 2021], ensuring the maximum satisfaction of both landowners‘ and land users‘ economic interests [Fetai et al., 2022; Martyn et al., 2019]. Drained soils in the United States are among the most productive [Sands, 2018]. In agricultural areas, drainage systems improve field working conditions and help regulate soil moisture levels [Mika, 2017; Petel, 2020]. In the United Kingdom, improved drainage has been observed to yield numerous positive outcomes in fields: better seedling emergence, yield, and quality [Hill et al., 2015].

Relief also plays a significant role in the formation of waterlogged areas. In depressions or even small indentations, greater amounts of snow accumulate during the cold season and remain in these low-lying areas. In spring, as a result of higher snow accumulation, pools and wetlands form, potentially leading to the destruction of all existing vegetation in the soil. Water flowing down from higher soil elevations can clog drainage ditches with sediment, washing away the fertile humus layer from the soil. The likelihood of waterlogging increases with the slope of the plot, elevation above sea level, and poor soil characteristics. Land areas in undulating relief have a higher risk of waterlogging during rainy periods than areas in higher elevations [Yossif, 2022; Křeček et al., 2019]. Water runoff regulation is crucial not only for collecting and draining surface water but also for reducing erosion. This problem arises in large drained, uneven relief areas. To prevent surface erosion, it is advisable to establish a denser network of drains. Natural drainage occurs even without human intervention, according to the landscape's topography and the soil's properties. However, when the relief and soil do not facilitate the timely removal of unwanted water, the installation of artificial drainage becomes necessary.

The risk of land waterlogging is also related to soil composition. The most widespread and damaging soil processes include nutrient leaching, erosion, compaction, acidification, organic matter decline, crust formation, and waterlogging. Compacted soil can cause adverse changes—during periods of excess moisture, the soil becomes waterlogged [Feiza, 2016]. In heavy soils, surface water accumulates on the soil surface, similarly saturating both higher and lower soil locations.

Numerous studies indicate that the cultivation of agricultural crops also affects optimal soil water regime management [Tokarev et al., 2022], but it has been theoretically and practically proven that waterlogged land areas have low agricultural land use potential [Wang et al., 2022]. Prolonged waterlogging leads to the formation of a low-value soil layer on the surface. Agricultural losses due to temporarily flooded or saturated soils are a persistent problem in many countries [Kaur et al., 2020; Kaur et al., 2017]. Excessive soil moisture, resulting from extreme rainfall in early spring, can reduce yields by up to 30% [Ahmed et al., 2023; Nash et al., 2015]. Waterlogged soils are also affected by water erosion, which further diminishes profitable farming and fails to meet the good agricultural and environmental condition requirements for agricultural land. Protecting soil from erosion and improving the fertility of agricultural landscapes are common environmental issues that have recently intensified [Kaminskyi et al., 2024]. Failing to meet the good agricultural and environmental condition standards may result in land users losing access to direct subsidies (also known as direct payments) [Pipíšková et al., 2023].

In the context of climate change, selecting and adjusting crop cultivation systems in moisture-deficient and risky farming zones is crucial for ensuring production profitability [Pichura et al., 2024]. One of the main challenges we face is the increasing climate changes and extreme weather events (e.g., droughts, floods, heavy rains), as these changes lead to irregular water supply, a reduction in agricultural land areas, and contribute to land degradation. Waterlogged areas also cause land degradation [Erian et al., 2023]. In the context of global climate change, drainage is an urgent issue for achieving high agricultural yields. Waterlogged lands negatively impact soil fertility [Pichura et al., 2023]. Analyzing the impact of drainage has shown it to be important not only in agriculture but also in engineering infrastructures. To mitigate the effects of heavy rainfall, which brings significant amounts of water, good drainage through melioration systems must be ensured. Water is a substance capable of penetrating all structures and surfaces, whether clay or concrete. This phenomenon can cause problems, as it can saturate essential structures such as dams, which can directly affect objects on the land's surface. Due to rapid urbanization and climate change, not only agricultural areas but also urban flooding disasters frequently occur, causing significant economic damage and threatening public safety. Understanding the main urban flooding factors significantly impacts the reduction of flooding [Liu et al., 2023].

Waterlogged land areas can also be investigated using remote methods. The works of foreign authors substantiate the need to develop multidimensional soil maps to make scientifically grounded decisions regarding soil drainage at all levels. Integrating spatial data on soil and soil-forming factors is a critical issue in soil science [Nikiforova et al., 2019; Thorslund et al., 2017]. Various datasets integrated into a geographic information system help monitor land use changes [Meng et al., 2022]. A 50-year analysis using remote sensing data indicated that soil waterlogging during rainy periods is periodic, with no clear trend of increasing area [Shapovalov et al., 2020].

In analyzing scientific research on the increase of waterlogged areas in arable lands over recent decades, it has been noted that retrospective soil and land cover monitoring methods are applied. Remote monitoring is also conducted [Koroleva et al., 2019]. In the scientific and practical communities, soil and other spatial planning documents for waterlogged areas are being compiled. Such maps clearly depict the surface areas of waterlogged land, which are represented in various shaded colors according to the degree of waterlogging [Dagar, 2013].

Changes in waterlogged areas

An analysis of orthophotographic maps (scale 1:10,000) was conducted. The study examined an area of nearly 100 square kilometers using these orthophotographic maps. Analyzing seven orthophotographic maps from 1995 to 2023 revealed that the extent of waterlogged areas increased during this period (Table 1).

The average size of a single waterlogged area increased from 1.7 hectares to 3 hectares. Based on the analysis of the orthophotographic maps, it was found that the area of waterlogged lands is increasing annually. The most significant increase in the size of waterlogged areas occurred after 2013. A forecast is being made regarding the anticipated increase in area in the future (Fig 2).

If the current situation persists, the area of waterlogged lands will continue to increase, and by 2060, the extent of waterlogged areas will be double what it is today. An example of the changes in one of the studied areas is presented in the orthophotographic map (Fig. 3).

Table 1. Waterlogged areas identified in orthophotographic maps in the studied locations

Year	Size of waterlogged areas (ha)	Quantity of waterlogged areas	Average size of a single area (ha)
1995-1999	274	164	1.67
2005-2006	325	165	1.97
2009-2010	479	162	2.96
2012-2013	472	160	2.95
2015-2017	539	179	3.01
2018-2020	569	196	2.90
2021-2023	550	192	2.86

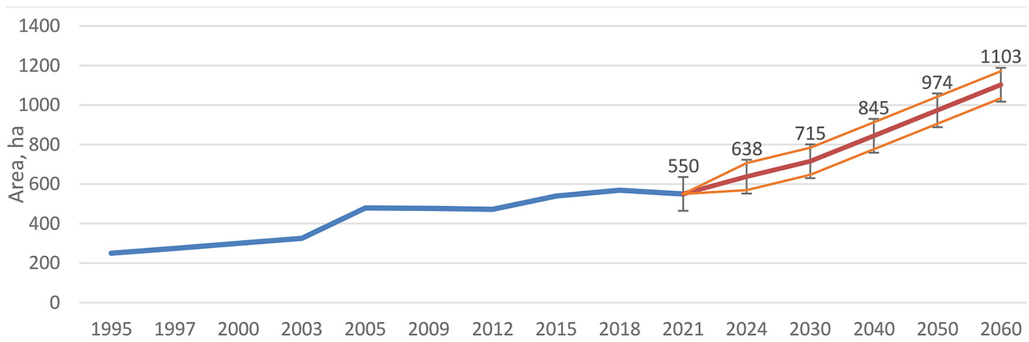


Figure 2. Forecast of changes in waterlogged areas

Figure 3. Condition of waterlogged areas in orthophotographic maps from (a)1995, (b) 2005, (c) 2015 and (d) 2023 years

The changes in the area over 30 years are presented, showing a long-term state of waterlogging. According to the spatial soil data set Dir_DR10LT, peat is predominant in the area. Using orthographic data, signs of waterlogging and swamp formation can be monitored. Field studies of this area have revealed that the area and shape of waterlogged land remain unchanged, although the level of waterlogging in the soil varies (Fig. 4).

During the study, field verification was conducted using drone inspections to assess whether the representation of waterlogging levels in the orthophotographic maps aligns with the actual conditions on the field. Based on this research, a classification system for waterlogging levels is created. When analyzing orthophotographic maps, it is essential to consider that these maps are created during different time periods. Level I waterlogging may be less discernible, while Levels II and III can be observed in the orthophotographic maps, regardless of extended dry periods.

Classification of waterlogging levels

All waterlogged land areas were classified into three levels. The identification criteria and examples for each waterlogging level are presented below.

Level I waterlogging: areas classified under Level I have slightly waterlogged soils. These plots exhibit mild waterlogging, typically occurring after rainfall events. The waterlogging is temporary and does not cause significant long-term damage to the soil structure or agricultural productivity (Fig. 5).

Level I waterlogged areas, as identified through orthophotographic maps, are characterized by smooth, dark-toned patches that are a few shades darker than the surrounding soil, appearing sporadically throughout the surveyed area. These areas typically exhibit surface-level soil waterlogging, where crops show signs of slight water saturation. While agricultural machinery can still be used on these plots, the consistent pressure from heavy machinery may further increase soil moisture, quickly elevating the level of waterlogging. This can result in issues related to soil productivity, necessitating additional measures to manage soil moisture levels effectively.

Orthophotographic maps also identify Level II waterlogged areas, where the soil is moderately saturated with moisture. These areas are easily distinguishable by more defined contours, with the color of the waterlogged surfaces being noticeably more prominent compared to non-waterlogged

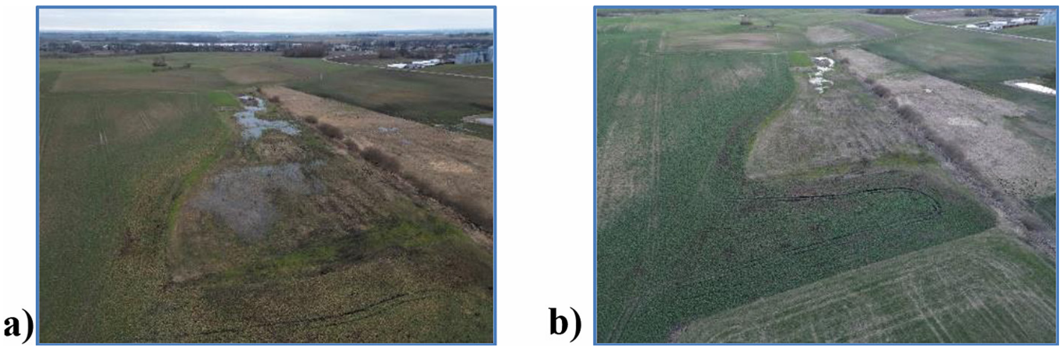


Figure 4. Waterlogged land area in the field for (a) 2022 and (b) 2024 years

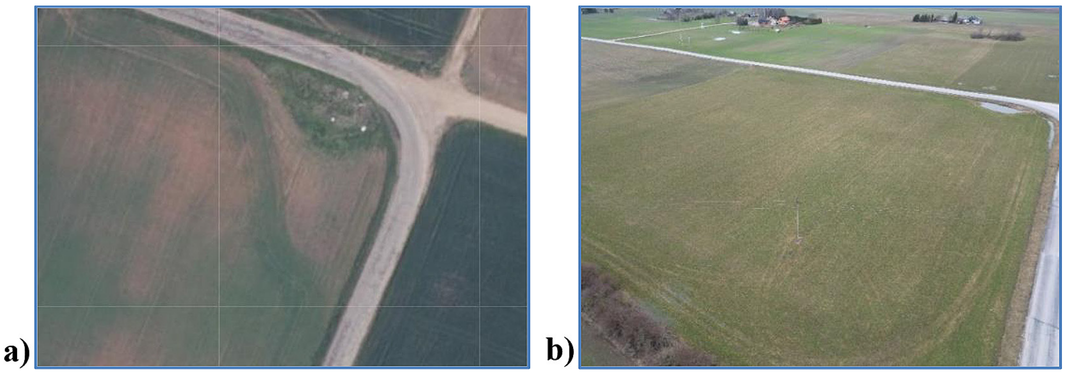


Figure 5. Level I waterlogged land (a) in an orthophotographic map (source: www.geoportal.lt) and (b) in the field

soils, based on soil type. This suggests that Level II waterlogging has a moderate impact on land conditions and may require special attention and management to ensure optimal moisture levels and create favorable growing conditions for crops (Fig. 6).

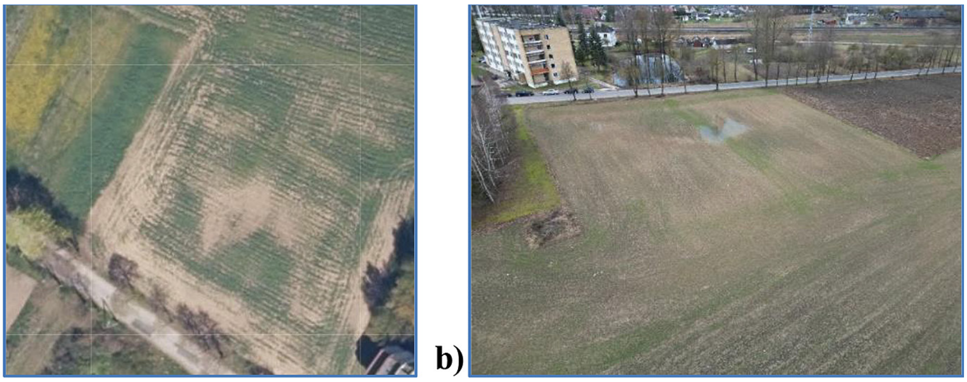
At this level, waterlogging is characterized by deep, large-scale flooding, where significant amounts of water accumulate. The shape and depth of these waterlogged areas remain stable regardless of changes in surrounding conditions. Due to the inability to cultivate these waterlogged lands, farmers face losses as they are unable to use these areas. This situation highlights the need for effective water drainage management and soil moisture control to minimize agricultural losses and ensure sustainable land use.

Orthophotographic maps clearly show that Level III waterlogged areas are heavily saturated with water. The color of these plots contrasts sharply with non-waterlogged soils, and standing water is visibly apparent (Fig. 7). This situation can significantly impact land use and surrounding agricultural activities. Special interventions and measures may be required to manage moisture levels effectively, ensuring agricultural sustainability and efficiency.

These land areas are highly saturated with moisture, which persists for extended periods, making them prone to transitioning into wetlands. Due to the constant presence of moisture, these surfaces are often overgrown with grasses and marsh vegetation. This ecological condition requires special attention and management, as the wetland formation process can have various negative impacts on the environment and agricultural activities. These may include habitat loss, moisture stress for plants, the spread of pests and diseases, degradation of water quality, and reduced biodiversity. Therefore, it is crucial to implement measures to manage and monitor these areas effectively to preserve the environment and ensure sustainable land use.

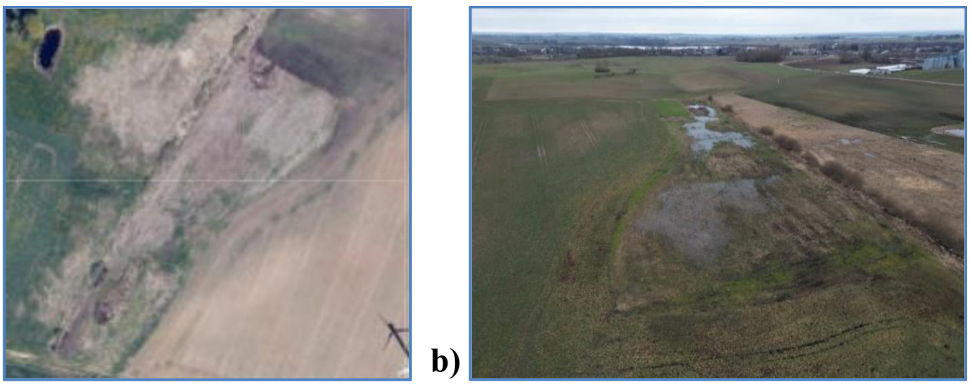
Soil waterlogging assessment

Based on orthophoto maps from different periods and field survey data identifying waterlogged areas, a granulometric analysis of the soils confirmed the hypothesis that waterlogged areas are primarily due to soils that retain moisture. The accumulation of high moisture content



a) b)

Figure 6. Level II waterlogged land (a) in an orthophotographic map (source: www.geoportal.lt) and (b) in the field



a) b)

Figure 7. Level III waterlogged land (a) in an orthophotographic map (source: www.geoportal.lt) and (b) in the field

prevents evaporation, leading to soil saturation and waterlogging (Table 2).

Clay and peat soils are the most prone to waterlogging. In Lithuania, peat soils cover 6.4% of the total land surface. In areas where peat is the dominant soil component, long-term moisture retention, including peatland formation, is observed. These waterlogging trends are clearly visible in the orthophotographic maps (as seen in the analysis of Figure 3).

A comparison of the granulometric composition of soils with their respective waterlogging levels has been performed, leading to the recommendation of a list of soil granulometric composition impact coefficients (Table 3).

The coefficients are categorized from 0 to 5, where 0 indicates no probability of waterlogging, 1 indicates a low probability, 2 indicates a moderate probability, 3 indicates a high probability, 4 indicates a very high probability, and 5 indicates that the area will become waterlogged unless there are functioning drainage systems in place. The coefficients established by the authors are based on the analysis of orthophotographic maps to identify flooded areas and moisture levels.

In determining the values of these coefficients, the local soil conditions were assessed, and a comparison of moisture levels and soil types was conducted. The list of coefficients was compiled after consultation with four experts in the fields of geology and agriculture. These established coefficients can be used to forecast the future usage prospects of agricultural lands in areas with excess water.

Another cause of waterlogging evaluated is the relief of the terrain. Topographical irregularities are a significant factor contributing to soil moisture retention. In areas with uneven relief, waterlogging tends to expand further due to continuous water accumulation, leaching of soil materials, and the effects of intense water erosion. This is clearly observable when analyzing orthophotographic maps. In many locations examined for these reasons, it has been noted that waterlogging has been intensifying every few years. In areas with soil depressions, water quickly accumulates from higher ground, which encourages moisture retention. This phenomenon is particularly characteristic of areas with stagnant runoff (Fig. 8).

Significant topographical undulation encourages water to accumulate in low-lying areas. The relief of waterlogged regions was assessed, revealing that the highest probability of waterlogging is found in depressions, saddles, and valleys.

The study determined that 35% of the areas became waterlogged due to non-functional drainage systems and the soil‘s ability to retain moisture from the surrounding environment. The remaining

Table 2 Granulometric composition of waterlogged areas

Predominant soil granulometric composition	Number of waterlogged areas		Waterlogging level (early spring/late spring)		
	Early spring 2024	Late spring 2024	I	II	III
Sand	0	0	0/0	0/0	0/0
Loamy sand	4	3	3/2	1/1	0/0
Loam	18	13	13/9	3/2	2/2
Clay	76	74	12/10	28/28	36/36
Peat	102	102	1/1	39/39	62/62

Table 3. Soil waterlogging probability coefficients

Soil composition	Coefficient	Soil composition	Coefficient
Sand	0	Dusty light loam	2
Cohesive sand	0	Dusty medium loam	2
Sandy loam	1	Dusty heavy loam	3
Light sandy loam	2	Sandy clay	3
Heavy sandy loam	3	Dusty clay	3
Medium loam	3	Clay	5
Heavy loam	4	Peat	5
Silty sandy loam	1	Gyttja	5

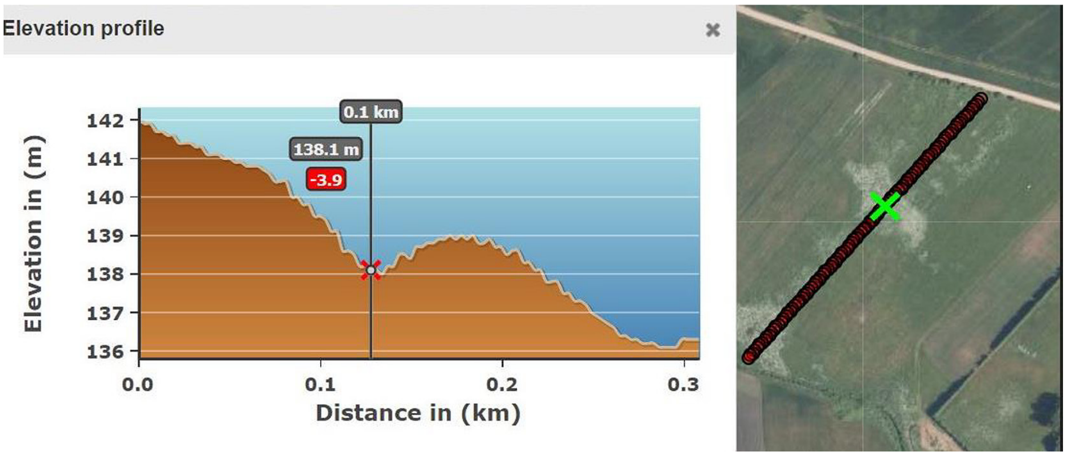


Figure 8. Relief of the waterlogged area in an orthophotographic map (source: www.geoportal.lt)

65% of waterlogging was attributed to the terrain's relief. A follow-up study conducted in late spring indicated that the extent of waterlogged areas had decreased by approximately 25% (see Table 4).

Another cause of waterlogging is beavers. Water from drainage systems has nowhere to flow and accumulates on the field surface. Prolonged blockage by a beaver dam can completely damage drainage pipes, which may become clogged with mud and other river sediments.

Soil waterlogging can be influenced by human activities and efforts to reduce or even neutralize this issue. One temporary method to slow down or reduce soil waterlogging is soil cultivation or the addition of new soil, which decreases soil compaction and reduces the likelihood of excessive water saturation. Cultivation also facilitates soil drying and significantly decreases the probability of waterlogging. A long-term solution to combat soil waterlogging is the installation of collectors. This approach ensures that even after prolonged rainfall, the land will not remain saturated for long periods. It allows for better management of moisture levels and maintains the soil in optimal conditions for plant growth.

Table 4. Field study data

Study period	Size of waterlogged areas (ha)	Number of waterlogged areas
Early spring 2020	704	204
Late spring 2020	482	180
Early spring 2022	675	199
Late spring 2022	530	188
Early spring 2024	681	200
Late spring 2024	524	192

CONCLUSIONS

In all scientific and practical studies, the importance of regulating water levels is emphasized, as achieving this leads to greater resilience in the agricultural sector under changing conditions. The research revealed that 35% of the analyzed areas were waterlogged due to non-functional drainage systems and the granulometric composition of the soil. The study found that clays and peats are the most prone to waterlogging. Additionally, un-drained areas with peat soils account for 28% of the analyzed territory. The remaining areas experience waterlogging primarily due to the relief, which consists of moisture-retaining soils.

A comprehensive analysis of 100 square kilometers was conducted using orthophoto maps from 1995 to 2023. During this period, the amount of waterlogged land doubled. Previously observed only in un-drained lands, waterlogging is now also recorded in drained areas due to the dysfunction of drainage systems across all seven analyzed time periods.

Based on the orthophoto maps and field studies, a classification of waterlogging levels was developed, categorizing waterlogged areas into three levels based on their suitability for agricultural use. The study indicated that up to 50% of waterlogged areas, due to severe waterlogging (i.e., Level III), are unsuitable for agricultural purposes.

Through the analysis of waterlogged areas, waterlogging levels, and soil granulometric composition, soils were classified according to their composition and likelihood of waterlogging. It was found that clays and peats are the most likely to become waterlogged, whereas sands and cohesive sands never experience waterlogging.

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