LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES
UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN (Poland)
VITAUTAS MAGNUS UNIVERSITY (Lithuania)

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FOREWORD

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The journal includes original articles on land administration, land management, real property cadastre, land use, rural development, geodesy and cartography, remote sensing, geoinformatics, other related fields, as well as education in land management and geodesy throughout the Baltic countries, Western and Eastern Europe and elsewhere. The journal is the first one in the Baltic cou ntries dealing with the mentioned issues. Journal disseminates the latest scientific findings, theoretical and experimental research and is extremely useful for young scientists.

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CONTENT

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ANALYSIS OF THE LAND FUND OF THE REPUBLIC OF LITHUANIA

Puziene Ruta
Vilnius Gediminas Technical University

Abstract
The aim of the study is to analyse changes in agricultural land using recent data and to assess changes in ecological stability in Jurbarkas district. The study was carried out in the period 2010-2023. Land use area and ecological stability coefficients were calculated for the entire period, sequentially for each year. The area of tree and shrub varied considerably over the study period, ranging from 20.7 % to 60.8 %, that is, from one-fifth of the area of other land to three-thirds. The areas of wetlands, unused, and damaged land are decreasing during the study time. The urbanised areas were mainly concentrated in the areas with low ecological stability. The situation with ecological stability is not good in all the studied territories.
Key words: land fund, land use, change detection.

Introduction

Anthropogenic landscape change has been the dominant driver of landscape change in Europe for the last two millennia and more (Meyer and Turner 1994). Land use change is both a cause and a consequence of global environmental change. Land cover changes affect biogeochemical cycles, zoo and biodiversity, and contribute to climate change processes (Song et all. 2018). Anthropogenic activities associated with the redistribution of the Earth's resources have allowed humans to take land from natural vegetation and animal habitats, altering ecosystems, often to their detriment, and reducing freshwater and forest resources. While land use has long been seen as a local problem, it is becoming a global issue affecting biodiversity loss, pollution, and climate change. Humanity faces the challenge of finding a compromise between satisfying human needs and preserving ecological resources, reducing the impact on the environment (Folley et all. 2005). Land use change is driven by a synergistic combination of resource scarcity factors leading to increased production pressure on resources, changes in market opportunities, external policy interventions, loss of adaptive capacit, and changes in social organisation and attitudes (Lambin et all. 2003).
E. Tasser and Tappeiner (2002) and Tasser et al. (2007) argue that land use change is strongly influenced by road infrastructure development – if an area is accessible to transport, it is intensively used, and vice versa. Areas that are difficult to access are abandoned or used for grazing. They found that current vegetation is determined by current land use, and changes in land use determine changes in vegetation.
Over the past 70 years, land use has undergone radical changes that have significantly improved human well-being, met human needs, and promoted economic development. However, these changes have led to serious environmental problems (Perez-Soba et all., 2008; Winkler et. all., 2021). To address these problems and develop a sustainable land use model focused on natural resource management, it is necessary to study and analyse land use changes and their trends. Modelling land use change is an important way to anticipate alternative pathways into the future, through research that improves our understanding of the underlying processes of land use change (Veldkamp and Lambin, 2001).
The most common sources of land use data used in surveys are: satellite images, aerial photographs, maps and land registers. The advantages of surveys based on data from real estate registers are their relatively good availability, country-wide coverage and updating of data at regular annual intervals, as well as the direct possibility of linking data with published statistics on administrative units (Łowicki, 2008). This study will use data from the Real Estate Register, which can be accessed at https://nzt.lrv.lt/lt/statistine-informacija/lietuvos-respublikos-zemes-fondas/. Since land use and land area determine the coefficient of ecological stability of the territory and its change over time, the study determines the coefficients of ecological stability of the territory for the whole study period.
The aim of the study is to analyse changes in agricultural land using recent data and to assess changes in ecological stability in Jurbarkas district.
The objectives of the study are:
1. To assess the changes in land cover in Jurbarkas district and in the urbanised areas of Jurbarkas city and Smalininkai town in the period 2010-2023.

2. To determine the coefficient of ecological stability in the areas selected for the study and assess its change. To assess the ecological stability of the territories.

Methodology of research and materials

Monitoring of land use change is relevant for identifying major trends in land use change, analysing potential drivers of change, and tracking trends in Land Fund use and their evolution. The statistics provided by the Land Fund distinguish the following types of land use:
1. Area occupied by agricultural land:
a) Arable land
b) Orchards
c) Meadows and natural pastures
2. Forest land
3. Roads
4.Built-up area
5. Land occupied by water bodies
6. Area occupied by other land:
a) Tree and shrub plantations
b) Wetlands
c) Damaged lands
d) Unused land
The selected period is 2010-2023, i.e. the period when Lithuania has been a member of the EU for 6 years already. EU payments and requirements for agriculture have already been partially established, but changes in them and in socioeconomic factors have influenced and continue to influence land use change.
The study area is Jurbarkas district, located in the south-western part of the country. The southern part of the district borders the Nemunas River, the largest river in Lithuania.

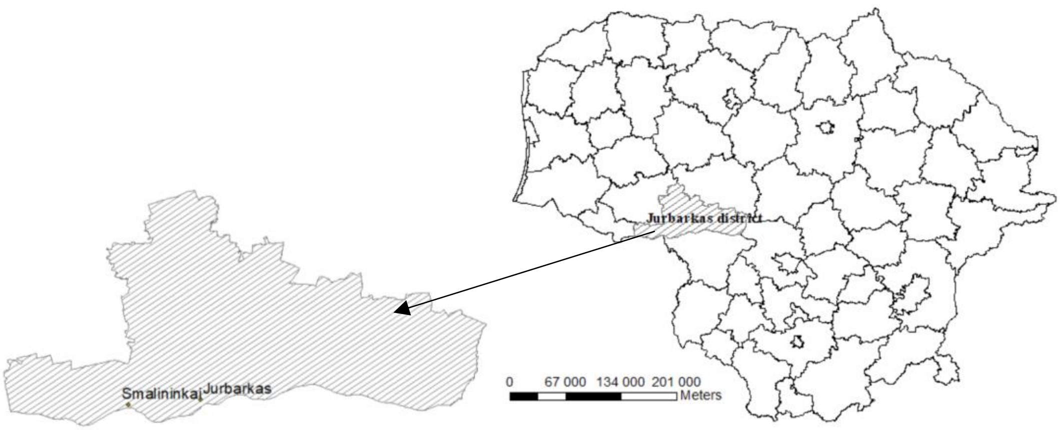


Figure 1: Administrative division of the Republic of Lithuania; Jurbarkas district

The district covers an area of 1507 km2 and is located in the Karšuva Lowland, where the Earth's surface slopes downwards from north-east to south-west, from 90 m in the eastern part of the district to 8 m near the Nemunas River. The population density is 17 inhabitants per km2. The soil of the district has one of the highest productivity scores in the republic, 49.77, and the conditions for agricultural activity are particularly favourable. In the western part of the district, where the land productivity is the lowest in the district, there is the Karšuva Forest. In the southern part, there are practically no forests along the Nemunas River.
During the research, the data of the Land Fund of the Republic of Lithuania were analysed using comparative and graphical methods, as well as the latest data.
An assessment of the changes in the ecological stability of the district territory during the selected period was carried out. Ecological stability was calculated according to the formula (P. Aleknavičius, 2008):

$$K_e = \frac{\sum(K_{es} * p_i)}{\sum p_i}$$

here Kes – coefficient of ecological stability of the type of land use, pi – area occupied by the type of land use, ha.

Territory is called ecologically stable when the ecological stability coefficient of the territorial unit is $K_e \geq 0.67$. A moderately stable territory is considered to have a coefficient of 0.51-0.66, a low stable territory has a K_e of 0.34-0.50 and an unstable territory has a K_e of 0.34.

Discussions and results

An analysis of the land use statistics provided by the Land Fund was carried out. The area of agricultural land in relation to the area of the district was calculated (Figure 2).

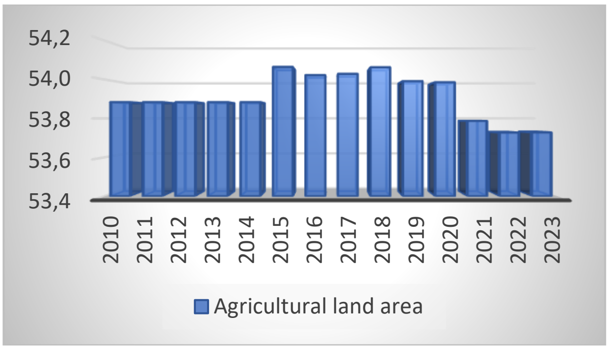
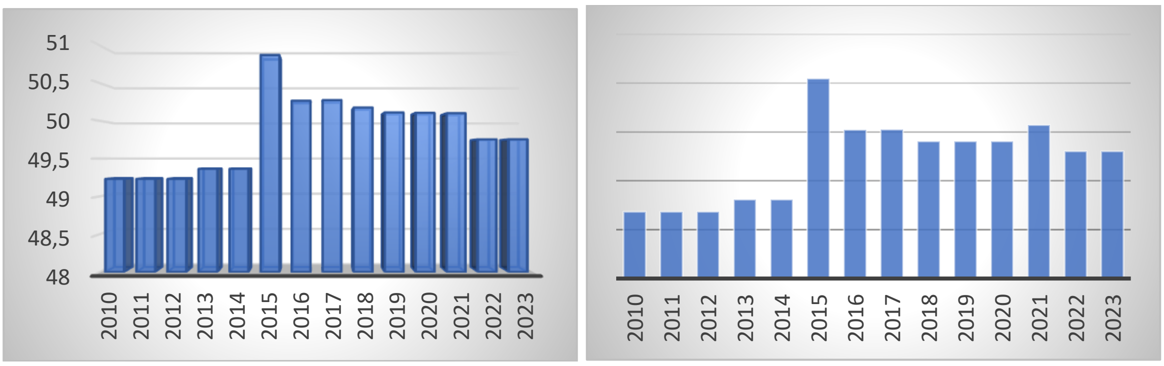


Figure 2. Agricultural land area, in percent

The predominantly fertile soils of the district make it favourable for agricultural activities. Figure 2 shows that land of this type occupies more than half of the total area of the district. Over the entire 13-year study period, the area varied from 53.7% to 54.1%. There is a slight increase from 2015 and a decrease from 2021. From 2022, the area of agricultural land is at its lowest level over the entire period, but this is a very small change of 0.4%.

The area of arable land, orchards, meadows and natural pastures as a percentage of the total area of the district and of agricultural land was calculated (Figure 3):



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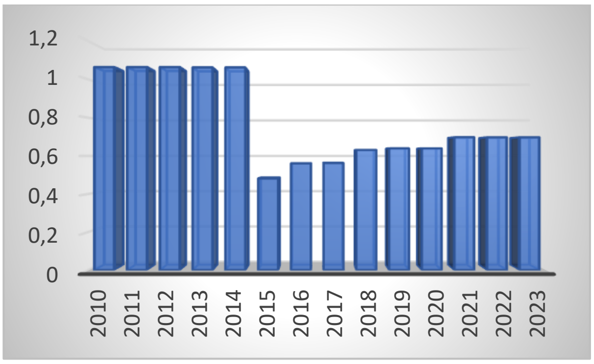

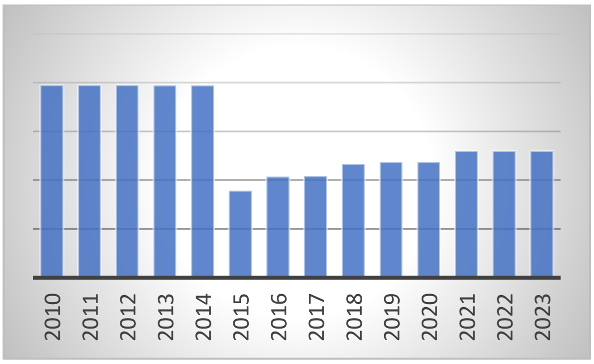

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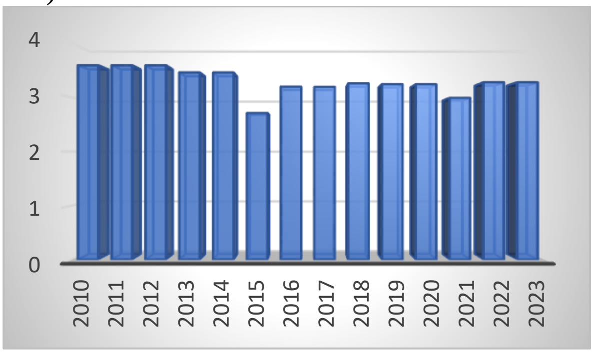
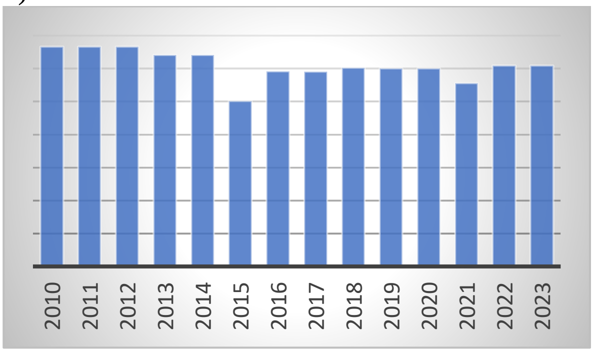




3. a) b)

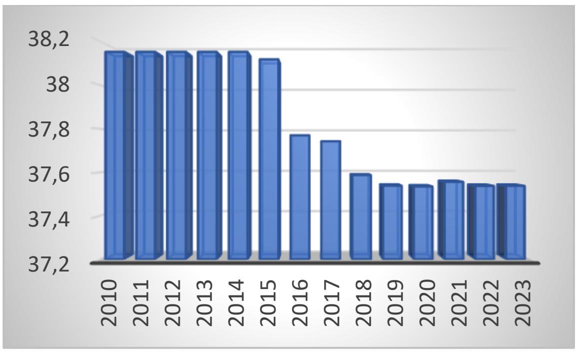
Figure 3: Proportion of cultivated agricultural area: 1. arable land, 2. orchards, 3. meadows and natural pastures; a) as a percentage of district area, b) as a percentage of total cultivated area

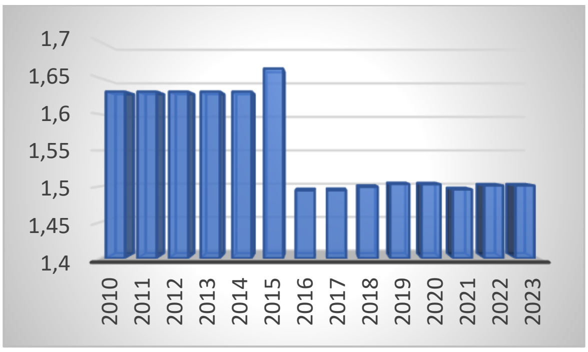
Arable land accounts for the majority of agricultural land (significantly more than gardens, meadows, and natural pastures), from 91.4 % (2010) to 94.1 % (2015). From that year onwards, the share of arable land declined slightly to reach 92.6 % in 2023. Despite the decrease observed since 2015, the area of arable land has increased by 725 ha over the whole 13-year period. Arable land accounted for 49.2 %-50,3% of the district area.

Gardens make up a very small proportion of agricultural land – only 1,2 -2 %. The area has decreased more than twice since 2015, from 2 % to 0.9 %. There has then been a slight increase to 1.3 %, but the original level has not been reached. As a proportion of the district's area, these areas cover between 0.6 % and 1.1 %. The area of gardens in the district is very small and there is no clear upward trend.

Meadows and natural pastures account for only 5.0 %-6.7 % of the agricultural area. This is more than the area occupied by orchards, but not as significant overall. For the district, the figure is only 2,7-3,6 %. The area of meadows and natural pastures has declined despite EU efforts to retain permanent pastures, greening payments since 2012 and the requirement for ploughing.

The share of other agricultural land in the area of the district is presented in Figure 4.





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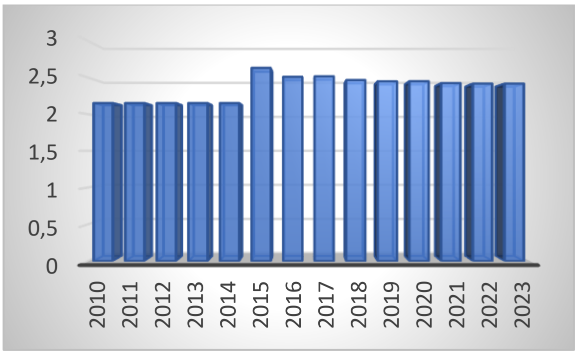

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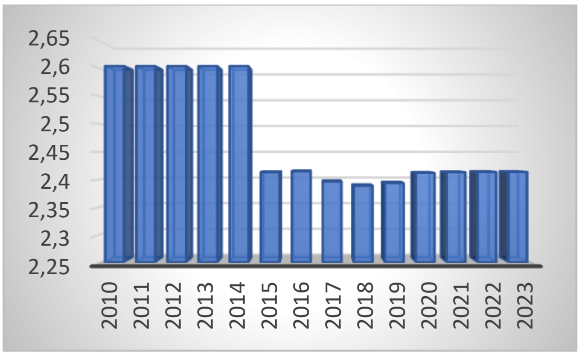

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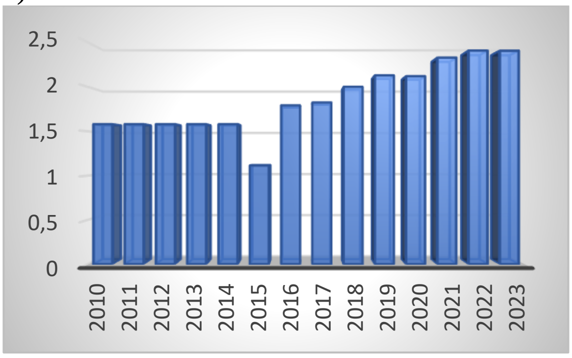
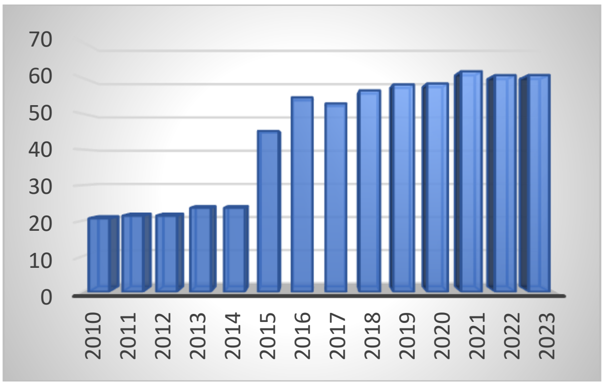


e)

Figure 4. Agricultural land as a percentage of district area: a) forest land, b) roads, c) built-up area, d) land occupied by water bodies, e) other land

Forest land occupies 37,5 %-38,2%. Since 2016, the area of forest land has steadily decreased from 38,3 % to 37,5%. Roads have also declined since 2016 by 0,1%. The built-up area has increased by 0.4 % since 2015, and has slightly decreased (0.2 %) since 2018. The water bodies have decreased by 0.2 % since 2015. The area of other land has varied between 1.6 % and 2.4 % over the period under study. In 2010 these areas were 1.6 %, in 2015 they dropped to 1.1 % and since 2016 they have increased steadily from 1.8 % to 2.4 %.

The study further determined the percentage composition of other land components in relation to its area and to the area of the district (Figure 5).



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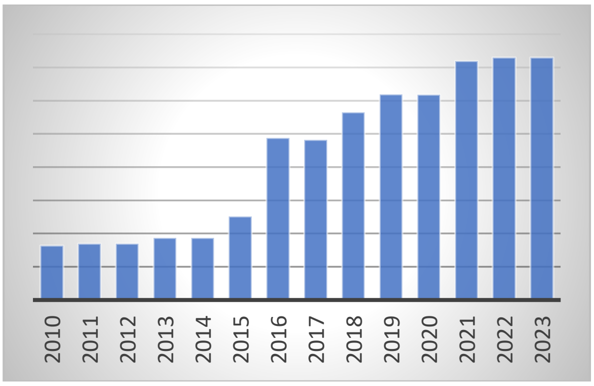

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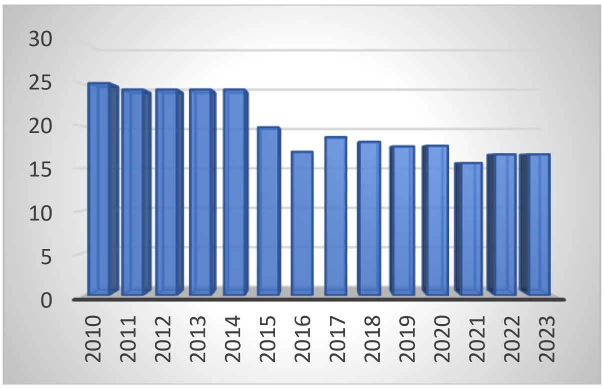

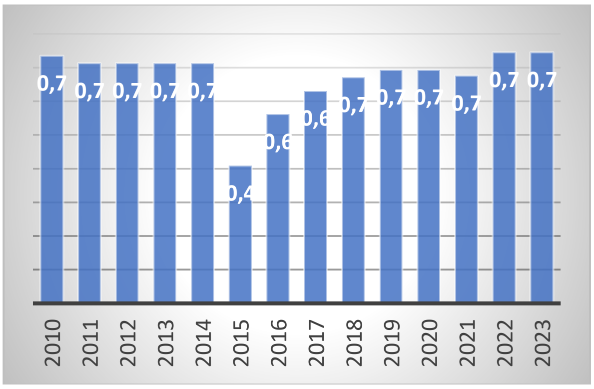

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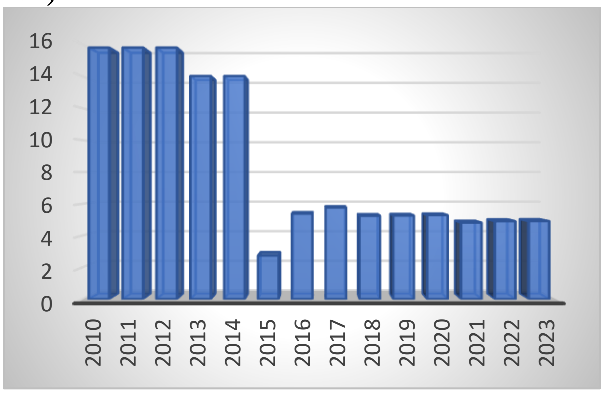

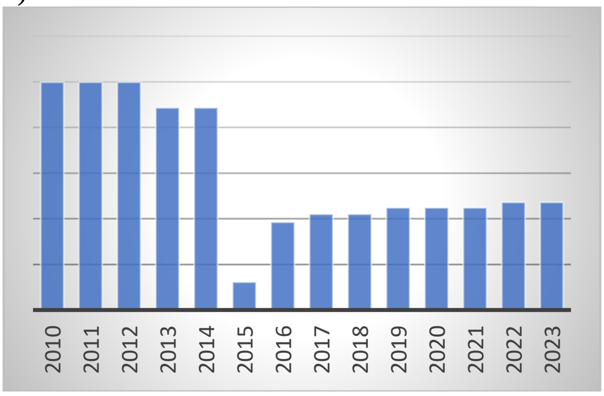

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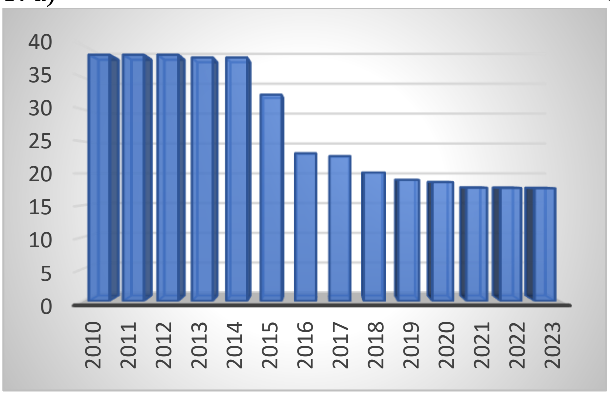

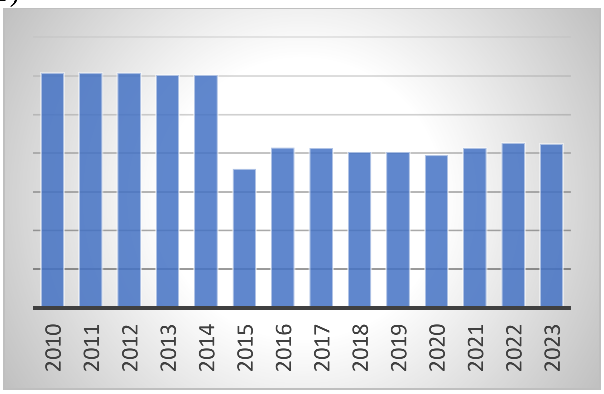

4. a) b)

Figure 5: Proportions of other land: 1. shrubland, 2. wetlands, 3. damaged land, 4. unused land; (a) as a proportion of total other land area, (b) as a proportion of district area

The largest proportion of other land in 2023 is shrubland and unused land. The area of tree and shrub plantations varied considerably during the study period, ranging from 20.7 % to 60.8 %, that is, from one fifth of the area of other land to three fifths. However, in terms of the area of Jurbarkas district, this figure ranged from 0.3 % to 1.5 %. Thus, at the district level, the area of these territories is very small. The area of wetlands, unused and damaged land is decreasing during the study period. Unused land in 2010 was 38.5 % of other land area and in 2023 it was only 17.7 %, which was only 0.4 % at district level.
The area of damaged land decreased from 15.8 % to 4.9 %, which is 0.2 % (2010)-0.1 % (2023) for the district.
As a follow-up study, ecological stability coefficients were calculated for the whole period, sequentially for each year. Ecological stability coefficients for soil types are presented in Table 1.

1 Table

Ecological stability coefficients

Land use types	Ecological stability coefficient of land use type
Arable land	0.14
Orchards	0.43
Meadows and natural pastures	0.65
Forest land	1.00
Roads	0.00
Built-up area	0.00
Land occupied by water bodies	0.79
Tree and shrub plantations	0.40
Wetlands	0.79
Damaged lands	0.00
Unused land	0.68

The resulting changes in ecological stability are presented in Figure 6.

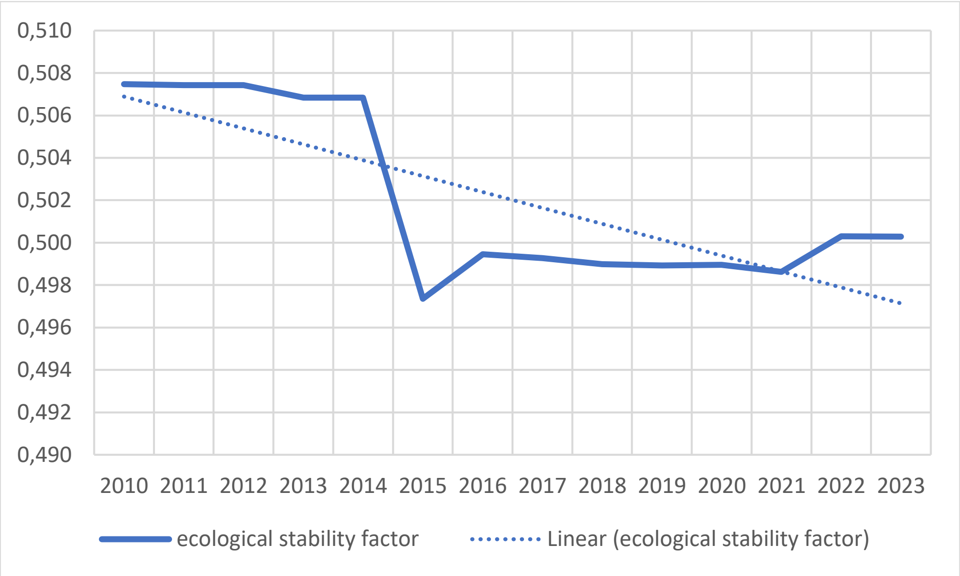

Figure 6: Changes in ecological stability in Jurbarkas district

From 2010 to 2015, Jurbarkas district was considered a moderately stable territory. Since 2015, the coefficient of ecological stability decreases from 0.51 to 0.49 and the territory becomes low stable. From 2022, the coefficient increases to 0.50 but does not reach the level of 0.51 to be classified as a moderately stable area. Reducing the area of arable land by 3,000 ha at the expense of 3,000 ha of grassland would move the area into the moderately stable category. However, this would require a change in the nature of agricultural production, which is unlikely.

Land Fund statistics show land areas in two towns in Jurbarkas district. Therefore, the study was continued to identify changes in the land area and ecological stability coefficients of Jurbarkas city and Smalininkai town of Jurbarkas district.

In Jurbarkas (Figure 7), the largest areas are occupied by built-up areas. During the period under study it decreases from 44.7 % to 33.4 %. Agricultural land is increasing from 14.2 % to 22.0 %.

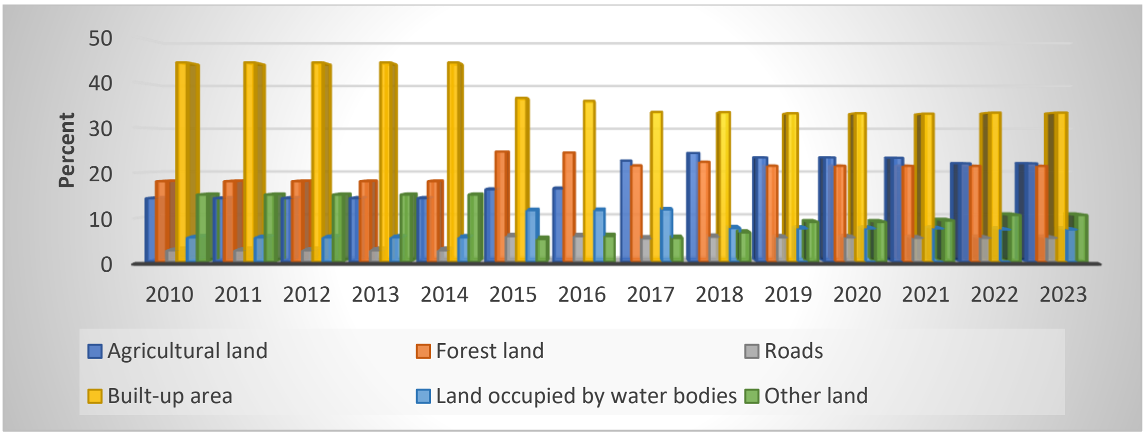

Figure 7. Change of land use in Jurbarkas from 2010 to 2023.

The area of forest land is also increasing from 18.0 % to 21.5 %. Road and water areas are also increasing, from 2.6 % to 5.4 % and 5.5 % to 7.3 % respectively. The area of other land decreases from 15.0 % to 10.5 %.
Calculated coefficients of ecological stability of Jurbarkas city, in 2010-2023.

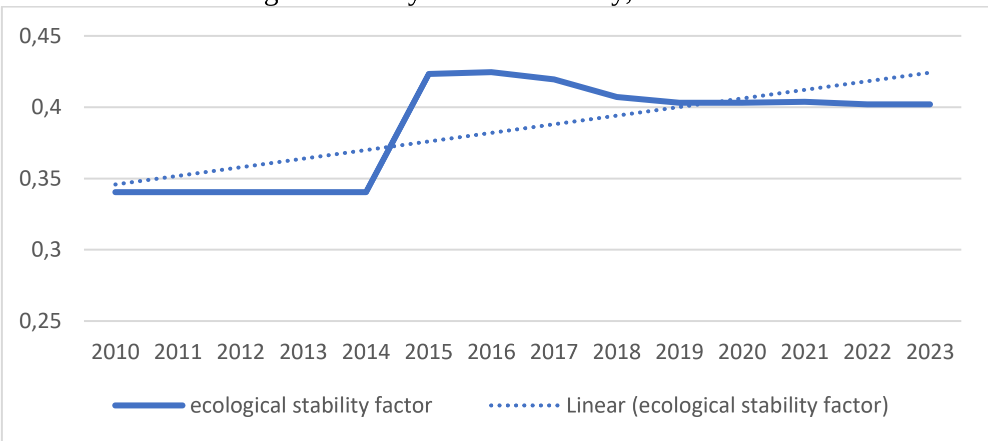

Figure 8: Changes in ecological stability in Jurbarkas

Jurbarkas is considered to be a low stability area. Since 2010, the ecological stability coefficient increases from 0.34 to 0.42 (2015), but the value of the coefficient subsequently decreases and reaches 0.40. Throughout the period under consideration, the ecological stability coefficient does not rise to 0.51 to place the city in the category of moderately stable area.
In Smalininkai (Figure 9), unlike in Jurbarkas, the built-up area increases from 22 % to 43 % – almost doubling. The number of roads is increasing from 3.2 % to 5.3 %. Agricultural land is increasing from 19.3 % to 38.2 %. The area covered by water increased from 1.0 % to 2.7 %.

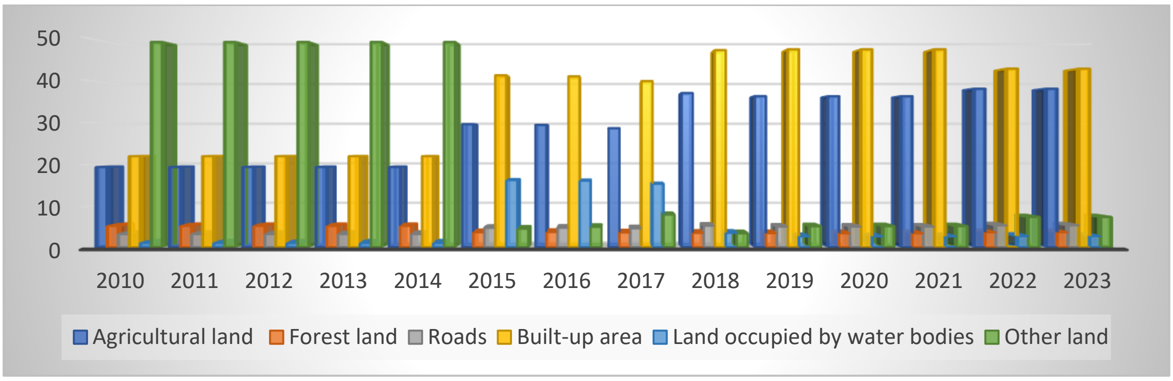

Figure 9: Land cover change in Smalininkai in 2010-2023

The area of land with high ecological stability, such as forests and other land, has declined. The area of forest has decreased from 5.1 % to 3.6 %. Other land decreased from 49.4 % to 7.3 % . The situation in this town in terms of the change of land use types is quite different from that of Jurbarkas. As a follow-up to the study, the ecological stability coefficient (Figure 10) was calculated for the period under study.

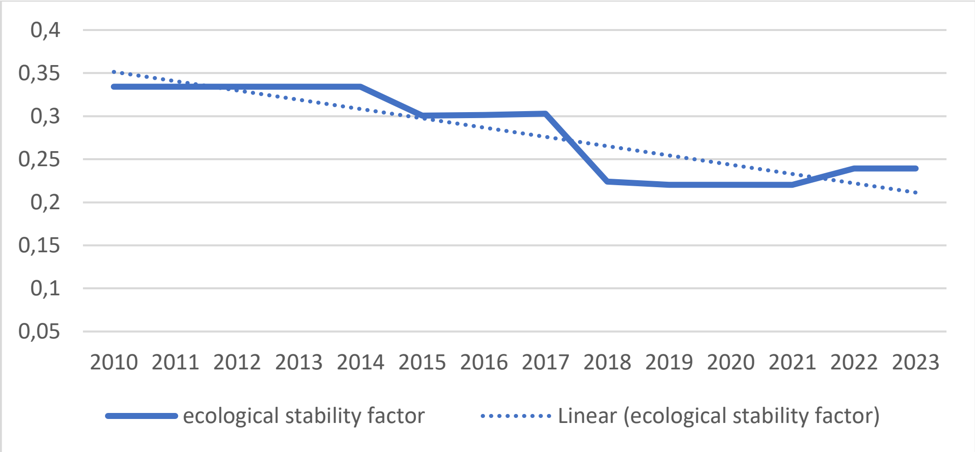

Figure 10: Changes in ecological stability in Smalininkai

The territory of Smalininkai is considered to be ecologically unstable throughout the whole study period. In 2010, it was still on the borderline of low stability, with an ecological stability coefficient of 0.33, close to the threshold of 0.34, which would make it low stable. As time went on and changes in land cover continued, the ecological stability of the urban area only decreased, reaching a coefficient of 0.22. From 2022 onwards, the ecological stability coefficient has risen above 0.02 to reach 0.24.
The ecological stability coefficient for the whole study area has been decreasing. Whereas an agrarian area is moderately ecologically stable, the situation is different in urbanised areas. The situation in Jurbarkas is better and positive trends can be observed there. However, in Smalininkai the ecological stability is only decreasing.

Conclusions and proposals

1. More than half of the territory of Jurbarkas district is occupied by agricultural land (53.7 %), of which 92.6% is arable land. Forest land accounts for the second largest area – 37.5%. However, while arable land area is increasing, forest land area is decreasing. Other land areas are small and account for only 8.7% of the total area. Due to the distribution and changes in the area of these land uses, Jurbarkas district is considered a district with low ecological stability. Until 2015, the district was classified as moderately ecologically stable.
2. The city of Jurbarkas belongs to the territories with low ecological stability throughout the study period. Since 2015, the coefficient of ecological stability increases from 0.34 to 0.41 and then slightly decreases to 0.40. The town of Smalininkai belongs to ecologically unstable areas throughout the study period, with the ecological stability coefficient, which was low in 2010, decreasing from 0.33 to 0.24.
3. The situation with ecologicall stability is not good in all the studied territories. In urbanised territories the situation is much worse than in non-urbanised ones. In Jurbarkas district the ecological stability has decreased but stabilised. The situation is particularly bad in Smalininkai, where ecological stability has remained stable throughout the study period. While in Jurbarkas the situation is improving, in Smalininkai the ecological stability of the area is deteriorating.

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RURAL SETTLEMENT PLANNING IN LATVIA: CRITERIA, PROCESSES, CHANGES OVER TIME

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Abstract
The aim of the study is to evaluate the main aspects of rural settlement planning in the Republic of Latvia. The object of research is rural settlements, specifically - villages. The article analyzes the development of rural settlements in Latvia. Types of classification of settlements, their official classification and changes over time are evaluated. The study found that the population is decreasing in the entire territory of Latvia, with the exception municipalities around the state capital Riga. This process also affects the structure of rural settlements in the counties, the number of villages and their role as development centers decreases. As part of the study, an analysis of the location and development of rural settlements in the Ventspils municipality, which is located in the north-west of Latvia, in the Kurzeme planning region, was carried out. According to the data of the State Land Service, the number of villages in the Kurzeme planning region decreased by 56, from 456 villages in 2016 to 400 villages in 2024. Among them, the number of villages in Ventspils municipality decreased by 38 during this period - from 92 villages to 54 villages.
Key words: rural settlement, village, development planning, population.

Introduction

The challanginf demographic processes can be observed throughout Europe, as a result of which rural areas are emptying, aging and, naturally, it is increasingly difficult not only to restore, improve and provide the necessary infrastructure and services, but also to maintain them at the current level. To address the aforementioned challenges, various planning approaches are being emphasized. These approaches prioritize the engagement of a strong and interested community, alongside other resources available within the local territory, which can be leveraged to foster development. Community initiative and participation play a decisive role in village planning (Zamarina, 2020). However, the inhabitants of an area do not automatically constitute a community. A community is formed by the civically active part of society and its mutual relations, including not only people with similar interests - in the specific case, the development of the local territory - but also a network of institutions that bring together different social groups and where mutual relations are formed - local shops, schools, churches, non-governmental organizations, etc. (Zamarina, 2020).

The importance of the community and its connection with village planning issues has been emphasized in several foreign studies devoted to the problems of rural development. (Rural Movements of Europe, S.a.). The village movement is based on efforts to build and develop communities and inspire residents to participate in the growth of local territories, thus strengthening democracy, promoting social inclusion, creating new business, service and employment opportunities.

In recent years, smart village planning has become a topical approach to village planning all over the world. Conceptually, the term "smart village" refers to rural settlements and communities that develop based on local strengths and resources (Zavratnik et.al., 2018). In Latvia, the campaign on the concept of smart villages and its application in rural development, adopting the European experience, was launched in 2021. The campaign was launched by defining the term smart villages, as well as, based on the European experience, determining the analysis of five criteria in the assessment of community development according to the principles of smart villages - management and decision-making in the community, population and its activity, implementation of innovative solutions, interaction and cooperation, identification and use of resources (Experiences of Smart Villages ...., b.y.).

The formation of communities and the active participation of residents in the development of villages and solving various problems attract residents to their places of residence, promoting pride in their homeland, its history, traditions, and thus reducing the outflow of residents to cities or even abroad. Therefore, the smart village movement plays a major role in rural development and maintaining the population. There is also a continuous decrease in the population in Latvia, as evidenced by the collected data on changes in the population in Latvia in the last two years (Tabl. 1).

Table 1

Population changes in the planning regions of the Republic of Latvia in the period from 2021 to 2023

No	Planning region	Population by year			Difference 2023 - 2021	
		2021	2022	2023	population	%
1.	Kurzeme	280 433	277 130	276 317	- 4 116	- 1.5
2.	Latgale	786 673	773 902	775 692	- 10 981	- 1.4
3.	Riga	853 796	850 353	860 142	+ 6 346	+ 0.7
4.	Vidzeme	324 741	321 666	321 890	- 2 851	- 0.9
5.	Zemgale	249 149	246 435	246 483	- 2 666	- 1.1
Total in Latvia		**2 494 792**	**2 469**	**2 480 524**	**- 14 268**	**- 0.6**

(Source: compiled by the authors to the data of Central Statistical Bureau of Latvia)

As can be observed, the population of Latvia is declining across most of its territory, with the exception of municipalities surrounding the capital, Riga, where it is increasing. Just in the last two years, the population of Latvia has decreased by almost one percent, the most in the Kurzeme and Latgale planning regions - by 1.5% and 1.4%, respectively. The most common reasons are migration, also the economic and social situation, as well as the low birth rate. As a result, rural settlements are also becoming empty. Therefore, the authors aimed to investigate the current state of rural settlements and their development trends in rural areas of Latvia.

Methodology of research and materials

Rural settlements, specifically villages, have been chosen as **the object** of this research. **The aim** of the study is to evaluate the main aspects of rural settlement planning in the Republic of Latvia. To achieve this goal, the following **tasks** have been set: 1) to analyze regulatory acts and special literature on settlement planning, 2) to analyze the structure and dynamics of population distribution and rural settlements in Latvia; 3) to evaluate the structure and development of rural settlements on the basis of a selected administrative territory.

In the research the laws of the Republic of Latvia and other regulatory documents that determine the classification of settlements, their criteria, previously conducted studies on the classification of settlements have been investigated. Also data, maps and other cartographic materials of the Central Statistical Bureau of Republic of Latvia, the Latvian Geospatial Information Agency and the State Land Service were used in the analysis. The research uses the statistical analysis method, the document analysis method, as well as the descriptive monographic method.

For a more detailed analysis and visualization of the research results, the Ventspils municipality, located in the northwest of Latvia, by the Baltic Sea, was chosen as the research area. Ventspils municipality, after the administrative territorial reform, is the tenth largest municipality in Latvia. The municipality consists of 12 rural territories and the town of Piltene. The total area of the municipality is 2457.63 km^2, its territory is crossed by the main state highway A10 Riga - Ventspils, several state highways of regional and local importance, as well as the railway line Riga - Ventspils. The coastline of Ventspils municipality along the Baltic Sea stretches for less than 97 km. The sea coast with its wide beaches affects business sectors in the coastal rural territories (Jurkalne, Uzava, Varve and Targale rural territories), where busineses are often related to tourism and fishing. Jurkalne's steep bank has become one of the most popular places for recreation (Mucenieks, 2022). The formation structure of settlements in Ventspils municipality was affected by geographical factors - forest massifs, swamps, separate agricultural lands, the sea coast, historical factors and transport structures - road and railway network. A more concentrated population structure has developed around the city of Ventspils, along the highways and on both sides of the Venta river. In the eastern and southern parts of the municipality, where the territory is covered by large forest massifs, there is a relatively rare population (Mucenieks, 2022). According to the data of the Office of Citizenship and Migration Affairs Republic of Latvia (Population of the Republic..., b.y.), at the beginning of 2023, 10,512 residents had declared their place of residence in the Ventspils municipality. The population in the municipality continues to decrease.

Discussions and results

Within the framework of the study, the types of classification of settlements, their official classification and changes over time were evaluated.

1. Concept and classification of settlements

On June 10, 2020, the Saeima of the Republic of Latvia carried out another administrative reform by adopting a new Law on Administrative Territories and Populated Areas. The law provides a definition of a populated place: a populated area is a territory which is inhabited by people, where material pre-conditions for residence therein have been established and to which the relevant status of populated area has been granted according to the procedures specified by laws and regulations (LR Saeima, 2020). It should be noted that exactly this definition of a settlement already existed before the adoption of this law, however, this law determined a new classification of settlements. According to it, there are the following settlements in Latvia: cities and towns, villages, small villages and farmsteads (Fig. 1).

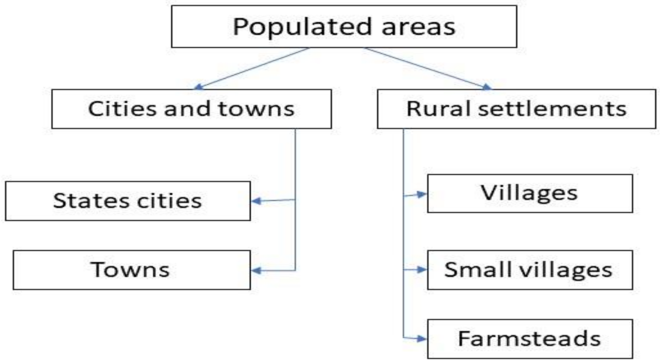

Fig. 1. Classification of Latvian populated areas since 2021
(Source: compiled by the authors to the Law on Administrative territories …., 2020)

The law was applied in 2021, and according to it, cities are divided into State cities and municipality towns. There are 10 State cities: Daugavpils, Jelgava, Jekabpils, Jurmala, Liepaja, Ogre, Rezekne, Riga, Valmiera and Ventspils, with Riga as the capital. Apart from these state cities, there are 71 municipality towns in Latvia. The law defines 3 types of rural settlements: villages, small villages and farmsteads.

The law stipulates that the status of a village can be granted to a part of the municipality territory where there is or is planned to be a concentrated settlement, people live permanently and relevant infrastructure is established. In addition, it is stipulated that if the village has more than 5,000 permanent residents, then the council of the relevant municipality may, in accordance with this law, submit to the Cabinet of Ministers a proposal for determining the status of a city for the relevant village.

The law defines a so far unclassified settlement as a small village, and it is defined as a historically established settlement with dominant entertainment or dominant concentrated construction, which does not have a defined boundary in the municipality's territorial planning and whose name is included in the Latvian Geospatial Information Agency's Place names database.

A farmstead, on the other hand, is defined as a single detached residential building or several detached residential buildings, as well as farm buildings functionally connected to this building or buildings in the territory where the land is primarily used for agricultural or forestry purposes.

Before the adoption of the Law on Administrative Territories and Populated Areas (2020), an assessment of Latvian villages was carried out. The study was organized by the Ministry of Environmental Protection and Regional Development and when preparing the draft of the new law, according to the summarized results, it was explained that out of 6,314 villages registered in the State

Register of Addresses, 4,877 (77.2%) villages did not meet the status of a village at that time, that is, they there was no concentrated construction and the village boundaries were not defined in the planning of the municipality's territory (Turpmāk Latvijā ciemi..., 2018). However, revoking the village status of these settlements would undermine the usual addressing system, and changing addresses would create a burden for municipalities and the State Register of Addresses. Residents would also experience inconvenience.

As the Ministry explained, such a situation had arisen because the previous law, when determining village status norms, did not consider the historically formed actual situation of villages, because villages in Latvia are very different both in terms of the composition of the population, the existence of infrastructure facilities, the character of the population, and the density of buildings, as well as other characteristic features. Although the conclusions of the conducted research already indicated this situation. The situation was also complicated by the fact that several normative adopted the same requirements for the territories of cities and villages, for example, the width of the guard lanes, determination of building permits, accuracy of cadastral surveying and other requirements (Turpmāk Latvijā ciemi..., 2018).

According to the Ministry of Environmental Protection and Regional Development information, considering the diversity of villages in several municipalities (for example, in the territories of Livani, Kraslava, Preili, Dundaga, Vecumnieki, Balvi, etc. municipalities), two types of village groups have been formed. The first is villages that met the requirements of the previous Law on Administrative Territories and Populated Areas (2008), and the second is parts of rural territory that have a common name but no concentrated construction and no boundaries are marked in the graphic part of the spatial plan. Therefore, in accordance with the task given by the Cabinet of Ministers and the long-standing practice of several local governments, the Ministry of Environmental Protection and Regional Development proposed, while maintaining the village status of inhabited places, to define two subgroups of villages - the village of concentrated construction and the historical village (small village).

The status of a village of concentrated construction was granted to an existing or planned settlement in which people live permanently and relevant infrastructure has been created. For such a village, the boundaries of the territory of the village must be determined in the regional territorial planning, as well as the regional council determines the addresses and the name of the village included in the village.

On the other hand, the status of a historical village is granted to a historically established settlement with dominant entertainment or dominant concentrated construction, the name of which is included in the Pace names database of the Latvian Geospatial Information Agency. The boundaries of such a village are not defined in the regional territorial planning, but the regional council determines the name of the village and the addresses included in the village. The Ministry also stated that the historical villages are one of the cultural and historical values of the municipality, which should be preserved for future generations, and which serve as an element of the address system, are used in the social environment and serve as an identifier for orientation in the municipality, which is used by the assistance services, as well as people in everyday communication.

The concentrated establishment villages (LR Saeima, 2020) sets the same village status criteria as before the adoption of the law, so municipalities that have complied with the requirements of regulatory acts in determining the status of villages will not have to make any amendments to the development planning documents. On the other hand, municipalities will apply their regulatory act to historical villages.

2. Village status and criteria for its determination

Among the inhabited places, villages have the greatest diversity in terms of the number of inhabitants, the concentration of buildings and other indicators in Latvia. Therefore, it is essential to find out the criteria for determining the status of the settlement. Nowadays, the status of the village is confirmed by the local municipality based on the spatial plans, which define the border of the village and justify the need for the establishment of the village. Most often, they are historically established rural settlements.

From the definition of a village provided in the law, it can be concluded that the indicators determining the status of a village are more qualitative - the concentration of buildings, permanent residents and relevant infrastructure, but it does not determine quantitative indicators that would allow determining whether a given territory is considered a village, for example, the density of buildings, the minimum population number, what infrastructure provision. Looking at the definition of a village in the context of the definition of a city as a settlement, it can be concluded that 5,000 is the number of inhabitants that separates cities from villages, at which the municipality can request to grant the village the status of a city (LR Saeima, 2020). So, the Law on Administrative Territories and Populated Areas does not allow for an unambiguous definition of the concept of a village, but provides a general idea of its features.

In addition to the definition of villages established by the law, various interpretations of the criteria for defining a village have been formed in Latvia until the adoption of the mentioned law. For example, in the study of J. Turlajs and G. Millins (1998) on Latvian settlements emphasized the built-up parameter, and a village was considered a rural settlement with concentrated settlement, in which the distance between built-up areas does not exceed 200m. The book "Latvijas ciemi. Nosaukumi, geografiskais izvietojums" authors, in turn, emphasize the historical context, and a village is defined as a rural settlement with a historically unified, compact or recreational inhabited area and a unifying name (Latvijas ciemi. Nosaukumi ..., 2007).

In order to distinguish villages according to their characteristics - the number of inhabitants, the existence of infrastructure facilities (state and municipal institutions, schools, shops, etc.), the location of farmsteads (dense or recreational), the nature of the population (seasonal or permanent) - and thus improve the understanding of this concept Latvian Geospatial Information Agency and the Faculty of Geography and Earth Sciences of the University of Latvia developed a classification of villages, defining 6 types of villages:

1) large village – a rural settlement with compact buildings and a unifying name. It usually has developed infrastructure - school, shops, medical institutions, post office, etc. – and at least 400 permanent residents. If the village has only a few infrastructure objects, its population must be at least 500, but if there are none at all - at least 600, so that the village can be considered a large village. Large villages in Latvia are most concentrated in the central part, especially around Riga;

2) medium village - a rural settlement with compact or semi-compact construction and a uniting name with 40-400 permanent residents, if the village has infrastructure facilities, or 100-600 residents, if there are none;

3) small village - a rural settlement with a unifying name, which has at least 3 compactly located residential houses. Villages with a population of up to 40, if there are infrastructure objects in the village, or up to 100, if there are none, qualify for the status of a small village. Small villages are the most common type of villages in Latvia. These are mainly centers of former manors and ancient, now shriveled villages;

4) scattered village (skrajciemi) – a group of at least 3 existing farmsteads with a unifying name. Each house can have its own separate name. In nature, skrajciemi mostly do not look like villages, but they are not quite separate farmesteads;

5) summer cottage village – a rural settlement with compact buildings and a unifying name, but mainly seasonal population;

6) care village – a rural settlement with compact or semi-compact buildings and a unifying name, where the majority of residents are those living and working in care institutions (Latvijas ciemi. Nosaukumi ..., 2007).

As can be seen, in this case too, interpretation is possible in the assessment of the level of infrastructure, however, the developed classification provides a relatively more accurate, more realistic picture of the possible variations of the villages. In this classification, the unifying elements for all types of villages are rural area, unifying name and built-up, although its density can vary greatly.

Only about 12% of all villages are large and medium villages, most are small villages, the number of which has decreased rapidly in recent years. On the other hand, summer cottage villages, especially near Riga, are turning into permanently inhabited villages. In addition, the design and construction of completely new villages is rapidly expanding in Pieriga and some other places (Latvijas ciemi. Nosaukumi ..., 2007).

3. Structure and dynamics of villages in Latvia

Since 2016, the State Land Service has recorded all Latvian villages by municipalityies from the Address Register (Ciemu skaits, 2016-2024). Gathering these data within the framework of the research, we can conclude that there is a significantly larger number of villages in Latgale than in other planning regions, while the smallest number of villages is in Riga and Zemgale planning regions. However, a decrease in the number of villages can be observed in all planning regions, within eight years the largest decrease in the number of villages (-56 villages) was in the Kurzeme planning region, and the least (-19 villages) in the Latgale planning region.

Table 2

The number of villages in the Republic of Latvia from 2016 to 2024

Planning region	Number of villages as of January 1			
	2016	**2020**	**2022**	**2024**
Kurzeme	456	412	401	400
Latgale	5105	5104	5086	5086
Riga	217	207	182	182
Vidzeme	393	343	357	357
Zemgale	274	246	246	245
Total in Latvia	**6445**	**6312**	**6272**	**6270**

(Source: compiled by the authors to the data of the State Land Service)

Table 2 lists all the villages included in the Address Register. But since 2022, information on the official division of villages has been available in the State Land Service. According to the law (LR Saeima, 2020), those territories are listed as villages, where there is or is planned to be a concentrated building, people live permanently, relevant infrastructure has been established and the boundaries of which have been defined in the spatial planning of the municipality. The village council grants and revokes the village status to these rural settlements. On the other hand, small villages are listed as historically established settlements, which do not have defined boundaries in the regional planning and whose names are included in the Latvian Geospatial Information Agency's Place names database.

As can be seen in Table 3, the majority of the villages listed in the Address Register as of January 1, 2024 are small villages, there are especially many small villages in the Latgale planning region, their number is many times smaller in the other regions (Table 3).

Table 3

The number of villages by their types, as of January 1, 2024

Planning region	Number of villages		
	villages	**small villages**	**total**
Kurzeme	350	50	400
Latgale	286	4800	5086
Riga	165	17	182
Vidzeme	329	28	357
Zemgale	227	18	245
Total in Latvia	**1357**	**4913**	**6270**

(Source: compiled by the authors to the data of the State Land Service)

4. Structure and development of rural settlements in Ventspils municipality

In order to more closely evaluate the structure of villages and its dynamics, an analysis of the location and development of rural settlements in the Ventspils municipality, which is located in the north-west of Latvia, in the Kurzeme planning region, was carried out as part of the study.

However, it should be noted that there are differences between individual national databases in the enumeration of villages. According to the data of the State Land Service, the number of villages in the Kurzeme planning region decreased by 56 within 8 years, from 456 villages in 2016 to 400 villages in 2024 (Tab. 2). Among them, the number of villages in Ventspils municipality decreased by 38 during this period - from 92 villages to 54 villages (Tab. 4). According to the data of the State Land Service, in 2016 there were 92 villages in the Ventspils municipality, but in 2022 there was only 54 villages, and none of them is classified as a small village.

On the other hand, according to the database of the Latvian Geospatial Information Agency, there are 100 rural settlements in the Ventspils municipality. The Agency's Place names database maintains information on the names of villages, which are classified as large villages, medium villages, small villages and the group of farmsteads (skrajciemi). There is also a classification of villages according to their functions, for example, summer cottage village (Fig. 2).

Table 4

Number of villages in the Kurzeme planning region, on January 1, 2024

Municipality	Number of villages		
	villages	small villages	total
Dienvidkurzeme municipality	66	3	69
Kuldiga municipality	40	0	40
Saldus municipality	36	0	36
Talsu municipality	109	35	144
Tukums municipality	45	12	57
Ventspils municipality	54	0	54
Total in planning region	**350**	**50**	**400**

(Source: compiled by authors from the State Land Service, 2024)

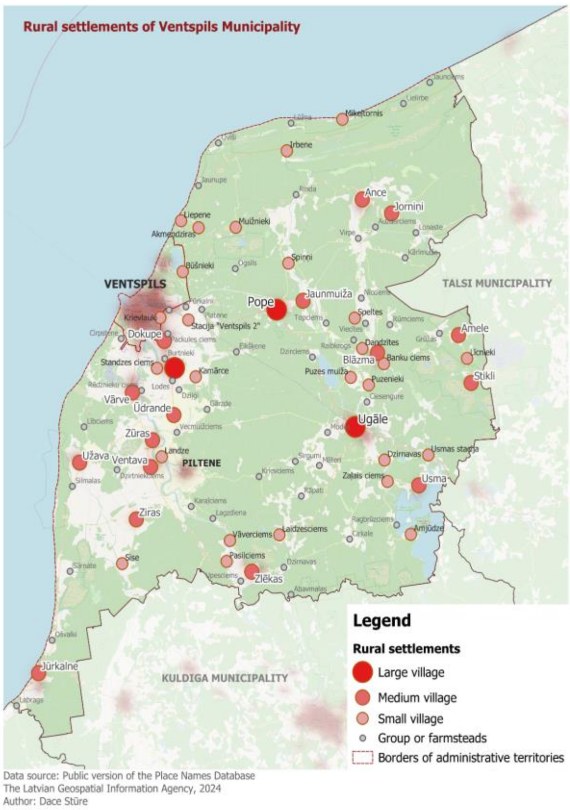

Fig. 2. The current distribution and location of rural settlements in Ventspils municipality, 2024
(Source: *Public version of the Place names database of Latvian Geospatial Information Agency)*

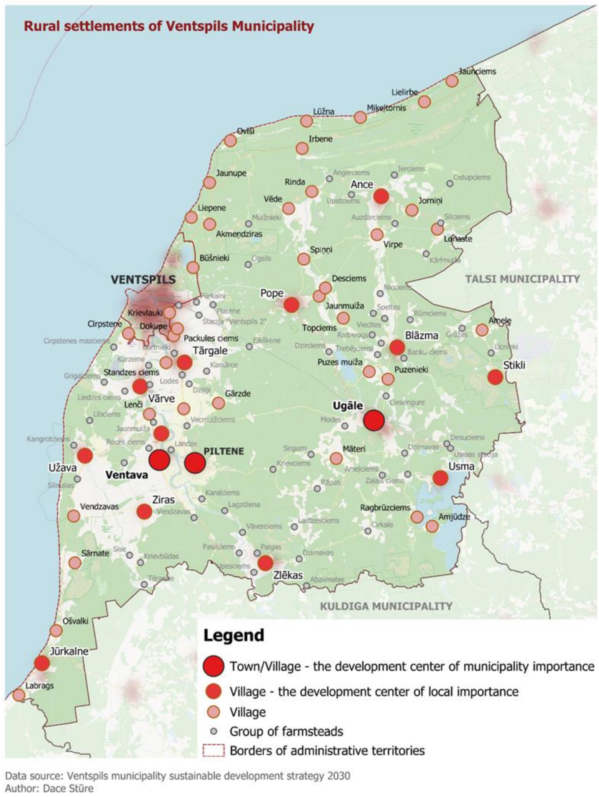

Fig. 3 The planned division and placement of rural settlements in Ventspils municipality, 2030
(*Source: Ventspils municipality sustainability development strategy, 2030*)

In order to preserve the settlements structure, in the development planning document of the local municipality, for example, in the sustainable development strategy of Ventspils municipality 2030, towns and villages are defined as development centers depending on their level of development, creating a polycentric development structure. The population structure of the municipality is made up of conditionally three-level development centers:

- development centers of municipal importance;
- development centers of local importance;
- villages (Fig. 3).

As it can be observed from images above, each of these centers has planned to maintain a certain amount of services and infrastructure. Also, rural settlements are preserved as suitable places for the development of neighborhoods and services in the future, even if almost no one lives there permanently. It can be concluded that, although the number of settlements in Ventspils municipality is decreasing, small villages and groups of farmsteads, which are planned for development, play an important role, especially on the Baltic Sea coast.

Conclusions and proposals

1. As in the whole of Europe, the population of Latvia is also decreasing. In the last two years, the population of Latvia has decreased by almost 1%. The population is decreasing throughout the territory of Latvia, with the exception of Pieriga municipalities, where a small increase of residents is observed.
2. Until the adoption of the Law on Administrative Territories and Populated Areas in 2020, several studies on the classification of settlements in Latvia have been conducted, with particular emphasis on too broad use of the village as a settlement for settlements that are very different in terms of population, construction, and significance. According to the Ministry of Environmental Protection and Regional Development data, 77% of the villages registered in the State Register of Addresses did not match to village status, as they did not have a concentrated structure, nor were there defined boundaries in the territory development plans.
3. Analyzing the distribution of villages by regions of Latvia, it was found that the largest number of villages is in the Latgale planning region, where it many times exceeds the number of villages in other regions. Most of the villages of the Latgale planning region are small villages. Like the population, the number of villages in all regions is gradually decreasing.
4. In the Kurzeme planning region, most of the villages consist of concentrated inhabited area, and only a small part (12.5%) consists of small villages or historical villages. In the Venstpils municipality, there are no settlements corresponding to the status of a small village.
5. There are differences in the accounting of rural settlements between Latvian state institutions.
6. When planning the development of the territory, municipalities try to preserve the existing infrastructure and services for further development. This is evidenced by the practice of the Ventspils municipality, where rural settlements are preserved as suitable places for the development of neighborhoods and services in the future, even if almost no one lives there permanently.

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PROBLEMS OF CADASTRAL DATA DETERMINATION FOR FOREST LAND PLOTS IN LITHUANIA

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Abstract
Assessing the importance of cadastral measurements, to achieve work efficiency, it is important to identify the factors that affect the efficiency of measurement works, to provide measures that can help solve the problems that still exist in this area of activity. This topic is very relevant, because the analysis of specific examples can reveal sensitive problems of cadastral measurements and preparation of documents.
The aim of the research: to analyze the problems arising during the cadastral measurements of land plots.
The objectives of the research: to discuss legal acts and scientific literature regulating cadastral measurements of land plots; to identify the problems of establishing land plot cadastral data on selected land plots.
The research analyses 37 cadastral measurements of plots. The research looks at a few examples and discusses solutions - the most common problem is poorly defined boundaries and areas. Poorly prepared land reform land-use planning projects, the "accuracy" of preliminary measurements makes cadastral surveys difficult.
Key words: Land plot, forest, cadastral measurement

Introduction

Cadastral surveys are a guarantee of people's ownership and justice for the future. Due to the rush for land reform and the lack of qualified staff, preliminary surveys today pose a number of problems in terms of boundaries and the accuracy of the area of the land plot. Land reform has involved land restitution, land plot formation and on-site marking. Geodetic instruments were not used for cadastral surveys. Nowadays, land surveyors carry out cadastral surveys with very small errors, use electronic measuring instruments and carry out all measurements in the national coordinate system. It is quite common to encounter inaccurate primary data (Femenia-Ribera, 2022) using old cadastral maps. There are also problems with inaccurate and illegible drafts, inaccurately drawn up land reform projects, and boundary markers not being found in the area. Inconsistencies in the boundaries and areas of land plots are encountered when cadastral surveys are carried out in the national coordinate system.

Subject of the study: Cadastral survey files for 37 plots of land in forests.

The aim of the research is to analyse the problems encountered during cadastral surveys of land plots in forests.

Tasks: To discuss the legislation and scientific literature on cadastral surveys of land plots. To identify the problems of cadastral data establishment on selected plots of land.

At the beginning of the land reform, land plots were surveyed by means of preliminary surveys, which allowed for a faster identification of real estate objects and their boundaries. However, this haste led to inaccurate and poor quality land reform land-use plans and land plot surveys. Preliminary surveys were carried out by inadequately qualified specialists, using two-metre tape measures and tape measures, and only since 2008 have cadastral surveys become compulsory for the creation of new land plots. These shortcomings are becoming more apparent when cadastral data are revised and cadastral measurements are carried out with more accurate tools (Balevičius et al., 2015, Bikuvienė et al., 2017, Ponamariovienė et al., 2016; Živatkauskas, 2018).

Baranauskaitė and Živatkauskas A. (2017) analysing the cadastral measurements of forest plots, found that during the land reform, a fundamental error was made, land plots were formed on the basis of inaccurate preliminary measurements. As a result, cadastral surveys of land plots often result in a situation where the area of the land plot or the length of the boundary lines or even the location of the land plot does not correspond to the land reform project. Balčiūnas A. (2019) examines the compliance of land plot boundaries with the approved land reform project in Ignalina district. Cadastral measurements of 17 land plots in 5 (29.4%) of the land plots revealed non-compliance with the project. Discrepancies between the forest areas in the locations and cadastral maps are also analysed by researchers from other countries (Park et al., 2022; Jeon et al., 2015, Forejt et al., 2020), and it is a topic of full relevance

Methodology of research and materials

Analysis of literature sources (legislation of the Republic of Lithuania, scientific articles), analysis of problematic situations of cadastral surveys of land plots. The research was carried out using data from cadastral measurements of 37 forest land plots. During the land reform, the land plots were measured with preliminary measurements. At the beginning of this reform, there was no strong legal framework to regulate the preparation of land reform land-use projects. Land reform projects were drafted in a hasty manner, without control or expertise. The method of preliminary surveys allowed for the rapid identification of immovable properties, their formation and delimitation. However, these days, cadastral surveys are problematic because they often involve overlapping plots, a mismatch between the actual boundaries and the cadastral data, and a lack of surface area. The study analysed different cadastral documents for 37 plots in forests.

Discussions and results

The most important laws regulating cadastral surveys in Lithuania are the Law on Land of the Republic of Lithuania, the Law on Cadastre of Real Estate of the Republic of Lithuania, the Law on Real Estate Register of the Republic of Lithuania, the Law on Spatial Planning of the Republic of Lithuania, the Law on Geodesy and Cartography of the Republic of Lithuania, the Law on Land Reform of the Republic of Lithuania, and the Regulations of Cadastre of the Republic of Lithuania. The procedure for cadastral measurements of land plots, determining the coordinates of the turning points and boundary markers of the boundaries of the land plots in the state coordinate system, shall be regulated by the Regulations of the Cadastre of Real Estate of the Republic of Lithuania and by the Rules on Cadastral Measurements of Real Estate Objects and on the Compilation and Adjustment of Cadastre Data.

When carrying out measurements using more accurate means than the previous measurements, the calculated area may differ from the area of the land plot registered in the Real Estate Register or the area designed in the spatial planning document or in the project of the land holding, but not registered in the Real Estate Register, by no more than the maximum permissible (marginal) area error (Table 1).

Table 1.

Table of maximum permissible (marginal) errors for the area of a plot of land (Lietuvos..., 2002)

Cartographic material used	Plot area, hectares	Scale of the plan				
		1:10000	1:5000	1:2000	1:1000	1:500
Orthophotographic maps	Up to 1	0,05√P	0,03√P	0,02√P	-	-
	1.0001-2.0000	0,06√P	0,04√P	0,03√P	-	-
	2.0001-4.0000	0,07√P	0,05√P	0,04√P	-	-
	4.0001 and more	0,08√P	0,06√P	0,05√P	-	-
Other cartographic material	Up to 1	0,07√P	0,05√P	0,04√P	0,03√P	0,02√P
	1.0001-2.0000	0,08√P	0,06√P	0,05√P	0,04√P	0,03√P
	2.0001-4.0000	0,09√P	0,07√P	0,06√P	0,05√P	0,04√P
	4.0001-10.0000	0,10√P	0,08√P	0,07√P	0,06√P	0,05√P
	10.0001 and more	0,12√P	0,10√P	0,08√P	0,07√P	0,06√P

Remark. P-land area (ha)

If the area of the land plot determined by the measurements exceeds the permissible tolerance, or if the boundaries (configuration) of the land plot do not correspond to the boundaries designed in the territorial planning document or land holding project, the land surveyor shall inform the client and the territorial department of the National Land Service under the Ministry of the Environment in writing about it. The territorial department, after examining the situation on the ground, shall determine the reasons for the difference and draw up a conclusion on the necessity of adjusting the boundaries of the land plot in the locality or the necessity of adjusting the boundaries or the area of the land plot in the spatial planning document or in the project of the land holding. The cadastral surveys shall continue in accordance with the conclusions of the territorial division.

During the study 37 cadastral survey files were analysed. The analysis showed that the areas of 3 plots exceeded the permissible area tolerances (Table 2). The neighbouring plots of 3 of the measured plots were measured incorrectly (e.g. plot boundaries did not border the middle of the ditch, plot boundary in the middle of the road). The marking of 10 plots showed a boundary discrepancy, 5 plots have actual boundaries different from the plan boundaries and 1 plot does not correspond to the area recorded in the cadastral data file.

Table 2.

Comparison of areas

Cadastral measurements	Preliminary measurements	Difference	Permissibility	Cadastral measurements	Preliminary measurements	Difference	Permissibility
2.6523	2.6600	-0.0077	± 0.1468	12.0926	12.0100	+0.0826	± 0.4159
2.832	3.3300	**-0.4980**	**± 0.1642**	12.5438	12.6900	-0.1462	± 0.4275
3.0254	3.1000	-0.0746	± 0.1585	15.0771	15.0200	+0.0571	± 0.4651
3.8439	4.2500	**-0.4061**	**± 0.2062**	16.235	16.3600	-0.1250	± 0.4854
3.9874	3.9500	+0.0374	± 0.1789	19.6394	19.8400	-0.2006	± 0.5345
4.0132	4.0800	-0.0668	± 0.2020	20.368	19.8600	+0.5080	± 0.5348
4.5656	4.8500	**-0.2844**	**± 0.2202**	20.4831	20.9100	-0.4269	± 0.5487
5.2356	5.1300	+0.1056	± 0.2265	21.412	21.1700	+0.2420	± 0.5521
5.5464	5.4600	+0.0864	± 0.2337	21.555	21.5800	-0.0250	± 0.5575
5.7333	5.8900	-0.1567	± 0.2427	24.0918	24.5600	-0.4682	± 0.5947
6.4965	6.4700	+0.0265	± 0.2544	26.7531	26.9100	-0.1569	± 0.6225
6.6141	6.7500	-0.1359	± 0.2598	28.2819	28.5400	-0.2581	± 0.6411
7.816	7.5800	+0.2360	± 0.2753	28.3814	28.0200	+0.3614	± 0.6352
8.0275	8.1400	-0.1125	± 0.2853	30.0267	29.5500	+0.4767	± 0.6523
9.5452	9.8100	-0.2648	± 0.3132	30.0036	30.2600	-0.2564	± 0.6601
10.2487	10.2300	+0.0187	± 0.3838	34.7542	35.1200	-0.3658	± 0.7111
11.4436	11.6300	-0.1864	± 0.4092	35.9285	35.6300	+0.2985	± 0.7163
11.6335	11.8400	-0.2065	± 0.4129	37.4796	37.8400	-0.3604	± 0.7382

Examples are given for each situation.

The first example is in Panevėžys District Municipality. The land plot is formed and registered in the State Enterprise Centre of Registers through preliminary measurements. According to the Real Estate Register, the area of the plot is 3.3300 ha. The land plot was formed by the land reform land-use planning project in 2000 (Figure 1).

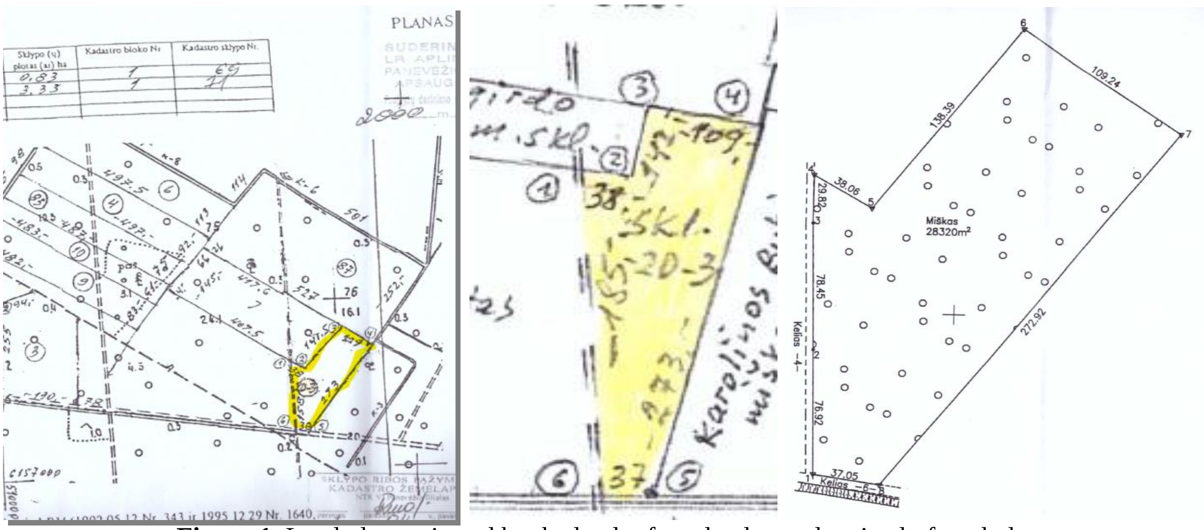

Figure 1. Land plot projected by the land reform land-use plan, its draft and plan

The site was cadastral surveyed in 2023. The plot has an area of 2.8320 ha. In accordance with point 21 of the Provisions of the Cadastre of Immovable Property of the Republic of Lithuania, the description of the procedure for compensating the difference in the area of private land and forest land, in the light of the situational drawing, and after examination of the original plan and the draft, it is noted that the land plot is marked in accordance with the lengths of the lines shown in the 2000 demarcation draft and the plan of the land plot. Table 3 compares the line lengths between the 2000 draft and the 2023 plot plan.

The site was cadastral surveyed in 2023. The plot has an area of 2.8320 ha. In accordance with point 21 of the Provisions of the Cadastre of Immovable Property of the Republic of Lithuania, the description of the procedure for compensating the difference in the area of private land and forest land, in the light of the situational drawing, and after examination of the original plan and the draft, it is noted that the land plot is marked in accordance with the lengths of the lines shown in the 2000 demarcation draft and the plan of the land plot. Table 3 compares the line lengths between the 2000 draft and the 2023 plot plan.

Table 3.

Comparison of boundary lengths

Line	*Data for 2023*	*Data for 2000*	*Line*	*Data for 2023*	*Data for 2000*
1-2; 2-3; 3-4	76.92; 78.45; 28.82 (total 184.19)	185	6-7	109	109.24
4-5	38.06	38	7-8	272.92	273
5-6	138.39	142	8-1	37.05	37

The data analysis shows a maximum mismatch of 5-6 lines of 3.61 m. The other line lengths are reasonably accurate. In this case, there may be a measurement error as the distance is long enough at almost 140 metres. This is because all 6 remaining old boundary markers were found during the marking.

The area resulting from the marking is 2.8320 ha. It is lower than the one registered in the Real Estate Register and exceeds the permissible margin of error. The permissible area error of 0.09√3.33 would be 0.1642 ha. Unfortunately, this has resulted in a plot almost 50 ares (0.4980 ha) smaller than the plot of land of the owner at the time of the restitution of the property rights (restoration in kind). This may have been due to the more complex configuration of the plot and the surveyor's inaccurate calculation of the area.

The landowners will not be compensated for the difference in the area of the land found, as the land was acquired in a sale and purchase transaction. The owners are only requesting a change to the cadastral data established for the land plot.

The second example is in Šakiai district municipality (Figure 2).

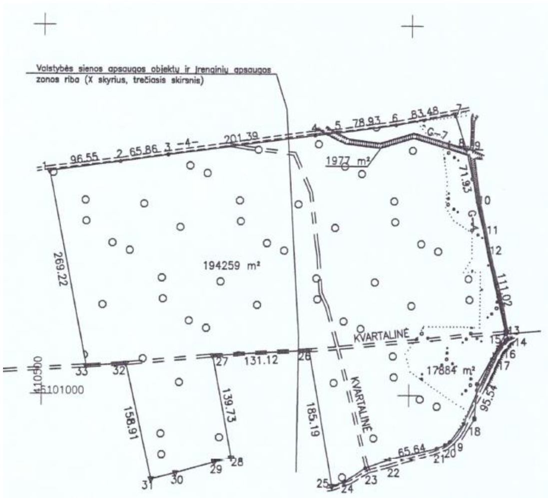

Figure 2. Forest plot

All points were measured by GPS and the coordinate corrections were obtained by connecting to the LitPos base station of the network of permanently operating GPS stations. The registered area of the plot is 21.17 ha, after the updated measurements it is 21.4120. The permissible area error of $0.12\sqrt{21.17}$ would be 0.5521 ha, the current area error of 21,4120-21,17 would be 0,242 ha. The area of the plot determined by the cadastral survey is within the tolerance of the error.

The survey of the plot found old boundary markers 25, 26 and 27, but the neighbouring plots were measured incorrectly, the boundaries of two of the plots were not in the middle of the ditch, and the boundary of another plot was in the middle of the road. For these reasons, a re-measurement is being carried out following the decision of the Šakiai Division of the National Land Service under the Ministry of the Environment to adjust the northern boundary of the land plot.

The third example is in Zarasai District Municipality. The land plot was formed and registered in the State Enterprise Centre of Registers through preliminary measurements (Figure 3).

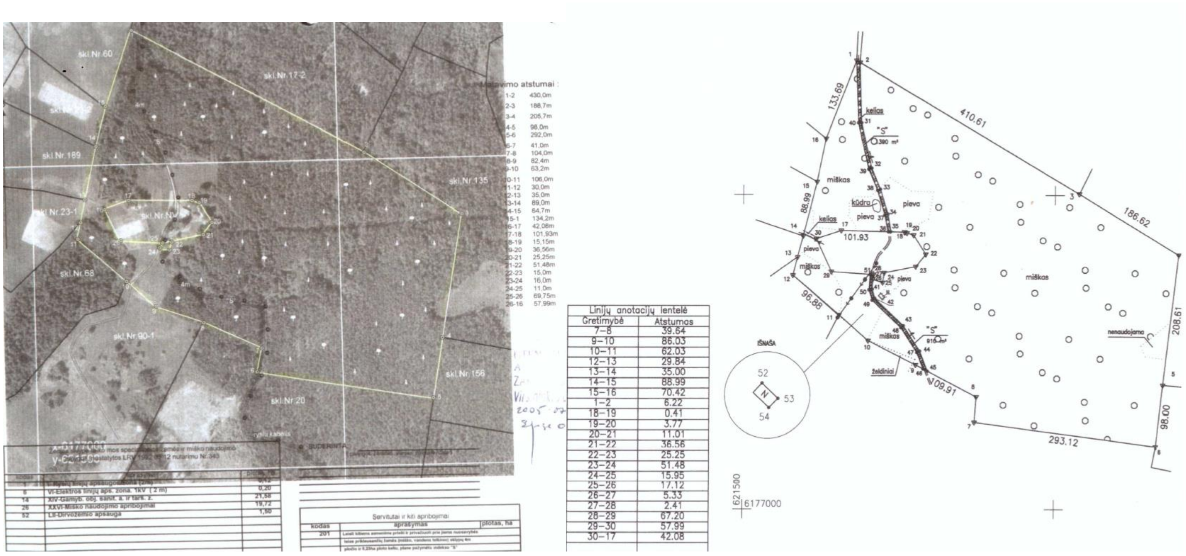

Figure 3. The plot measured in 2005 and 2023

According to the State Land Cadastral Data Register, the preliminary area of the land plot is 21.5800 ha. The cadastral measurements have resulted in a plot area of 21.5500 ha. The resulting difference in area is permissible.

The measurements are based on the 2005 plan. The survey includes 30 boundary markers, of which 19 are newly affixed and 11 non-standard boundary markers found have been replaced. A boundary discrepancy was observed during the marking. The territorial department of the National Land Service was contacted. The preliminary land reform land-use planning project of the cadastral area and the preliminary and cadastral survey data of the adjacent plots were examined and it was found that the boundaries do not correspond to the existing ones in the territorial planning documents. According to the documents examined, there are no grounds for changing the boundaries and line lengths and, in the absence of any surviving boundary markers, the boundaries must be restored in accordance with the zoning documents.

The fourth example shows that even a small difference in area can hinder cadastral surveys. The land plot has been formed and cadastral surveys have been carried out. However, it was not possible to register the cadastral measurements in the State Enterprise Centre of Registers, because according to point 31 of the Rules on cadastral measurements of immovable property objects and on the collection and adjustment of cadastral data, the person establishing the cadastral data of an immovable property object must use the data and information from the State Forest Cadastre of the Republic of Lithuania when carrying out the cadastral measurements. However, a check of the data from the State Forest Cadastre of the Republic of Lithuania on the area of the land plot and the data recorded in the cadastral data file has shown that the data from the State Forest Cadastre of the Republic of Lithuania on the area of the land plot's forest land (2.3754 ha) does not correspond to the area recorded in the cadastral data file (2.3663 ha). The plot also overlaps the boundaries of the adjacent land plot.

The fifth example is in Švenčionys District Municipality. The land plot was formed and registered in the State Enterprise Centre of Registers by preliminary measurements (Figure 4).

Figure 4. Land plot projected by the land reform land-use plan, its draft and plan

All points were measured by GPS and the coordinate corrections were obtained by connecting to the LitPos base station of the network of permanently operating GPS stations. Only one old boundary marker was found during the land survey. Comparison of line lengths between the 2004 draft and the 2023 plot plan in Table 4.

Table 4. Comparison of boundary lengths

Line	*Data for 2023*	*Data for 2004*	*Line*	*Data for 2023*	*Data for 2004*
1-2	90,55	98,00	5-6	110	108,61
2-3	141,39	142	6-7	152,95	155,5
3-4	128,25	127,5	7-8-9-10-11-12-13-14	83,90	83
4-5	49,56	50	14-15-16	160,75	160,2

The data analysis shows a maximum mismatch of 1-2 lines of 7.45 m. The other line lengths are reasonably accurate. The registered area of the plot is 4,0800 ha, the updated measurement gives 4,1468. The permissible area error of 0,06√4,08 would be 0,1212 ha, the current area error is 0,0668 ha. The area of the plot as determined by the cadastral survey is within the tolerance of the error.
The sixth example is in the municipality of Vilnius district (Figure 5).

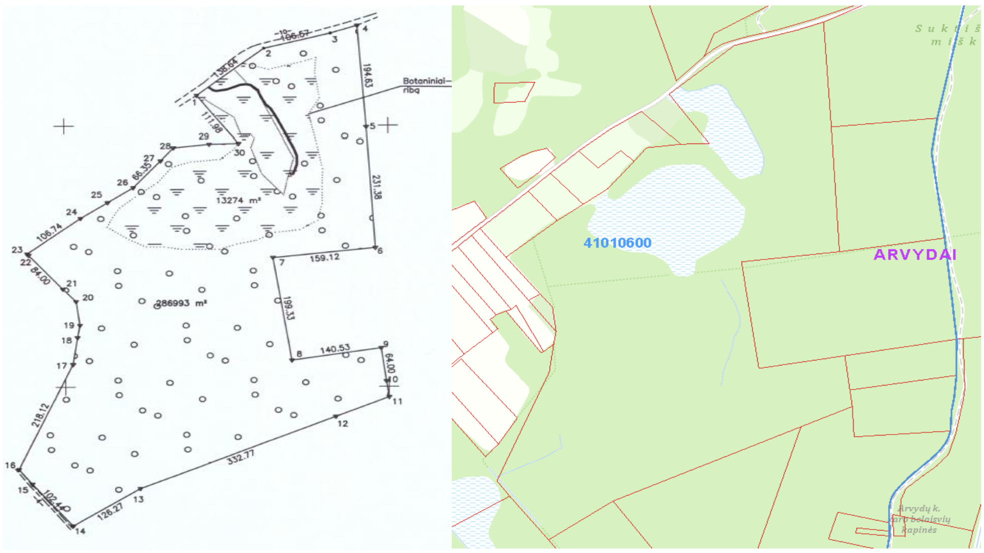

Figure 5. Forest plot

The boundaries of the plot of land on the cadastral survey plan at the boundary turning points 10-11 are found to be changing and do not correspond to the boundaries of the plot of land and the layout of the plot of land as marked in the project, i.e. the configuration of the plots of land is being changed. The cadastral survey of the land plot must be carried out in accordance with the boundaries and layout of the land reform land use plan. The boundaries actually used are different from the boundaries drawn up in the plan, but the land plot solutions are the same. The registered area of the plot 29.5500 ha after cadastral measurements, resulting in 30.0267 ha. The area of the plot determined by the cadastral survey is within the margin of error.

Conclusions and proposals

1. The most important laws regulating cadastral surveys in Lithuania are the Law on Land of the Republic of Lithuania, the Law on Cadastre of Real Estate of the Republic of Lithuania, the Law on Real Estate Register of the Republic of Lithuania, the Law on Territorial Planning of the Republic of Lithuania, the Law on Geodesy and Cartography of the Republic of Lithuania, the Law on Land Reform of the Republic of Lithuania, and the Regulations on Cadastre of the Republic of Lithuania. The procedure for cadastral measurements of land plots, determining the coordinates of the turning points and boundary markers of the boundaries of the land plots in the state coordinate system, shall be regulated by the Regulations of the Cadastre of Real Estate of the Republic of Lithuania and by the Rules on Cadastral Measurements of Real Estate Objects and on the Compilation and Adjustment of Cadastre Data.
2. The research analysed 37 cadastral survey files. The analysis showed that 3 plots had areas exceeding the permissible area tolerances (the area of other plots is not within the permissible limits). 3 nearby plots were incorrectly measured (e.g. the plot boundaries did not follow the middle of the ditch, the plot boundary in the middle of the road). 10 plots were marked with a boundary discrepancy, 5 plots had actual boundaries that differed from the plan boundaries and 1 plot did not correspond to the area recorded in the cadastral data file. The most common problem was poorly defined boundaries and areas. Poorly prepared land reform land-use plans, the 'accuracy' of preliminary measurements, and the lack of preserved boundary markers make cadastral surveys difficult.

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USE OF LAND MANAGEMENT AND CADASTRE DATA FOR FORESTRY LAND MANAGEMENT

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Abstract
Analysis of land management and cadastre data to ensure efficient use of forest resources was conducted. Insufficient updating of data was identified, which leads to discrepancies between the records in the relevant cadastres and the actual state of the land. This complicates planning and management of both land and forest resources. Irrelevant or incorrect information has a negative impact on the ecological state of forest areas. The object of the study is the territory of Skrypai forestry in Chuhuiv district of Kharkiv region. The article highlights the shortcomings in the legislative framework that create space for legal conflicts and misunderstandings regarding the use and protection of forest areas. Limited access to cadastre information for the public and stakeholders restricts control and monitoring opportunities. The lack of effective integration between information systems makes it difficult to share and analyze data to make reasonable decisions. Technological limitations, such as insufficient equipment to handle large volumes of data, are another barrier to the effective use of information. Inaccurate cadastral and land management data, such as on plot boundaries or land classification, can lead to misuse of land resources. The discrepancies between the boundaries obtained as a result of cadastral and forestry surveys were analysed using the least squares and vector shift methods. The area measurement method and the polygon intersection method were used to analyze the discrepancies in areas in different data sets: cadastre, land management, open spatial data, forestry. Through a survey of specialists in the relevant field, GIS research of forest resources revealed manifestations of a low culture of using open remote sensing data. Comprehensive measures to address the above problems are offered: strengthening the legislative framework, transition to a unified state coordinate system, improvement of technological infrastructure, ensuring data accessibility to the public, development of interagency cooperation, and integration of information systems. This approach will help to achieve efficient forestry land management.
Key words: forestry land, GIS, land management, cadastre, remote sensing

Introduction

Merging land and forest cadastre data is an important factor in the development of a country. The potential need to follow specific procedures for handling special data and spatial information should be taken into account (Choi, 2020 et. al.; Kocur-Bera et. al., 2021; Çay, 2023). Integration of these two systems allows for a more complete and accurate picture of land resources, which contributes to more efficient planning and use of land, especially in the context of sustainable development and environmental protection. Clearly defining the boundaries of land plots, including forest areas, helps to avoid disputes and conflicts between different land users ("Про затвердження Інструкції..., 2010; Koshkalda, Stoiko et. al., 2023).

Forests play a key role in ensuring ecological balance and biodiversity. The integration of forestry documentation with land cadastre data contributes to better monitoring, protection and management of forest resources ("Про затвердження Порядку..., 2013).

On the other hand, land cadastre and forestry records are often maintained in different formats and on different platforms, which can make it difficult to combine and integrate them. It can also require significant financial and technological investments. Data merging may be resisted by the various administrative and legal authorities that have control over these databases (Koshkalda, Grek et. al., 2023; Koshkalda, Dombrovska et. al., 2023).

The scientists draw attention to the latest principles and innovations in the legal support of the State Land Cadastre in Ukraine (Forejt et. al., 2020; Станіславський, 2022). The author highlights the legal regulation issues of information interaction between the State Land Cadastre of Ukraine and the national geospatial data infrastructure. The author identifies the advantages of adapting the current legislation in the field of land relations (Сопов et. al., 2024).

The problems of the institutional environment of land and other types of cadastres were studied by a group of researchers (Третяк et. al., 2018; Mika, 2020; Cienciała et. al., 2021). They examined the issues of defining the state cadastre of territories and objects of natural resources use, as well as the specifics of maintaining the state forest cadastre in the forest code. The research covers not only the technological side of land and forest cadastre data integration, but also the legal, environmental and institutional components of this process, which is key to the successful spatial data integration (Khainus et. al., 2023; Dorosh et. al., 2024).

Methodology of research and materials

GIS software and statistical methods were used to assess the discrepancies in spatial data. The percentage of overlap between the coordinates of land plots from different information sources was calculated, which allows to quantify their similarity. For this purpose, GIS tools were used to automate the process: buffering, distance matrix, overlay operations.

Another way to quantify differences in data is to use a geometric metric such as Hausdorff distance, which measures how far two subsets of space are from each other. This metric is particularly useful for assessing the similarity of polygon shape (cadastral and forest management). The Hausdorff distance is a measure used to determine how much a set of spatial objects recorded in the land cadastre differs from those recorded in forestry records This metric is widely used in various fields, including mathematics and geographic information systems (GIS) (Hoptsii et. al., 2023).

Another method used to study the similarities and differences between land and forestry data was to compare the coordinates of land plot vertices. This was done by calculating the root mean square error between the corresponding points of the two plots.

In order to measure the vector shift in coordinates of land cadastral and forestry survey plots, coordinates were transformed to a common system. Next, we selected steady reference points (333 pairs) that are present in both sets of polygons. These points served as the basis for measuring the shift. Statistical methods were also used to compare the distribution of geometric characteristics (side lengths, angles, centroids) of the boundaries of the two spatial data sets.

Each of these methods was applied to achieve a more detailed understanding of the similarities and variations in the boundaries of the land cadastre and forestry spatial datasets (Koshkalda, Sadovyy et. al., 2023).

Remote sensing data from various available geoportals and online services were also used. Remote sensing combined with GIS are interrelated and complementary modern technologies that, when combined, can improve the processes of monitoring, mapping and management of forest resources. Today, these two tools cannot be considered separately from each other, and the choice of a particular method of obtaining remote sensing data and software depends on the tasks set for monitoring the use of forest resources (Siedov et. al., 2023; Sadovyy et. al., 2022).

Discussions and results

The object of the study is the territory of the Skrypayivka Educational and Research Forestry of the State Biotechnological University, which is located in the central part of Kharkiv region in the Chuhuiv administrative district. According to the forestry report, the area of the two forestries is the following: Mokhnach forestry covers 4555.0 hectares and Skrypayi forestry covers 3716.0 hectares. The total area of both forestries (forestry) is 8582.0 hectares. This information can be used to analyze the distribution of land resources between forestries, plan the use of forest resources, protect nature and other purposes related to the management and conservation of forest resources.

The cartographic (geodetic) basis for the preparation of forest management plans was the materials of the previous forest management, as well as the materials of the state act on the right to use the land. In other words, the modern geodetic basis was formed not as the latest cadastral survey with modern instruments of the actual use of forestry lands, but as a long (34 years) process of forestry and cadastral spatial information integration. Where old mistakes, inaccuracies and gaps in the methodology were overlaid on top of each other over the course of time.

For the forest inventory, spectral-zone aerial photographs of satisfactory quality, flown in 1990, at a scale of 1:10000 were used as auxiliary data. As of 2000, the discrepancy in area with the previous forest inventory was +17.0 ha. This was due to the correction of land areas when drawing up the State Act on the right to use land.

The external boundaries of the forestry, forestry districts, administrative districts, and forest boundaries are shown in figure 1.

Fig .1. The territory of the Skrypayi Educational and Research Forestry

Figure 1 shows that the territory is divided into 226 quarters. The size of the quarters varies from 8.0 to 90.0 hectares, with an average of 38.0 hectares. Within these quarters, 2891 taxation blocks were defined. A taxation block is an elementary accounting unit in forest management that is homogeneous in terms of stand composition, age, fullness, productivity, forest type, etc. The average area of one taxation block is 3.0 hectares.

When analyzing the land resource potential of the Skrypayi Forestry in Chuhuiv district, Kharkiv region, we found shortcomings and inaccuracies in the classification of certain land categories. Such inaccuracies lead to incorrect accounting of available land resources, which complicates planning and management processes. Inconsistencies in the records are caused by both changes in legislation and natural and economic processes that occurred in a certain period, such as the expansion or reduction of forested areas, changes in the networks of forest roads, clearings and firebreaks. Most of these accounting gaps are the result of a lack of systematic monitoring.

Management decisions based on the use of outdated data can lead to misjudgements of forest resources and the risk of biodiversity loss, which in turn can lead to disruption of existing ecosystems and other natural processes. It should also be noted that outdated information can make it difficult to predict and manage the risks of natural disasters, such as fires, extreme weather or other natural hazards that can have a large-scale impact on the ecological state of forest resources.

The land cadastre plan focuses on registration, accounting and control of land resources, while the forestry plan focuses on forestry, protection, reproduction of forests and rational use of forest resources. Differences in the legal requirements for these documents can lead to uncertainties regarding the use of land plots, especially in the context of forestry land. Figure 2 shows what the study area looks like on the Public Cadastral Map (downloaded from QGIS).

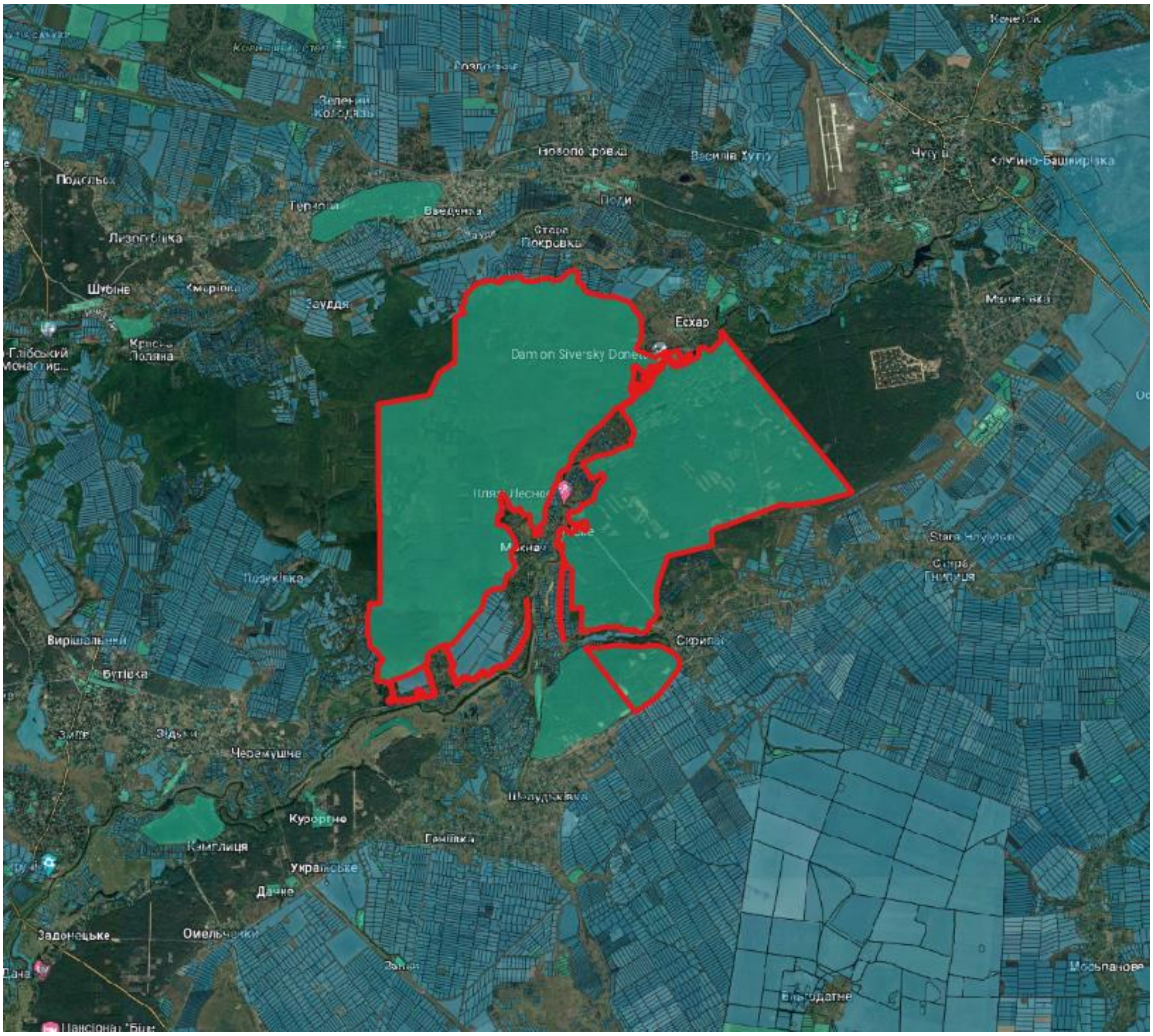

Fig.2. Public cadastral map and boundary of the study area

Figure 2 shows that the data of neighboring land plots along the perimeter of the study area have not yet been input into the State Land Cadastre database. This poses a potential threat of boundary disputes. It also shows that the forestry has a complex configuration, which makes it difficult to analyse its spatial characteristics. We can see the following land use deficiencies: inclusions, wedging, far-land, etc.

There are differences in the methodologies for collecting and processing spatial information, including requirements for mapping, geodetic data, etc., which may lead to conflicts in determining the boundaries of land plots. In our opinion, geospatial data of forestry enterprises should not only be open, but also displayed in various information systems. The lack of their effective integration complicates the exchange and analysis of data, which leads to conflicts when delimiting forestry lands, private property, nature reserve objects, etc.

Another factor that hinders effective data integration is the use of different coordinate systems in different organizations and agencies at different levels, which complicates the processes of monitoring, accounting and planning of forest resources use.

Integration of forest resources data into different geodatabases is possible only in a single coordinate system. Our study found that different systems are used in different sectors instead of one unified one. The coordinate systems SK-63 (land cadastre data), USK-2000 (state coordinate system) and UTM-36 (forestry plan data) were developed for different purposes and are based on different principles, which is why they do not coincide with each other.

Each coordinate system uses its own datum, which defines the position and shape of the Earth for that system. The SK-63 is based on the Soviet datum of 1942 (the Krasovsky ellipsoid), the USK-2000

uses the WGS-84 datum, and the UTM-36 is also based on WGS-84, but with a specific meridian (36 degrees) orientation. Projection defines how points on the Earth's surface are projected onto a plane. The SK-63 uses the Gauss-Kruger projection, while the UTM is a system that uses the transverse mercatorial projection.
These coordinate systems were developed to meet the needs of different geographical and administrative areas. Due to the use of different datum and projections, the methods of coordinate conversion between these systems also vary. This can lead to small or sometimes significant differences in the coordinates of the same geographic location.
In recent years, the forestry industry has been increasingly integrated into geospatial data analysis processes, such as mapping and remote sensing data. Processing large volumes of geospatial data usually requires powerful computing resources and efficient algorithms.
For effective forest management, it is necessary to take into account a variety of data on the state of forest resources, such as data on species distribution, health status, forest cover dynamics, etc. Large volumes of this data require an appropriate technical infrastructure for efficient processing and analysis.
It should also be noted that effective forest management may require rapid exchange of information on the state of the forest between different stakeholders, including foresters, scientists, governments, environmental services, etc.
To overcome these limitations, it is important to improve the technological infrastructure, use specialized information systems and integrate data processing technologies to ensure the effective use of information in forestry.
One of the methods of studying the turning points of the forest boundary is the satellite images analysis. Satellite imagery provides detailed information on the state of forest cover, detecting the loss of forest areas and changes in their size. Such analysis allows us to identify areas where there are problems with the loss of forest resources.
Aerial photography is another effective means of studying the turning points of the forest boundary. Aerial photography of forest areas has provided high-quality images that have been used to analyze the forest cover structure of the forestry enterprise, identify damage and changes in the landscape. This method can also detect illegal logging and other violations of forestry legislation.
Geographic information systems are also used to study forest boundary turning points. These systems allow merging data from different sources, such as satellite images, aerial photography, existing planning and mapping materials, and others, to obtain comprehensive information on the state of the landscape and forest resources.
Assessment of differences and similarities between land plot turning points (boundary marks) obtained from land cadastre and forestry surveys can be carried out by visual comparison of polygons using geographic information systems. This allows quick identification of obvious discrepancies in the contours and shapes of the polygons. An example is shown in figure 3.
Differences in area may indicate errors in measurement or data interpretation. The area measurement method and the polygon intersection method were used to analyse the difference in area between the land cadastre and forest management datasets.
The study used only a part of the forestry territory for which spatial information was available. According to the land cadastre, the area of the study is 7804.2978 hectares. According to the forest plantation plan, the area is 7840.4335 hectares, and according to the GIS overlay operation, the overlapping area of the plots is 7794.4820 hectares.
The spatial data of the land cadastre coincide by 99.87% with the data of the forest plantation plan. And, accordingly, the spatial data of forest plantations is 99.41%. Data integration should lead to the fact that not only the area (size) should be exactly the same, but also the spatial cadastral plan and the plantation plan should occupy the same space. And not differ by 0.13% and 0.39% of the area, respectively.

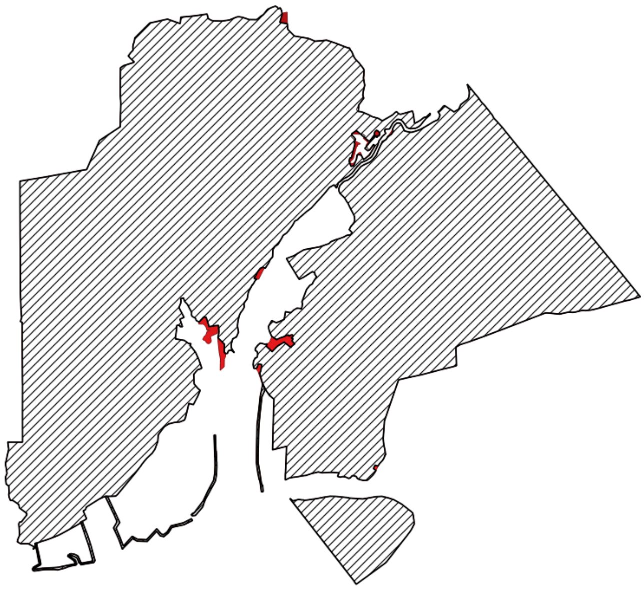

Fig. 3. Difference between the spatial location of land plots according to the land cadastre and the forestry plan

Figure 3 shows in red the fragments where the land plots do not completely coincide with the land cadastral information and the plan of forest plantations. The investigated parts of the plot boundaries (marked in red in figure 3) were not further analyzed, as the nature of the discrepancy is not related to the technical characteristics of geodetic objects: coordinate system, method of coordinating turning points or data processing. As noted above, forestry objects are characterized by some uncertainty regarding their boundaries. This is due to changes in legislation and business entities.

The next measure of difference was calculated using GIS Hausdorff distances. The Hausdorff distance provides a quantitative measure of the similarity or dissimilarity between two polygons, which is useful in analyzing geodetic data. The Hausdorff distance between two sets of points A and B is defined as the maximum distance by which any point in A can be removed from the nearest point in B, and vice versa. This means that it takes into account the largest of all minimum distances between points in the two sets.

Estimating the variations between the corresponding points and lines of two polygons. Calculating the average or maximum distance between points or lines helped to determine the degree of their variability.

We examined 333 points in each dataset. At the first stage, we used GIS to ensure that the points in both spatial datasets matched each other in terms of order or identification. The points were ordered in such a way that the corresponding points represented the same locations (boundary markers, geodetic points) on both polygons (land plots).

The average distance between the coordinates of the points is 1.32 m. Although in fact these are the same points and in the same coordinate system, i.e. there should be no discrepancy (the distance should be 0 m). The standard error is 0.02 m, the median is 1.24 m, and the mode is 1.21 m. In general, this information indicates that the measured distances have a fairly consistent and predictable distribution with little variation. The mean distance is slightly higher than the median and mode, which may indicate that there are some larger measured distances that slightly increase the mean value. The minimum distance is 0.19 m and the maximum is 2.48 m. The small variability and large average distance indicates the presence of a systematic gross error in either the geodetic survey or the parameters of the conversion of coordinates from one system to another.

The next method of quantifying differences in spatial data is to calculate the root mean square error of coordinate increments. The difference in coordinates for the same geodetic points in different geodetic surveys should be equal to 0. The abscissa root mean square error is 0.94 m, and the ordinate is 1.97 m. A smaller value of the abscissa error indicates a higher accuracy of coordinate determination in the

X-axis direction (east-west direction) compared to the accuracy in the Y-axis direction (north-south direction).
To evaluate the accuracy and reliability of the results, you can calculate the standard deviation of the shifts for each coordinate. This step allows us to quantify the vector shift in the coordinates of land parcels in different datasets. The obtained values are used to analyze the differences in spatial data and to make appropriate adjustments when integrating them. The shift vector was calculated for each pair of points (333 pairs). It was found that 67.87% (226 pairs of points) have the same direction of displacement. This indicates the systemic nature of geodetic information distortion. The reason for this may be the use of different coordinate systems described above. The correlation between the modulus and direction of the shift vector of points pairs is 0.28, which indicates a rather weak relationship. The mixing of land plot centroids also did not reveal any patterns.
It would have been possible to prevent such a discrepancy in spatial data if the achievements of geoinformation technologies had been widely used at the initial stages of forming the state cadastre database: exchange files, a single coordinate system, remote sensing data, etc.
One of the ways to control and verify land cadastre and forestry planning data is to use open spatial data. Given that forest resources are open in space, most of the issues related to monitoring their condition and creating a dynamic and up-to-date database can be solved today by means of remote sensing (RSD), which is an essential source of input data for geographic information systems (GIS). The processes of obtaining remote sensing data and the capabilities of geographic information software are developing dynamically, which affects the quality of the information received and its processing; efficiency and its interpretation expands the possibilities of its availability and reliability. However, the level of specialist awareness in forestry enterprises regarding the use of these technologies is currently insufficient.
Today, one of the most effective, convenient and cost-effective methods of remote monitoring is the use of satellite data. The existing services EO Browser, Planet Explorer, Sentinel Playground (Sentinel Hub), Copernicus Open Access Hub provide free access to viewing, analyzing and downloading space observation data from medium and high resolution satellites.
The use of open remote sensing data makes it possible to conduct mapping operations, monitor forest condition, assess timber stocks, monitor changes in forest cover, assess the ecological state, plan forest management, forecast forest fires, promptly record illegal logging, etc.
One of the ways to solve the problem of low culture of using open remote sensing data is to conduct special training courses, engage relevant specialists, and integrate scientific and technical developments into traditional forest management methods.

Conclusions and proposals

Thus, the integration of land cadastre and forest records is a key step towards sustainable natural resource management, leading to social, economic and environmental benefits for society. In general, while there are certain advantages of integrating land cadastre and forest records, potential disadvantages and challenges should also be carefully considered before deciding to integrate them.
The reasons for the discrepancies in spatial data are the lack of perfect geodetic tools and the methodology of cadastre maintenance at the initial stages of land reform.
The study of spatial data from different related sectors of the economy is an important factor for decision-making on forest management and conservation. The results of such studies can be used to integrate data, set restrictions on landscape use and develop sustainable forestry.
Comprehensive measures to solve the above problems are proposed: strengthening the legislative framework, transition to a unified state coordinate system, improvement of technological infrastructure, ensuring data accessibility to the public, development of interagency cooperation, professional development of relevant specialists and integration of information systems. These approaches will help to achieve efficient forest management.

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THE PROCEDURE OF USING AERIAL PHOTOGRAPHS TO CREATE THE GRAPHIC PART OF LAND MANAGEMENT DOCUMENTATION

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Abstract
The article is devoted to the use of aerial surveying issue to create a graphic part of land management documentation. For each type of land management documentation, the scale of graphic materials of land management documentation is determined, as the scale depends on the task and the required accuracy of the work. It has been established that aerial surveying is the most effective method for creating (updating) basic graphic materials of land management documentation at the scales of 1:5 000, 1:2 000, 1:1 000, space imagery is used to create of maps on a scale of 1:5 000 in plains and 1:10 000 in mountainous areas. It was determined that the use of aerial photographs in solving land management problems is possible only after passing all stages of their preliminary processing: post-processing, rectification and an orthophoto plan creation. General recommendations have been developed regarding the use of aerial photography to create the graphic part of land management documentation: aerial photographs or space images should be used for a large area; aerial photographs – for displaying land management objects within the boundaries of settlements; space images – outside of populated areas, or at the stage of designing land management documentation or performing planning works.
Key words: scale, land management documentation, aerial photographs, photogrammetric processing, cartographic materials

Introduction

Land reform, which has been taking place in Ukraine for more than 30 years, is a set of measures and mechanisms aimed at regulating land relations on the basis of rational, efficient and sustainable land use. The priority direction is the development of rural areas, decentralization of power in the use of land resources, ensuring equality of all forms of land ownership [1].

During analysis of definitions, types and approaches of land reforms in foreign countries [2-4], it was determined that land reform is a necessary socio-political and economic process of any country. The priority direction is the development of rural areas, decentralization of power in the use of land resources, ensuring equality of all forms of land ownership. In Ukraine, the priority tasks of improving land relations, taking into account the best practices of foreign countries, are [1]:

1) definition of clear rules and criteria, instructions and methods of agricultural land circulation subject selection, optimization of the size of economic structures, legislative limitation of permissible land areas that can be owned;
2) land market opening in few stages: first, allow the purchase of agricultural land only by individual natural persons - citizens of Ukraine, then gradually supplement the list of juridical entities;
3) imrovement of the institutional structure improvement of the land relations regulation through the creation of a state body that would regulate the circulation of land;
4) transfer of state-owned lands to territorial communities;
5) introduction of two-level (state and local) control over the rational and efficient use of land;
6) transformation of the State Land Cadastre into the State Real Estate Cadastre.

During solving most of the listed tasks, land management documentation is developed, which includes textual and graphic materials elaborted and approved in accordance with the Law of Ukraine "On Land Management" [5].

During the development of land management documentation, topographic and geodetic and cartographic works, land inventory, soil, geobotanical and other land surveys, land evaluation works are carried out [6]. Based on the results of the work, we receive graphic materials on a certain scale, which are formed based on the data of cadastral surveys, existing cartographic materials and data of aerospace surveying with the use of geoinformation systems. This determines the need for further research and specification of this direction.

Methodology of research and materials

The graphic part of land management documentation is performed using topographic maps and plans of various scales. At the same time, the scale of the cartographic material depends on the task and the required accuracy of the works. However, the law [5] does not specify the necessary accuracy of land management works. During the analysis of secondary legal acts of Ukraine (orders, methodological instructions and others) in the field of land management and urban planning, it was found that for most of the land management documentation no special rules and methodological instructions have been developed that would determine the accuracy of the work carried out.

The only document that regulates the accuracy of determining the boundaries of land plots is the Procedure for Conducting a Land Inventory [7], according to which the root mean square error of determining the coordinates of the turning points of the boundaries of land plots relative to the nearest points of the state geodetic network, geodetic networks of densification, urban geodetic networks should not exceed:

- in the city of Kyiv, Sevastopol and cities of regional subordination - 0.1 meters (corresponds to the scale accuracy of 1:500);
- in other cities and towns - 0.2 meters (corresponds to the scale accuracy 1:1 000);
- in villages - 0.3 meters (corresponds to the scale accuracy 1:2 000);
- outside the population centers - 0.5 meters (corresponds to the scale accuracy 1:5000).

The working inventory plan is drawn up on the basis of the regular cadastral plan or other planning and cartographic materials within cities and towns on a scale of at least 1:5,000, within villages and agricultural land massifs on a scale of at least 1:2,000, within territories defined by the projects of territory formation and establishment of village and settlement councils boundaries, on a scale of at least 1:10,000, within districts on a scale of 1:25,000. Boundaries of land plots entered into the State Land Cadastre, restrictions on their use, encumbrances of rights to land plots and lands are noted on the working inventory plan on a scale of at least 1:10,000.

Figure 1 shows various land management objects and the approximate scale of the image in the graphic part of the land management documentation.

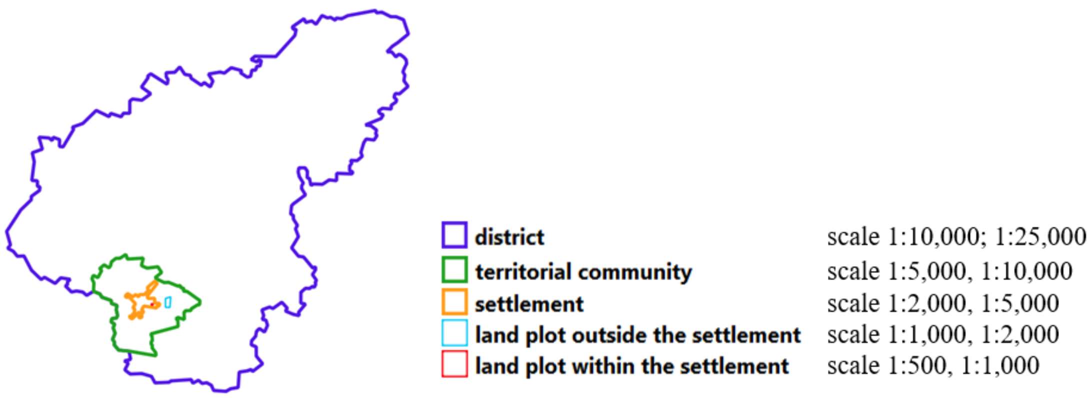

Fig 1. Land management objects and the approximate scale of the image in the graphic part of the land management documentation

Therefore, taking into account the requirements of the document [6], it can be determined that the graphic part of the land management documentation (main drawings) can be on a scale from 1: 500 to 1: 25,000 depending on the type of documentation, location and area of the territory (Table 1), and is compiled based on the results of cadastral surveys or available cartographic materials.

Table 1

The recommended scale of the land management documentation graphic part

No.	Land management documentation	Recommended scale of the map (plan)
1.	Land management schemes and technical and economic justifications for the use and protection of administrative-territorial units' lands	1:10 000, 1:25 000
2.	Land management projects regarding the territorial boundaries establishment of territorial communities	not less than 1:10 000
3.	Land management projects regarding the establishment (change) of the administrative and territorial units' borders	not less than 1:10 000
4.	Urban planning documentation, which is also land management documentation (complex plans for the spatial development of territories of territorial communities, general plans of settlements, detailed plans of territories)	from 1:500 to 1:5 000
5.	Land management projects regarding the organization and establishment of boundaries of the nature reserve fund and other nature conservation purposes, health, recreational, historical and cultural, forestry purposes, water fund lands and water protection zones, restrictions on the use of lands and their regime-forming objects	from 1:1 000 to 1:25 000
6.	Land management projects regarding land privatization of state and communal agricultural enterprises, institutions and organizations	from 1:500 to 1:10 000
7.	Land management projects regarding the allocation of land plots	from 1:500 to 1:5 000
8.	Land management projects regarding the arrangement of the territory for urban planning needs	from 1:500 to 1:5 000
9.	Land management projects that provide ecological and economic substantiation of crop rotation and land management	not less than 1:10 000
10.	Land management projects regarding the regulation of the settlements' territory	from 1:500 to 1:5 000
11.	Land management projects regarding the organization of the territory of land traces (shares)	from 1:5 000 to 1:10 000
12.	Land management working projects	from 1:2 000 to 1:25 000
13.	Technical documentation on land management regarding the establishment (restoration) of land plot boundaries naturally (on site)	from 1:500 to 1:5 000
14.	Technical documentation on land management regarding the establishment of the boundaries of the part of the land plot to which the rights of sublease, easement apply	from 1:500 to 1:5 000
15.	Technical documentation from the land surveying process and the association of land plots	from 1:500 to 1:5 000
16.	Technical documentation on land management regarding land inventory	from 1:1 000 to 1:25 000
17.	Technical documentation on land management regarding the reservation of territories and objects valuable for inheritance	from 1:1 000 to 1:25 000
18.	Technical documentation on land managemen regarding the establishment of regime-forming objects of cultural heritage boundaries	from 1:500 to 1:5 000
19.	Technical documentation on regulatory monetary assessment of land plots	from 1:500 to 1:10 000

Updating cartographic materials using traditional geodetic methods requires significant time, labor, material and financial costs. To reduce the listed costs, orthophoto plans of scales 1:2,000 and 1:5,000 were made, covering the entire territory of Ukraine according to the Project of Issuing State Acts on

Land Ownership in Rural Areas and Creating a Cadastre System, which was financed by the World Bank and implemented since 2004 until 2013 [8]. At the same time, the following difficulties arise:
1. The obtained materials are not available for most state and private geodetic and land management firms and enterprises.
2. Orthophoto plans become obsolete, which also leads to the need to update them (aerial photography was performed in 2007-2014). Therefore, a promising direction of research is the combined use of cadastral survey data, existing cartographic materials and aerospace survey data with the use of geoinformation systems at the stage of designing land management documentation.
Aerospace survey data are widely used to solve land management problems both in Ukraine and abroad. This is due to:
- relevance of data while shooting;
- ease of obtaining data (there is no need to obtain permission);
- high efficiency of data acquisition;
- significance of area coverage (starting with several square meters);
- high informativeness;
- lowering the cost of works compared to ground geodetic measurements.

Aerospace imaging data can be divided into three groups according to the way of shooting:
- aerial photographs from digital cameras mounted on aircraft or helicopters;
- aerial photographs from digital cameras installed on unmanned aerial vehicles (UAVs);
- space pictures obtained from artificial satellites of the Earth.

In Ukraine, aerial photographs obtained from the metric digital camera 3DAS of the scientific and production enterprise "Geosystem" are widely used [9].
To obtain images for end users (index block when using a stereo model or orthophotoplan), the original image necessarily undergoes photogrammetric processing using specialized software (Fig. 2).

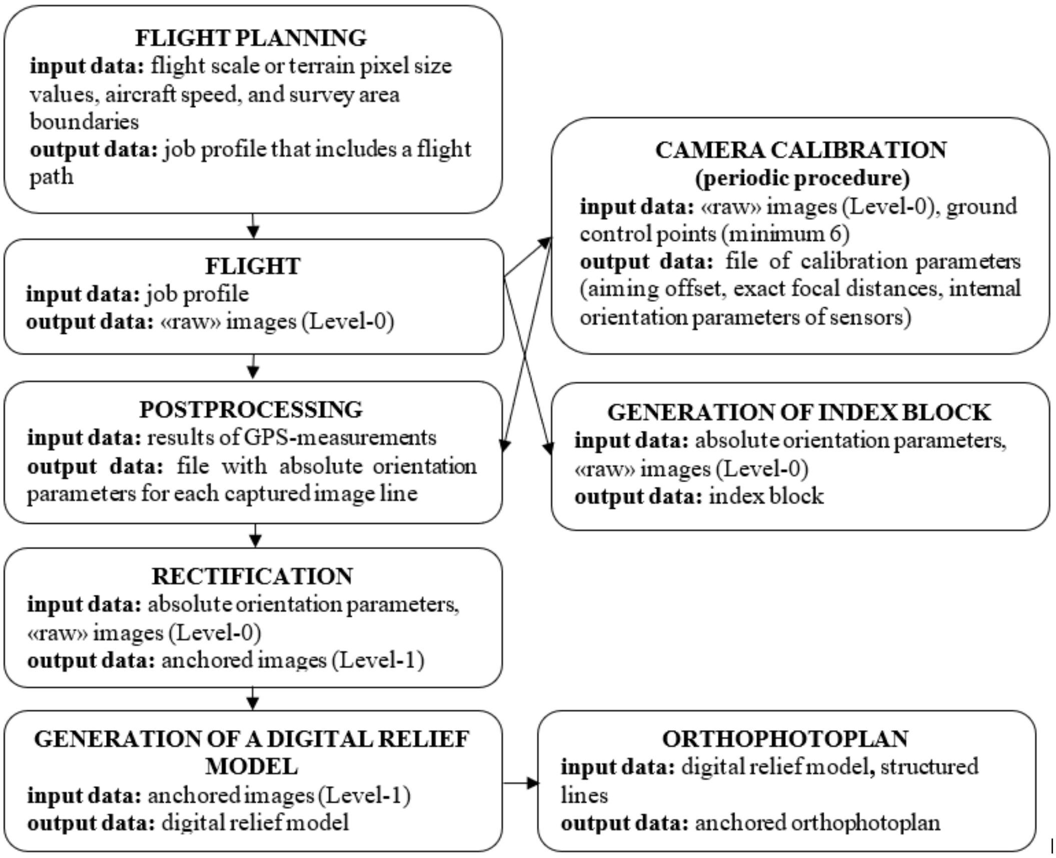

Fig. 2. Technological scheme of aerial photographs acquisition and photogrammetric processing

At the first stage of processing, flight GPS measurements are aligned together with measurements of base stations, at the second stage - automatic rectification of the original images using the data obtained at the first stage [10]. The image obtained in this way is corrected for the angles of inclination and the trajectory of the aircraft and has a geodesic reference. At the third stage, stereo drawing of the situation (creation of a digital map) or creation of a digital relief model (DRM), orthophoto transformation and composition of mosaic orthophoto plans in a geodetic layout is performed.

According to [11], aerial photographs obtained from a 3DAS digital camera are used:

- for the purposes of inventorying urban settlements (survey scale is 1:8,000-1:12,000, resolution on the ground is 0.07-0.10 m, accuracy tolerance is ±0.2 m);
- for the purposes of inventorying rural settlements (survey scale is 1:14,000-1:16,000, resolution on the ground is 0,12-0,15 m, accuracy tolerance is ±0,4m);
- for the purposes of forest taxation and forest inventory (survey scale is 1:25,000, resolution on the ground is 0,23 m, accuracy tolerance is ±1,0 m).

To control the accuracy of the obtained results, an independent selective accuracy control is performed by determining the coordinates of clear contour points using GPS measurements. The detected deviations for shooting scales of 1:10,000-1:12,000 are within tolerance and did not exceed the average error of ±0.15 m.

During shooting from unmanned aerial vehicles (UAVs), non-metric compact digital cameras are mainly used. The focal length of cameras is usually about 50 mm, which corresponds to a pixel size on the ground from 7 to 35 cm. The result of aerial photography is visible spectrum images (color images) or multispectral images – a synthesis of color images and near-infrared images. The possibility of using UAVs for aerial photography processes is considered in works [12-13]. In order to obtain the maximum accuracy of the results - about one pixel, which corresponds to the accuracy of orthophoto plans of scales from 1:500 to 1:2,000 depending on the shooting height - the shooting and processing of its results must be carried out based on strict photogrammetric data processing, i.e. perform phototriangulation.

The processing of aerial photography from UAVs at digital photogrammetric stations (DPS) is generally similar to the processing of aerial photography from "large aircraft" (Fig. 2). However, the peculiarities of the data from the UAV board often do not allow the use of automatic procedures of photogrammetric software. After strict photogrammetric processing of aerial photographs from a UAV, it is possible to obtain the accuracy of the planned position of the points of about 0.3-0.5 cm and the height - 1 m. The low results are explained by the following factors:

1. Image blurring during exposure.
2. Unsatisfactory tilt angles (more than 12°).
3. Longitudinal overlapping of images is not always satisfactory: unstable ground speed of the aircraft.

In addition, UAVs have an increased accident rate, so there is a high risk of losing the device and equipment. This is due to the fact that UAVs are not equipped with an obstacle detection and collision avoidance system, in addition, many models are equipped with less than perfect autopilots.

Currently, UAV data is not widely used due to the above-mentioned disadvantages. However, aerial photographs from UAVs, when eliminating the latter, can be used to solve problems:

- inventory of settlements lands and agricultural lands;
- monitoring the condition of forest areas, agricultural crops, monitoring the quality and timeliness of various activities in these territories;
- planning of agricultural and industrial land use;
- examination of the storage area of harmful and poisonous substances, to which human access is limited or dangerous;
- creation of large-scale plans of rural settlements for land registration and establishment of land plots boundaries.

To create large-scale plans (scale 1:5,000), space photographs with a spatial resolution of 0.61 m at nadir and 0.66 m at 15° deviation from nadir are also used. Space images are in color and multispectral. Multispectrality is provided by a panchromatic channel and a multispectral image, which consists of four channels − blue (0.45−0.520 μm), green (0.52−0.60 μm), red (0.63−0.69 μm), and infrared (0.76−0.90 μm) spectral range.

The theoretical basis for evaluating the suitability of space-based imaging systems for territory mapping is the resolution and radiometric characteristics. To improve the visual and geometric characteristics of the image, the following types of processing are carried out: sensory correction, radiometric correction, geometric correction.

However, the above data are valid only for perfect conditions. Under normal conditions, due to the influence of atmospheric turbulence, spacecraft and receiver tilt, image shift, residual defocusing, diffraction, and receiver discreteness, the accuracy can be 1.5–2 times lower [14]. Also, the scale of orthophoto plans, which can be created from space photographs, depends on many factors, among them: the quality and quantity of reference points, the quality of digital models of the terrain and the terrain, the characteristics of the software, and the qualifications of the performers. Moreover, all these factors must be considered together.

Despite all the advantages of using special software for working with data from aerial photography, there is also a significant drawback - its high cost. According to the authors, the problem can be solved by using special settings of modern multipurpose geoinformation systems that allow working with space images. However, in this case, it is necessary to buy a picture that has already been subjected to additional geometric processing, which, in our opinion, leads to an increase in costs of work.

The problem of using space survey data for large-scale mapping was also considered by the authors [15-18]. They developed a technological scheme for the creation of topographic materials with the involvement of space images, which includes the following stages:

1. Outline of the work area. Choosing the optimal type of pictures. Preparation of the nomenclature list and ordering of pictures.
2. Compilation, preparation, scanning and spatial reference of relevant large-scale cartographic materials.
3. Construction of a digital terrain model.
4. Radiometric correction of space shooting materials.
5. Geometric correction of space images using a digital terrain model.
6. Creating a mosaic covering the work area.
7. Spectral correction. Improvement of pictures visual perception.
8. Camera decoding and creation of necessary vector layers (vectorization of contours).
9. Selection of coordinate system and topographic projection. Compilation of the received materials into a single information system.
10. Generalization. Preparation of additional data to ensure fast and high-quality visualization of the vector and raster base at different scale levels.
11. Choosing the optimal data format. Transferring the resulting data into the required format for further inclusion in the geoinformation system.

While solving specific land management problems, orthoimages are used that have undergone preliminary processing and are an analogue of a plan or map.

Space images are successfully used to solve land management problems related to the use of agricultural land [19]. Using images with even a medium (2.5 m) spatial resolution, it is possible to decipher the boundaries of land (arable fields, meadows, gardens, etc.) and their condition (land disturbance, tree vegetation, types of crops, soil moisture, damage by pests or weeds, etc.). Agricultural land boundaries are determined by visual or automatic decoding.

Thus, at this stage the remote sensing methods, aerial surveying according to technical, economic and multifunctional characteristics development is still the most effective method of creating (updating) basic cartographic materials at the scales of 1:5,000, 1:2,000, 1:1,000 for solving problems cadastre and accounting of land resources, while ensuring a comprehensive approach to planning and functional organization of territories. Space images of high spatial capacity can be used to update only the contour part of maps at a scale of 1:5,000 in plains and 1:10,000 in mountainous terrain.

Discussions and results

So, let's assume that when using aerial photos, we receive graphic materials on a scale of 1:2,000, 1:1,000, and space photos on a scale of 1:5,000 and smaller, so the general recommendations for using data from aerospace photography are following:

1. aerial photos or space images are advisable to use when solving land management problems of a large territory;
2. aerial photographs are used to solve land management problems within settlements;
3. space images are used to solve land management problems outside settlements or at the stage of planning and designing land management documentation.

Recommendations for the use of aerial survey data during the development of the graphic part of specific land management documentation according to the Law [5] are given in the table 2.

Table 2

Recommendations on the use of aerial survey data for the development of the land management documentation graphic part

No.	Land management documentation	Recommended scale of the map (plan)	Aerospace survey data
1	2	3	4
1.	Land management schemes and technical and economic justifications for the use and protection of administrative-territorial units lands	1:10 000, 1:25 000	space images
2.	Land management projects regarding the establishment of territorial boundaries of territorial communities	not less than 1:10 000	space images / aerial photos
3.	Land management projects regarding the establishment (change) of administrative and territorial units borders	not less than 1:10 000	space images / aerial photos
4.	Urban planning documentation, which is also land management documentation (complex plans for the spatial development of territories of territorial communities, general plans of settlements, detailed plans of territories)	from 1:1 000 to 1:5 000	space images / aerial photos
5.	Land management projects regarding the organization and establishment of boundaries of the territories of the nature reserve fund and other nature conservation purposes, health, recreational, historical and cultural, forestry purposes, water fund lands and water protection zones, restrictions on the use of lands and their regime-forming objects	from 1:1 000 to 1:25 000	space images / aerial photos
6.	Land management projects regarding land privatization of state and communal agricultural enterprises, institutions and organizations	from 1:500 to 1:1 000	aerial photos
7.	Land management projects regarding the allocation of land plots	from 1:500 to 1:5 000	aerial photos
8.	Land management projects regarding the arrangement of the territory for urban planning needs	від 1:500 to 1:5 000	aerial photos
9.	Land management projects that provide ecological and economic substantiation of crop rotation and land management	not less than 1:10 000	space images
10.	Land management projects regarding the regulation of the settlements territory	from 1:500 to 1:5 000	space images / aerial photos
11.	Land management projects regarding the organization of the territory of land traces (shares)	from 1:5 000 to 1:10 000	space images / aerial photos
12.	Land management working projects	from 1:2000 to 1:25000	space images / aerial photos
13.	Technical documentation on land management regarding the establishment (restoration) of land plot boundaries naturally (on site)	from 1:500 to 1:5 000	aerial photos

Table 2 continuation

1	2	3	4
15.	Technical documentation from the land surveying process and the association of land plots	from 1:500 to 1:5 000	aerial photos
16.	Technical documentation on land management regarding land inventory	from 1:1 000 to 1:25 000	space images / aerial photos
17.	Technical documentation on land management regarding the reservation of territories and objects valuable for inheritance	from 1:1 000 to 1:25 000	space images / aerial photos
18.	Technical documentation on regulatory monetary assessment of land plots	from 1:500 to 1:5 000	aerial photos

The specified list is not exclusive and can be supplemented taking into account the development of modern information systems and the legal field.

Conclusions and proposals:

1. The successful solution of land management problems in the modern conditions of Ukraine requires constant updating and actualization of cartographic materials along with a reduction in the cost and labor intensity of works. The solution to the given problem requires the improvement of joint use areas at the stage of designing land management documentation of cadastral survey data, existing cartographic materials and aerospace survey data with the use of geoinformation systems.
2. The analysis of existing approaches to the use of aerospace survey data made it possible to establish that at this stage of the development of remote sensing methods, aerial surveying is the most effective method for creating (updating) basic cartographic materials at scales of 1:5,000, 1:2,000, 1:1,000 to solve cadastre problems and accounting for land resources while providing an integrated approach to planning and functional organization of territories. Space images can be used to update only the contour part of the 1:5,000 scale maps in plains and 1:10,000 in mountainous terrain.
3. The use of aerial photographs when creating the graphic part of land management documentation is possible only after passing all stages of preliminary processing: post-processing, rectification and creation of an orthophoto plan.
4. The approach of using aerial photographs during the formation of land management documentation graphic materials is based on general recommendations:

- it is advisable to use aerial photographs or space photographs during the formation of graphic materials of land management documentation of a large territory;
- aerial photographs are used during the formation of land management documentation graphic materials within settlements;
- space images are used during the formation of land management documentation graphic materials outside of settlements, or at the stage of designing land management documentation or performing planned works.

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THE GEODETIC NETWORK ANALYSIS, PREREQUISITES AND FACTORS OF THE NEED FOR GEODETIC MONITORING OF SETTLEMENTS AND STRUCTURES DEFORMATIONS

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Abstract

The purpose of this article is to analyse the geodetic network, prerequisites and factors that arise for geodetic settlements monitoring and deformations of the ChNPP engineering structures. It is determined that one of modern applied geodesy directions is deformation monitoring. It consists in regular monitoring of buildings deformations and other important structures by geodetic methods, carried out with the aim of timely detection and prevention of emergency situations. The factors influencing the emergence of new tasks and changes in the construction situation at the shelter facility, which necessitated the reconstruction of the planned and height geodetic network, are analysed. The necessity of organising observations of new control marks in the western part of the shelter is established. The influence of external factors that cause structural changes to the foundation under the building, the outer parts of the brick walls and man-made factors, the mechanism and intensity of these processes were analysed. The optimum height of sedimentary marks from the level of the blind area is determined. The list of objects for monitoring and observation of the building structures of the shelter was determined. The scheme of the main planned reference geodetic network at the facility and ensuring the required accuracy of deformation measurements was developed. The long-term control leveling of the height network of the investigated object shows that its reps, especially the deep and fundamental ones, are stable and can be used for further observations of vertical structures deformations. Thus, to ensure proper accuracy of leveling control marks of buildings and structures of the shelter complex, the height network of deep and fundamental references should be such that the distance between them does not exceed 0.5 km. The tolerance for the accuracy of subsidence determination of the marks of the upper shelter levels, which can be determined only by remote method, for example, trigonometric leveling, should be taken as for the II class of measurement accuracy, not more than 2 mm.

Key words: deformation monitoring, geodetic reference network, subsidence marks, depth and foundation raps.

Introduction

One of modern applied geodesy directions is deformation monitoring. This concept includes geodetic monitoring of settlements and deformations of foundations, as well as other important structural elements of buildings and structures. In addition to them, the objects of deformation monitoring can be foundations, structures of buildings or their parts, new construction objects, engineering networks, underground structures and infrastructure facilities surrounding them (Celms et. al., 2022; Яковенко and Нестеренко, 2019).

Deformation geodetic monitoring involves regular monitoring of deformations of buildings and other important structures using geodetic methods, and is carried out to detect and prevent the development of emergencies in a timely manner. This type of engineering monitoring is an important link in construction, as well as in the system of state and departmental technical supervision (Sztubecki et. al., 2022; Vynohradenko et. al., 2023).

Monitoring of building structures is carried out on the basis of an approved programme using technical means of non-destructive testing and the frequency established in the programme. The frequency of work is determined taking into account the responsibility classes of building structures, according to Building code DBN B.1.2-14:2018 (ДБН, 2019). The minimum frequency of observations is set according to the design and regulatory documents or special requirements for a particular facility. If necessary, the frequency of certain types of observations of building structure elements and the construction object may be adjusted.

Continuous monitoring of the technical condition of buildings and structures using automated systems is organized on structures that are responsible for safety criteria. In this case, devices and equipment

with automatic storage, processing and transmission of measurement results via information communication channels are used (Третяк and Савчин, 2013; Могильний et. al., 2010).
Limit parameters values of construction objects are assessed according to the criteria for the condition of buildings and structures elements, which determine under what conditions it is impossible for them to perform their functions for technical reasons, which include the risk of destruction of individual elements, loss of overall stability, etc. Assessment of technical condition parameters according to their limit criteria is used to make decisions on:

- ensuring people's safety;
- transfer of the facility to emergency operation, implementation of emergency measures and minimisation of possible consequences;
- bearing structures strengthening of the facility.

Analyzing the causes of structures deformation, it can be argued that man-made factors have the greatest impact. They are the most dangerous, as the creation of artificial reservoirs not only floods hundreds of thousands of hectares of land, but also disrupts the water balance of the planet as a whole. Such human activity leads to changes in riverbeds, which in turn cause endogenous and exogenous phenomena that lead to emergencies, so it is necessary to monitor the condition of engineering structures located in close proximity to reservoirs (Смолій, 2015; Войтенко et. al., 2009).
Having considered the causes of engineering structures deformation, their measurements can be divided into two independent groups (Суярко et. al., 2019). The first group includes: studies of the physical and mechanical properties of the foundation soils, pressure measurements under the foundation sole, measurements of the foundation temperature, groundwater level fluctuations, etc. All these types of measurements can be united under the common name of "physical and mechanical supervision". The second group includes measurements of settlements and deformations of structures. These measurements are carried out both by classical geodetic and other methods. It is clear that the measurement results of these two groups should be considered comprehensively.

Methodology of research and materials

The plan-height position of the northern and southern foundations of the service area of the new safe confinement of the ChNPP is monitored by observing control marks installed on the structures of the outer wall of the hinged supports gallery, which rest directly on the grillage and are structurally connected to them. The marks are installed in increments of about 20 m, taking into account the location of the thermal joints. In this case, the installation of control marks is carried out on both sides of the grillage. A total of 25 control marks are to be installed: 12 marks on the northern foundation and 13 control marks on the southern foundation.
To protect against corrosion, the control deformation marks shall be painted, numbered with indelible paint, and tied to the corners of walls or ledges according to the scheme. The nearest points of the geodetic network shall be used to determine the planned elevation of the control marks.
The layout of control marks on the structures of the Arch hinged support gallery is shown in figure 1.
The planned geodetic network of the Shelter was constructed to ensure geodetic control over horizontal and vertical deformations.
The network includes a basic GPS network consisting of 9 points and a linear-angle network (triangulation) consisting of 16 points. The GPS network points are the starting points for determining the coordinates of the triangulation points.
Vertical movements of control marks of the lower tier are determined mainly by geometric leveling of class II, with a stroke misalignment of no more than

$$0{,}5\sqrt{n}\ мм, \quad (1)$$

with *n* – number of tripods in the course,
and where class I leveling lines are close to the structures, simultaneously with the main course. The length of the leveling stroke should not exceed 0.5 km. The value of the vertical movement of the control mark is determined by the difference between the marks obtained in the working and initial cycles. The tolerance for the accuracy of determining the settlements of the marks of the Shelter upper tiers, which can be determined only by remote method, for example, trigonometric leveling, should be taken as for the measurement accuracy class II, not more than 2 mm, especially for control marks located on the roof

and most exposed to temperature changes. For control marks placed on the upper levels of the Shelter, spatial (horizontal and vertical) displacements are determined by the following formulas (2):

$$\Delta X = X'' - X'' ; \quad \Delta Y = Y'' - Y' ; \quad \Delta H = H'' - H' ;$$

$$\ell = \sqrt{\Delta X^2 + \Delta Y^2} = \frac{\Delta X}{\cos \alpha_\ell} = \frac{\Delta Y}{\sin \alpha_\ell} ; \quad \alpha_\ell = \text{arc tg}\frac{\Delta Y}{\Delta X} ; \quad R = \sqrt{\ell^2 + \Delta H^2} , \tag{2}$$

with X', Y', H' та X'', Y'', H'' – equalized spatial coordinates of reference marks obtained from the initial and current measurement cycles; ΔX, ΔY, ΔH – are movements of the mark along spatial coordinate axes; *l*, *R* – horizontal and spatial vector of the mark movement; α_ℓ – the directional angle (azimuth) of the stamp movement direction (in the X, Y plane).

By uniting control marks into groups, for example, by belonging to separate tiers, structures, etc., and analyzing their movement, it is possible to derive a generalized vector of movement of the group of marks and its directional angle, in particular:

$$\overline{\Delta X} = \frac{1}{n}\sum_{i=1}^{n} \Delta X ; \quad \overline{\Delta Y} = \frac{1}{n}\sum_{i=1}^{n} \Delta Y ; \quad \overline{\Delta H} = \frac{1}{n}\sum_{i=1}^{n} \Delta H ; \quad \bar{\ell} = \sqrt{\overline{\Delta X}^2 + \overline{\Delta Y}^2} ; \quad \bar{\alpha}_\ell = \text{arc tg}\frac{\overline{\Delta Y}}{\overline{\Delta X}} , \tag{3}$$

with n – number of control marks in the group.

The degree of confidence in the generalized coordinate strain vector is characterized by its errors by the following formulas:

$$m_{\overline{\Delta X}} = m_X \sqrt{\frac{2}{n}} ; \quad m_{\overline{\Delta Y}} = m_Y \sqrt{\frac{2}{n}} , \tag{4}$$

with m_X , m_Y - errors in determining the coordinate (abscissa or ordinate) of the mark.

By comparing these generalized deformation characteristics with each other, their changes depending on the height or location on the structure or building, it is possible to derive generalized characteristics to take into account the influence of other factors. One of these factors may be the temperature deformation factor, which has the greatest impact on the change in elevations and, in large structures, affects the amount of roll.

Discussions and results

The planned geodetic network was developed in stages as the scope of engineering and geodetic surveys at the site expanded and the required accuracy of deformation measurements was ensured (Винограденко, 2023; Vynohradenko, Siedov et. al., 2022).

An engineering and geodetic network was constructed with observation points located on the southern, western and northern sides of the Shelter. A number of control references and marks were fixed on the walls of the structure and its roof, which were selected taking into account potentially possible areas of settlement and deformation displacements of structures. The height position of the control marks located on the lower level of the Shelter was controlled by leveling of the I and II classes with reference to the depth references laid by the Ukrhydroproject Institute during the construction of the ChNPP. Control of the spatial position of control marks located on the upper tiers of the walls and roof of the facility was carried out by the method of direct angular notches from the points of the engineering and geodetic network.

The emergence of new tasks and changes in the construction situation at the Shelter necessitated the reconstruction of the planned and height geodetic network. The first reconstruction of the primary geodetic network was carried out by Ukrinzhgeodesiya in 1996, when a number of new points and references were laid, and modern engineering and geodetic equipment was used: a satellite geodetic system (GPS signal receivers 4600 by Trimble), an electronic total station TC 1800 and an electronic digital level NA 3003 by Leica (*Програма*, 2000). To measure the deformation displacements of the frame columns, a laser rangefinder "DISTO" by Leica was used.

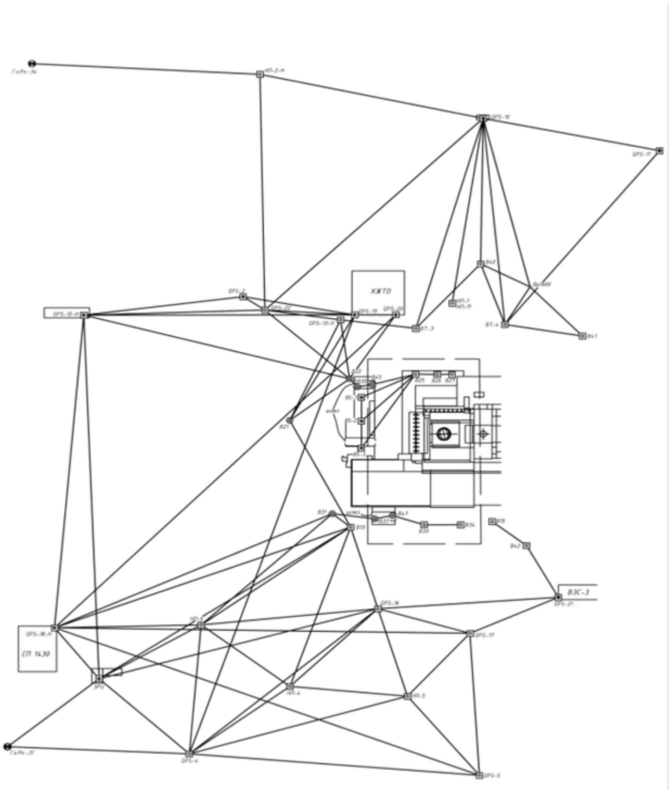
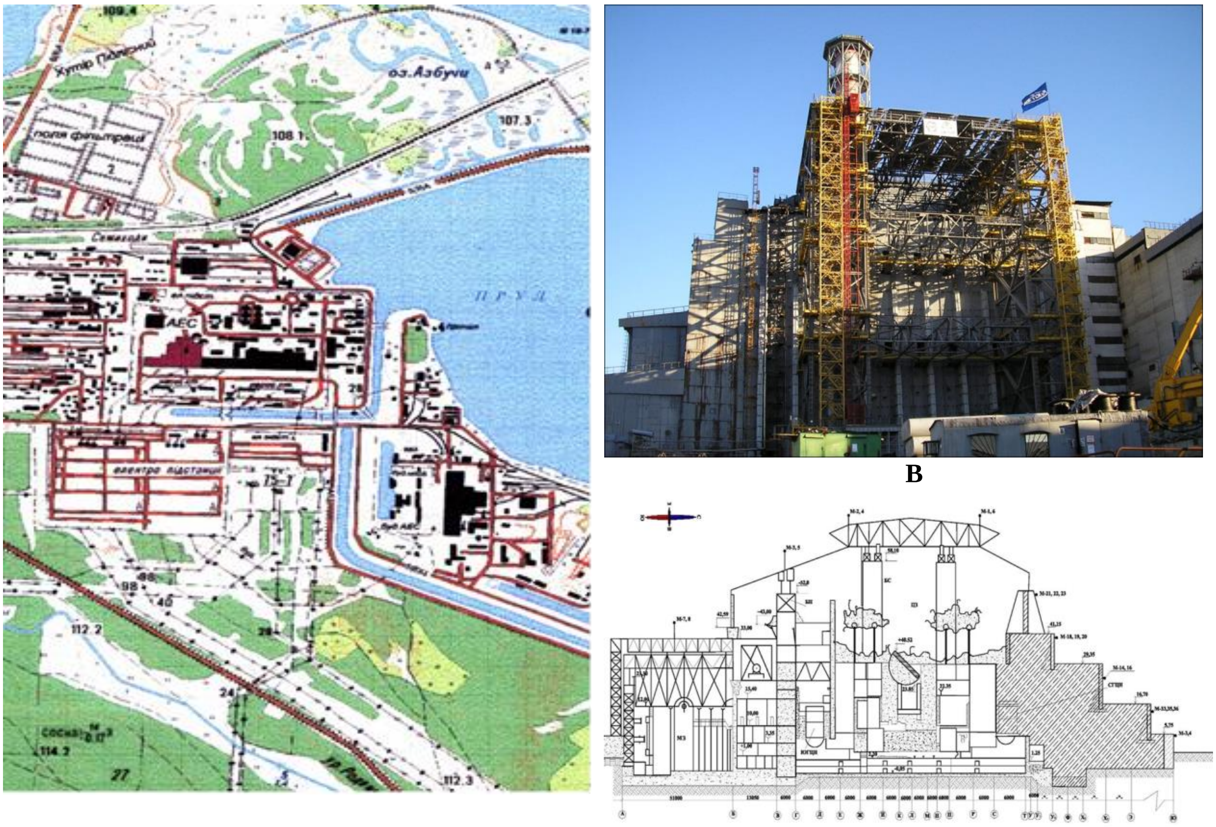


Figure 1. Scheme of the main planned geodetic reference network of the new safe confinement of the Shelter (source: developed by the author)

The second reconstruction of the planned geodetic network was performed due to the need to organise observations at new control marks M 9, M 10, M 11, M 12 and M 501, M 502, M 503, M 504, which resulted in the construction of a number of GPS network operating points in the Western Zone of the Shelter. In connection with the implementation of the Shelter transformation into an environmentally safe system, the planned geodetic network (and partially the height network) underwent a third reconstruction, which required a change in the structure of the network itself and placement of a part of the GPS network points on the roofs of the structures closest to the facility. The fourth reconstruction of the geodetic network was carried out in connection with the preparation of the site for the implementation of the action plan and partially for the construction of a new safe confinement (*Стратегія*, 2001). The fifth (last) reconstruction of the Shelter geodetic network was carried out in 2010. The results of observations performed at the facility show that vertical displacements of control references and marks reach 40 mm and increase annually. A map of the ChNPP industrial site is shown in figure 2 a, general view of the Shelter is shown in figure 2 b, and the layout of the main structures of the Shelter (section along axis 47) in figure 2 c.

It is an obvious fact that buildings in operation undergo gradual changes in the structure and properties of materials, and they are gradually destroyed by external factors: mechanical, physical, biological, chemical, etc. (erosion, corrosion). In the case of erosion, the greatest danger is posed by groundwater impact on the foundation under the building. Depending on the effects of air, water, and soil, different types of corrosion occur. The destruction of the outer parts of brick walls (weathering) occurs under the influence of temperature changes, alternating winds, moisture and drying, and freezing of water in the pores. On the surface, corrosion is caused by the penetration of water vapor into the pores and hygroscopic cracks of building structures. Another cause of corrosion damage to building structures is oxidation (*Розробка*, 2015).



A C

Figure 2, a - Map of the location of the Chornobyl NPP industrial site facilities; **b -** General view of the Shelter; **c -** Scheme of Shelter main structures location (section along axis 47) (source: developed by the author)

In addition to the significant material costs associated with restoring the operational properties of structures, their consequences lead to social and environmental damage. Therefore, it is important to correctly and timely assess the condition of structures, predict the possible development of defects and develop measures to stabilize or eliminate them. To do this, it is necessary to have an understanding of the mechanism of destruction and amortization of structural elements during operation and the impact of environmental factors on building structures.

Observations during the monitoring process consist of controlling vertical and horizontal displacements of characteristic points and lines:

1. To observe vertical deviations (precipitation monitoring), so-called sedimentary marks are placed in the foundation, and these marks are periodically leveled. The difference in the height of the marks after comparing the data from different measurement cycles characterizes the size of the deformations and their rate. If uneven settlement leads to the development of crack deformations, they also become objects of monitoring. When laying sedimentary marks, the conditions of access to them and the possibility of installing a leveling rail on them should be taken into account, as a rule, at 0.4-0.8 meters from the level of the blind area or the level of the clean floor. Sedimentary deformation marks should be painted with indelible demasking paint, numbered and tied to the corners of walls or ledges.
2. The second aspect of geodetic monitoring is the control of horizontal displacement of vertical structures: columns, walls, etc. The degree of influence of the factors in each case may vary in intensity, but in each case, the main factor in extending the life of the building is the timely detection of major damages and defects in the building, which is followed by their elimination.

The results of geodetic observations of vertical and horizontal displacements of deformation marks, the dynamics of changes in the vertical displacements of control marks between the research cycles installed on the building of the fire water supply pumping station (FWS), the building of electrical devices (BED) and the technological building (TB) are shown in figures 3 a, b, c.

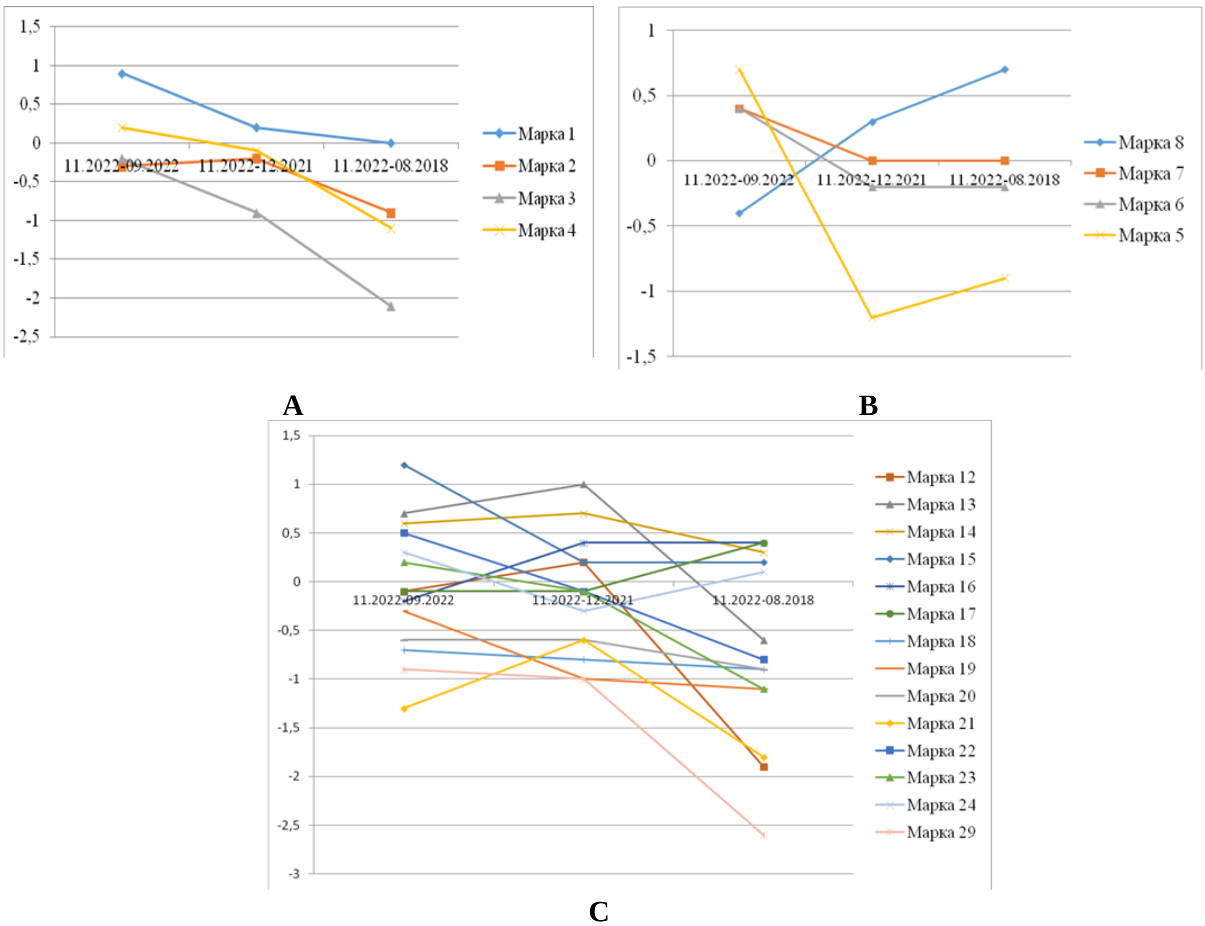


Figure 3. Dynamics of vertical movements of control marks between observation cycles: **a -** installed on the FWS building; **b -** installed on the BED building; **c -** installed on the TB building (source: developed by the author)

Figure 3 describes the vertical and horizontal spatial displacements of the control and deformation marks installed on the building structures, as well as the total (sum) linear deviations and roll.

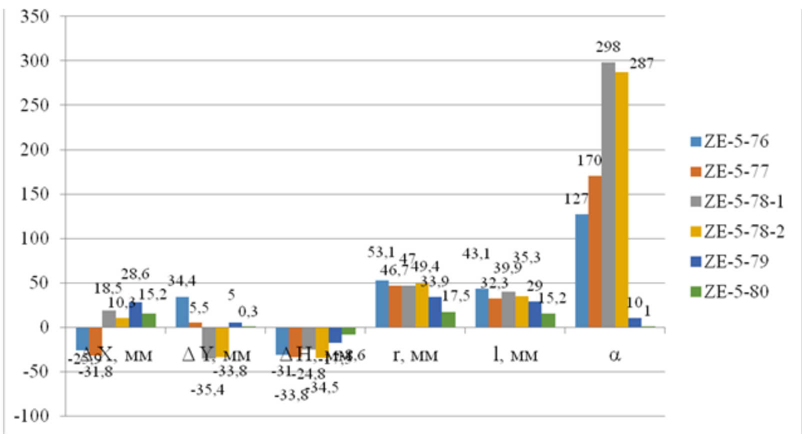


Figure 4. Dynamics of spatial displacements of control marks of NSC arch structures in the period 08.2018 - 11.2022 (source: developed by the author)

Based on the results of settlements and deformations observations, a technical report is prepared. If necessary, a forecast is made and recommendations are provided on measures to prevent the adverse effects of excessive deformations.

Conclusions and proposals

The analysis of the geodetic network, prerequisites and factors of the need for geodetic monitoring of settlements and deformations of the ChNPP Shelter structures, in particular, the values of horizontal and vertical displacements of control marks, in observation cycles, shows that the process of deformation of the NSC complex and adjacent buildings and structures continues. To analyze the displacements of control marks for a year, which is an integral part of monitoring the condition of NSC building structures, operational limits of safe operation were established, based on the fact that geodetic measurements are compared between the same observation seasons for a year with insignificant fluctuations in measurement temperatures. The obtained results will be used as initial data to track the dynamics of displacements, stability of building structures and take timely measures to prevent structural failure and predict emergencies of the NSC complex, as well as auxiliary buildings and structures.

The dynamics of control marks displacement between the cycles of two years of observations does not significantly manifest itself and does not exceed the permissible displacement parameters specified in the regulatory document "Technological Regulations for the Operation of the NSC-OU Complex", which may indicate a satisfactory condition of the complex building structures in general.

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COMPATIBILITY OF ABANDONED LAND IDENTIFICATION WITH OTHER SPATIAL DATASETS

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Abstract
The article analyses the identification of abandoned land on the example of the municipality of Jonava district of the Republic of Lithuania. Spatial analysis methods were used for the study. It was found that according to the spatial dataset of abandoned land (AŽ_DR10LT), the area of abandoned land in the municipality of Jonava district is 531.8 ha, which is 0.56 % of the total area of the district (including inland waters). The consistency of the identification of abandoned land in the study area with other spatial databases showed that identical areas in terms of land use are represented differently in different databases. The most frequent discrepancies were observed when assessing the relationship between abandoned land and land use identification in the spatial dataset of control land plots (KŽS_DR5LT). Both in absolute terms and as a percentage of the area covered, abandoned land was concentrated in blocks not formally associated with cultivated land, i.e. urban, forest and mixed blocks identified as plots. The compatibility of AŽ_DR10LT with the Spatial Data Set of (Geo) Reference Base Cadastre (GRPK) is much higher. It can be seen that the identification of abandoned land has been consistent with the GRPK and that some errors are topological in nature and occur during the spatial analysis process (e.g. inclusion of very small areas of abandoned land in buffers around linear features). However, areas of abandoned land are not included at all in the areas defined in the Forest State Cadastre. This is to be expected, as the identification of abandoned land is harmonised with the information contained in the Forest State Cadastre. The presence of abandoned land in neighbourhoods whose type is difficult to link to eradication processes can be explained by the detailed compilation of the different databases or by a lack of coordination in the compilation of the databases.
Key word: abandoned land, dataset, spatial data compatibility.

Introduction

As of 1 December 2023, there are 33954.4 ha of abandoned agricultural land in Lithuania. This is about 1% of the total agricultural land area of the country. Abandoned land includes the areas of agricultural land covered with woody plants (except plantations) on a plot of land or a part thereof, determined by remote sensing methods in accordance with the procedure established by the Government of the Republic of Lithuania or a body authorised by the Government of the Republic of Lithuania (Land tax law..., 2011). Since 2013, the State Enterprise "State Land Fund" has been systematically accounting, managing and actualising abandoned land throughout the territory of Lithuania. The accounting of abandoned agricultural land is carried out using remote mapping methods and in response to notifications of individuals and legal entities about inaccuracies in AŽ_DR10LT, in which they report the regularisation of areas of abandoned agricultural land or request to correct the areas of abandoned agricultural land due to changes of agricultural land on land plots based on the results of cadastral survey (Description of the procedure..., 2013). Note that for persons whose land plots have been identified as abandoned agricultural land, district and city municipal administrations apply an increased land tax for the current year, which can be up to 4 % of the value of the land plot.

Although the amount of abandoned land in Lithuania is decreasing year by year, the rational possible use of this abandoned agricultural land, assessed at national level, is a pressing issue today. The system of abandoned land monitoring is based on the realities of geographical information collection in Lithuania in the recent past. However, in recent years the geographical information infrastructure in Lithuania has developed significantly, the volume of collected data has increased and new data collection technologies have emerged. On the other hand, accurate and timely information on abandoned land is in demand for other tasks related to sustainable land management, such as managing greenhouse gas emissions and absorption, increasing the country's forest cover, etc. The development of an action plan for the sustainable use of abandoned land is envisaged in the Programme of the Government of the Republic of Lithuania (2021) for the implementation of Green

Deal measures, and is also relevant for climate change policy in terms of reducing greenhouse gas emissions, which contributes to the implementation of climate-neutral policy objectives of the European Union (Communication European Green...., 2019; EU Adaptation..., 2021; National Climate..., 2021). It is therefore important to assess the potential of the current methods of collecting and using information on abandoned land in general and how they can be improved to meet today's needs and opportunities. Therefore, in this paper we present the compatibility of the identification of abandoned land with other spatial datasets.

Methodology of research and materials

Improvement of the system of abandoned land identification and monitoring of its development is considered in more detail on the example of the study area – the territory of Jonava district of the Republic of Lithuania (Figure 1). It has extensive digital geographical data and favourable conditions for field verification data collection. Various methods of spatial analysis to analyse data reflecting the situation in 2021 were used in the study. That is, versions of datasets that were created with minimal differences in the date of creation or update compared to 2021 were used.

Fig. 1. Geographical position of Jonava district municipality in the Republic of Lithuania

The following datasets were used for the study:

- Spatial dataset AŽ_DR10LT of abandoned lands in the territory of the Republic of Lithuania;
- Spatial dataset KŽS_DR5LT of control land plots of the Republic of Lithuania;
- ORT10LT digital raster map of the territory of the Republic of Lithuania, scale 1:10 000;
- Spatial dataset of (Geo) reference base cadastre GRPK;
- The Forest State Cadastre of the Republic of Lithuania.

Discussions and results

According to the spatial dataset AŽ_DR10LT, the area of abandoned land in Jonava district municipality was 531.8 ha, which is 0.56% of the total area of the district (including inland waters). Visually, the concentration of abandoned land is higher in the southern part of the district than in the northern one (Figure 2).

Fig. 2. Abandoned land in Jonava district municipality according to AŽ_DR10LT

For the consistency of the identification of abandoned land, we assessed the relationship between abandoned land and the identification of land in the spatial dataset of control land plots (KŽS_DR5LT) (Table 2). We observed that, both in absolute terms and as a percentage of occupied area, abandoned land was concentrated in blocks not formally associated with cultivated land, i.e. urban, forest land, and in plots identified as mixed blocks.

Table 2

Distribution of abandoned land by block type in the dataset KŽS_DR5LT

Code	**Discription**	**Area, m^2**	**Percentage**	**Location coefficient***
bl1	Cultivated land control plot – an area of land that is predominantly cultivated (arable land, meadows, orchards and berry fields)	48365	0.909	0.022
bl1b	Cultivated land control plot means an area of land predominantly under cropland (arable land, meadows, orchards and berry orchards) for which no aid was requested in the previous year	38284	0.719	0.605
bl2	Urban built-up area control plot	161949	3.043	2.559
bl3	Control forest land plot – a plot of land that is predominantly forest land (forests, groups of trees, scrubland)	5011650	94.156	2.064
bl6	Built-up area control land plot outside the city	23292	0.438	0.144
bl9	Control mixed land plot – a plot of land that is largely unused for agriculture (wetlands, quarries, temporarily waterlogged areas, etc.).	29789	0.560	0.499
gc14p	Paved road without a hard surface	1634	0.031	0.053
gc16p	Dirt and forest road	3243	0.061	0.087
hc31p	1-3 m wide stream, ditch, canal	137	0.003	0.015

Code	Discription	Area, m²	Percentage	Location coefficient*
hc32p	3-6 m wide stream, ditch, canal	589	0.011	0.019
hc33p	6-12 m wide stream, ditch, canal	215	0.004	0.004
hd1	River	1915	0.036	0.028
hd4	Other surface water body (pool, peat)	1670	0.031	0.070

* Note: If the location coefficient is greater than one, this type of case is disproportionately high; if the location coefficient is less than one, this type of case is disproportionately low

Often, the presence of abandoned land in blocks whose type is difficult to relate to abandonment processes can be explained by the granularity of the compilation of the different databases, or by a lack of coordination during the compilation of the databases (Figure 3). For example, abandoned land is identified in water bodies, but this is explained by the fact that the identical contours of KŽS_DR5LT and AŽ_DR10LT are probably not sufficiently co-ordinated. In the urban blocks, the abandoned land identified is concentrated in the suburbs of Jonava. Blocks formed around linear objects (roads, ditches) often cross abandoned land polygons.

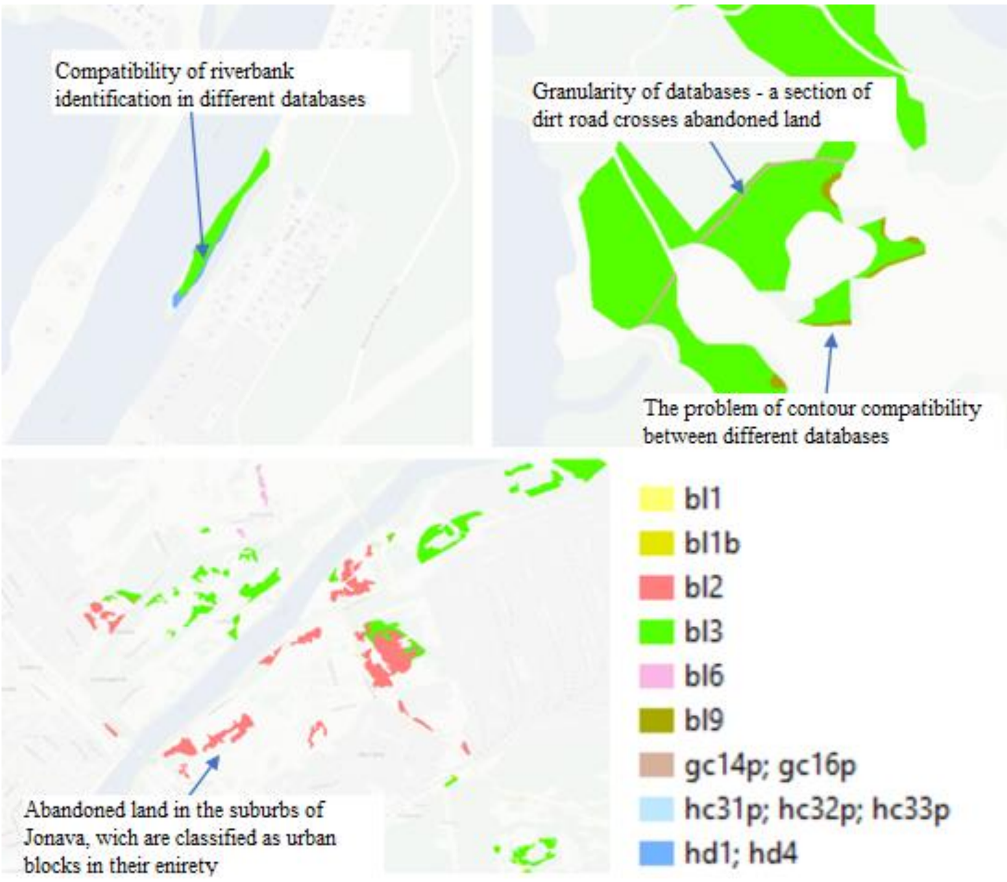

Fig. 3. Examples of compatibility problems between KŽS_DR5LT and AŽ_DR10LT

It should also be noted that the likelihood of abandoned land being present on farmland where no support has been claimed is significantly higher than on farmland where support has been claimed (locality coefficients of 0.605 vs. 0.022). Only about 1% of the abandoned land is classified as agricultural land (kept in the ŽŪN layer), mostly permanent grasslands (89.9%) and less often arable land (8.7%). Of the 6,817.8 ha of land mapped in the KŽS_DR5LT layer DG (permanent grassland), 15.7 ha (0.2%) are abandoned. Of the 3,869 ha mapped in the KŽS_DR5LT layer DE (soil erosion), 42.4 ha (1.1%) are abandoned. However, of the 1,421.5 ha mapped in the KŽS_DR5LT layer EASV (ecologically important areas), there are practically no abandoned areas. However, the areas of abandoned land are completely outside the areas identified in the Forest State Cadastre. This is to be expected, as the identification of abandoned land is combined with information from the Forest State Cadastre. I.e. the information from the Forest State Cadastre serves as limiting information for the compilation of the AŽ_DR10LT, i.e. areas falling under the Forest State Cadastre may not be considered. In contrast, the set of KŽS_DR5LT can be seen as an additional source of information that can be used for the detection, characterisation and (especially) modelling of abandoned land. At the same time, we would like to draw attention to the lack of responsible use of specific terms in the compilation of databases controlled by various agencies. For example, in the KŽS_DR5LT, forest land is defined as forests, groups of trees and shrubberies, whereas in the Forest State Cadastre, forest land is defined as 'forested land – stands of trees, also non-forested land – logging sites, dead stands, forest clearings, forest squares, small forest swamps, forest nurseries, forest tree seed plantations and clonal collections, and land intended for afforestation. Forest land includes forest roads, quarters, technological clearings and lines, firebreaks, areas occupied by timber stores and other forest-related facilities (ditches, culverts, bridges, fire towers, etc.), recreation areas, animal feeding grounds, and other facilities located in the same areas". For example, according to the KŽS_DR5LT, the area of forest land in Jonava district is 44,463.4 ha, whereas according to the Forest State Cadastre it is only 39,151.7 ha. "The area of 'forest land' in both databases is the same only for 38,346.4 ha, i.e. as much as 13.8% of the area marked as 'forest land' in KŽS_DR5LT is not included in the forest land records of the Forest State Cadastre. The areas in the Forest State Cadastre are forest land. About 1.7% of the areas (688.9 ha) marked in the Forest State Cadastre are officially non-forest land. 429.7 ha are classified as non-forest land covered with tree seedlings, i.e. according to the legislation in force in Lithuania they are closer to abandoned land than to forest land. This means that they will only be treated as forest land when the average age of the trees reaches 20 years – until then, landowners have the right to cut down such trees.

The compatibility of AŽ_DR10LT with the Spatial Data Set of (Geo) Reference Base Cadastre (GRPK) is significantly higher (Table 3). It can be seen that the identification of abandoned land is aligned with the GRPK and that some of the errors are of a topological nature, occurring during the spatial analysis (e.g. the inclusion of very small areas of abandoned land in the buffers of linear objects). However, it should be noted that, again, incompatibilities between other databases are observed. For example, one third of the abandoned land in Jonava district is covered by forest according to the GRPK. By the way, forest is defined in the GRPK specification as "land plots with an area of at least 0.1 ha, covered with trees at least 20 years old, other forest vegetation, thinned areas or areas of former forest temporarily deprived of vegetation as a result of human activity and natural factors (cuttings, burned areas, dead plantations, areas)". Forests also include lands occupied by firebreaks, nurseries, forest seed plantations, animal feedlots. This description is in line with the concept of forest land used in the Forest State Cadastre. However, we can see that, despite the same definition, the elements collected in the databases may not be identical. It should be noted that the concentration of abandoned land is highest in the areas identified in the GRPK as tree and shrub plantations and grassland, followed by quarries and pastures or meadows. Abandoned land is not recorded in areas that are not intrinsically linked to land abandonment processes but have significant amounts of woody vegetation – gardens, built-up areas, industrial sites, etc.

Table 3

Distribution of abandoned land by spatial feature types in the GRPK layer PLOTAI

Code	**Discription**	**Area, m^2**	**Percentage**	**Location coefficient***
ek0	Quarries	34999.309	0.65812529*	2.928
gt14	Buffers created from unpaved roads without solid base centrelines	0.001	0.00000002	0.000
gt16	Buffers created from the centrelines of dirt and forest roads	0.128	0.00000240	0.000

Code	Discription	Area, m^2	Percentage	Location coefficient*
hd21	Buffers created from the centrelines of streams, canals, drainage ditches narrower than 2 m wide	0.037	0.00000070	0.000
hd22	Buffers created from the centreline of streams, canals, drainage ditches with a width of 3-5 m	0.012	0.00000022	0.000
mj0	Tree belt	286.037	0.00537862	0.063
ms0	Forest	1790309.961	33.66490022	0.808
sd11	Cultivated land	13946.245	0.26224451	0.006
sd15	Trees, shrubs, plantations and shrubberies	3065152.629	57.63697890	24.087
sd2	Pastures and meadows	413105.887	7.76802272	2.047
sd4	Land not in use	231.144	0.00434641	0.002

* Note: The use of a large number of decimal places is intentional.

The problem of compatibility of the spatial datasets produced in Lithuania is illustrated in Figure 4.

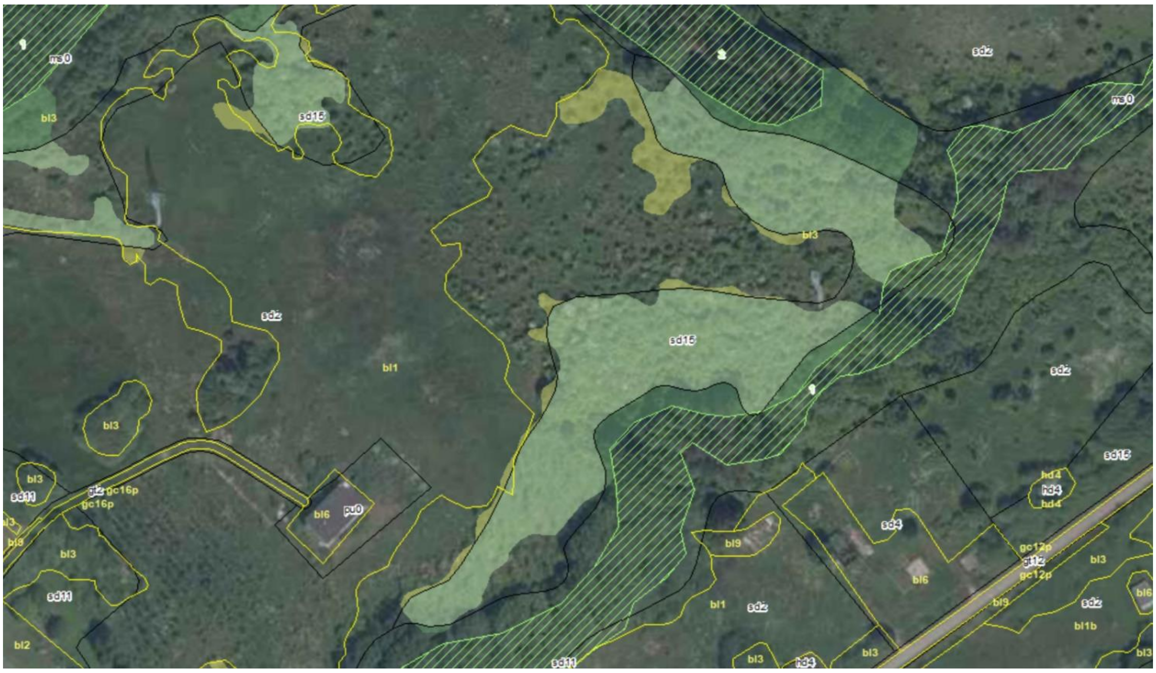

Fig. 4. Differences in land cover/land use identification (example) in different spatial databases created in Lithuania. The outline and type (attribute GKODAS) of elements from the GRPK layer PLOTAI are marked in black. Green colour indicates plots from the Forest State Cadastre and their land use category (1 – spontaneous stand, 2 – plantation). Land plots from the KŽS_DR5LT database are shown in yellow colour. Areas of abandoned land are shown in colour according to the type of land cover of the GRPK

The figure above shows that identical areas in terms of land use are represented differently in the different datasets. This is natural when different datasets are compiled by different authorised bodies. It should also be noted that, under different interpretations, the contours of the areas around the linear elements identified in the GRPK (roads, hydrographic features) are reasonably consistent, but problems arise in the rendering of the contours of the areal features of the area. The importance of georeferencing is emphasised in most spatial datasets in Lithuania. In general terms, georeferenced data is general-purpose geodata about key topographic, engineering and geodetic features. The georeferenced data set for a defined territory, compiled according to the principles of geoinformation systems, is the georeferenced data set that is linked to the GRPK in a given case. The georeferenced data are compiled and updated by the public authorities in accordance with the standardised content and format of the databases, and are used as a basis for the production of thematic, i.e. applied, GIS (Geographical Information Systems) datasets. In our case, this also includes the identification of abandoned land.

Conclusions

When checking the consistency of the identification of abandoned land in the study area with information from other spatial datasets, we found that identical areas in terms of land use were represented differently in different datasets. Both in absolute terms and as a percentage of the occupied area, abandoned land was concentrated in blocks formally unrelated to cultivated land, i.e. urban land, forest land and areas identified in a mixed block. Often the presence of abandoned land in blocks whose type is difficult to link to abandonment processes can be explained by the detailed compilation of the different databases or by a lack of coordination in the compilation of the databases. It should also be emphasised that the information from the Forest State Cadastre serves as limiting information for the compilation of AŽ_DR10LT, i.e. the areas covered by the Forest State Cadastre cannot be analysed. On the contrary, the KŽS_DR5LT set can be considered as an additional source of information that can be used for identification and characterisation of abandoned lands and (in particular) for modelling the evolution of such lands.

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GEOSPATIAL DATA ANALYSIS OF THE DEGRADED AREAS OF KURZEME AND ZEMGALE REGIONS OF LATVIA

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Abstract
The use of degraded areas reduces the burden on the use of agricultural land for industrial purposes. After the restoration of the country's independence in 1991, the area of agricultural land in Latvia has decreased by 21.7%. Taking into account climate change and the current geopolitical situation, it is necessary to look for suitable territories for the production of electricity with renewable energy sources in order to ensure the country's energy independence. In the study, 158 pcs.geospatial analysis of land units containing contaminated or potentially contaminated territory. The goal was to find out which of the land units, on which the municipal waste collection and storage sites of rural areas were historically located, would be suitable for the possible construction of solar and wind power plants. Measurements were made from the geometric center of the land unit to electrical networks, settlements, access roads, nature protection objects. It was determined that the state and the municipality own 71% of the land units with degraded territory. Of the land units included in the study, up to 10% have potential for electricity generation with renewable energy resources.
Key words: degraded area, renewable energy, geospatial analysis.

Introduction

After the restoration of the country's independence in 1991, the area of agricultural land in Latvia has decreased by 21.7%. In order to mitigate climate change and strengthen the country's energy independence, it is necessary to increase the use of renewable energy resources in electricity production. In the sustainable development strategy Latvia 2030, it is defined as one of the state's strategic goals [10]. The rational use of the land must be the focus of attention when it is necessary to determine new territories for the placement of electricity production with renewable energy resources (sun, wind, etc.). Latvia, like the other Baltic states, is an energy deficit country on an annual basis. The amount of water in the cascade of hydroelectric power stations of the Daugava River is important for Latvia. Unless there is a rainy summer or a snowy winter, it should be calculated that from the total annual gross electricity consumption of ~ 7 TWh, around 70% of the required amount of electricity is produced on site. The rest must be procured from international markets. In 2022, 67.6% of the total electricity consumption of 7.13 TWh was produced locally in Latvia [2], [20]. Under the influence of the geopolitical situation, regulatory acts have been approved in Latvia, which also allow the use of agricultural and forest land for the placement of solar and wind power plants [7]. The aim of the study is to search and evaluate alternative places for the placement of renewable energy resources - solar and wind power plants, thus reducing the impact of the placement of power generation equipment on agricultural and forest land. The Land Management Law stipulates that degraded areas should be primarily selected for construction [21]. Land units were selected for the analysis, on which the territories of former rural collective farms and village communal waste dumps were historically located, which are considered polluted or potentially polluted territories according to the regulatory framework [17]. In the article, we will designate them as degraded areas. These areas seem to have several important features. They are located at a certain distance from populated areas, access roads were built on them, and in some cases, connection to electrical networks was provided. The listed factors are important in determining the construction sites of solar and wind power plants, which is confirmed by previous studies [1], [8], [12], [13], [16]. In Latvia, the use of degraded areas has been little studied. The issues of degraded territories and guidelines for their research, planning and use are determined within the Interreg Latvia - Lithuania cross-border cooperation program 2014 - 2020 [5]. So far, in-depth studies have been carried out on the determination of potentially advantageous places for the placement of solar and wind energy equipment in the EU countries and the USA, both for the entire national territory and for local governments. In all cases, geospatial information analysis was used for data extraction. The use of brownfield sites for the construction of solar and wind energy facilities has been studied relatively less. So far, studies on degraded areas have focused on areas of former construction and mineral extraction sites. In the USA, guidelines have been developed for the use of brownfield sites for the placement of solar and wind power plants directly in the areas of former waste dumps [22]. However, in the studies so far, there has been less analysis of the land units in which the degraded area is located, the composition of the land use types, the areas of the areas suitable for the construction of solar and wind power plants, the legal ownership, the purpose of real estate use. The researched data are important in the feasibility study of the choice of possible construction sites, which is an essential part of the construction process of solar and wind power plants [9], [19]. The first results of the study are analyzed within the framework of the article. These are the 139 units of land located in the territory of the historical districts of Kurzeme (western part of the national territory) and Zemgale (central part of the national territory) of the Latvian state, where the degraded areas are located. The article provides an analysis of roughly 40-50% of the total research area. (Figure 1).

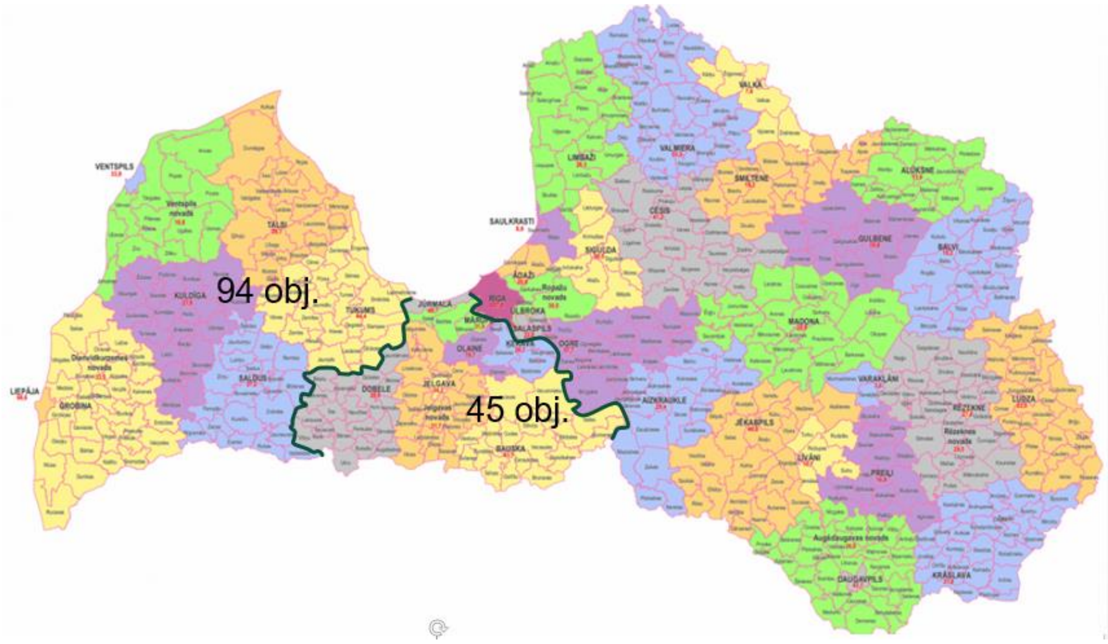

Figure 1. Location and number of objects to be analyzed in the Kurzeme (94 obj.) and Zemgale (45 obj.) regions of Latvia.

Methods and materials.

The database of the Latvian Environment, Geology and Meteorology Service (*lvgmc.lv*) was used to identify the territories, which contained the registration numbers of polluted and potentially polluted places and the cadastral designations of the relevant land units [11]. The area of the contaminated or potentially contaminated territory (ha) was determined from the data of the cadastral register according to the type of land use - "other land" or calculated [15]. Distances to objects of interest were measured in geospatial materials from the visually determined geometric center of the land unit, for which geographical and Latvian LKS-92 TM coordinates were fixed (Figure2). Using the availability of the *Balticmaps.eu* navigation function, the distances along the road network to the parish center and the capital Riga were determined (Figure 3) [3].

Figure 2. The geometric center of the land unit.

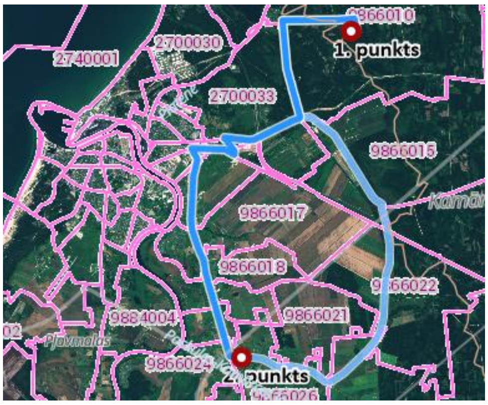

Figure 3. Distance measurements along roads

Figure 4. Location against electricity networks

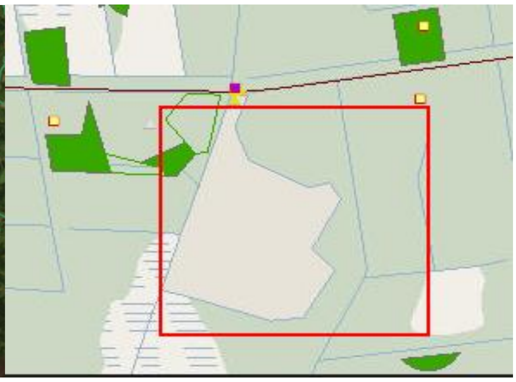

Figure 5. Location against nature protection objects

Distances to the nearest inhabited place (homestead) and electric network lines are only determined by measuring the shortest distance along the air line from the geometric center of the land unit to the nearest homestead or distribution electric network (0.4 to 20kV), hereinafter referred to as ST, and high-voltage network (110) up to 330 kV), hereinafter referred to as AST, for the line (Figure 4). Taking into account the addresses of AST 110/20 kV substations, the distance along the road network from the degraded area to the nearest AST substation was measured. Distances to nature protection objects are only determined in two ways [6]. First, by recording whether or not there is a nature conservation object in the land unit. Secondly, in geospatial data, the distance far from the geometric center of the land unit to the nearest nature protection object is measured (Figure 5). In addition to the geospatial analysis of the land units of the degraded areas, the theoretical potential of electricity generation was calculated according to the following scheme. Land units owned by the municipality were selected with the purpose of use (NLM1005) – construction of waste management companies [14]. Next, the areas of the land use type "Other land" of the specified land units were summed up . Taking into account that in this study we adopted approximate calculations, it was assumed that the sun is used for 1800 hours, the average solar radiation per unit of area is 1180 (kWh/m^2) per year, the placement factor of solar panels is 0.5 (50% of the area can be placed), the efficiency factor is 0.2 (the panels use 20% of the possible solar radiation) and the total amount of energy produced by the sun is calculated according to the following formula:

$$E1 = P \cdot A \cdot K1 \cdot K2, \text{ where} \quad (1)$$

E1 - the total amount of electricity produced by solar radiation (GWh) per year;
P - average amount of solar radiation (kWh/m^2) per year;
A - usable land area (m^2)
K1 – placement ratio of solar panels;
K2 – efficiency factor of solar panels.

The potential of electricity produced by wind energy was calculated assuming that the average number of operating hours of the wind generator per year is 2000 hours (h) and the average wind power per unit area is 165 W/m^2. The wind power utilization factor was set at 0.5. The total amount of electricity produced by wind was calculated according to the formula:

$$E2 = A \cdot K1 \cdot K2 \cdot K3, \text{ where} \quad (2)$$

E2 – total amount of electricity produced by wind power (GWh) per year;
A – in the area available for wind flow;
K1- wind power per 1m^2;
K2 – time of wind operation in hours per year;
K3 – efficiency coefficient of wind use.

Discussion and results

Analyzing the cadastral information of land units, it was calculated that out of the total 139 pcs. of the total area of land units 1412.9 ha, degraded areas made up 21% or 296.2 ha. Considering that 60.2% of the total number of land units and 45.2% of their total area belong to the state and local government, it can be predicted that the rest of the degraded land unit territory could also be used for the placement of solar and wind power plants. Additional analysis confirmed this, as 31.6% (44 units) of land unit use purposes were code 1005 (Waste management). On the other hand, 37.4% (32 units) and 15.1% (21 units) of land units had the purpose code of 0101 (agricultural land) and 0201 (forestry land), which indicated that more than half of 52.5% of degraded land units have been recultivated and returned to the economy. The results on legal ownership of land units are summarized in Table 1.

Table 1

Ownership of land units with degraded areas

Land ownership	Quantity, pcs.	Including, %	Area, ha	Including, %
Country	8	5,8	293,8	20,8
Municipality	77	55,4	344,7	24,4
Individual	37	26,6	588,2	41,6
Legal person	17	12,2	186,2	13,2
In total	139	x	1412,9	x

By carrying out geospatial measurements, it was confirmed that the land units with degraded areas are provided with an access road, as 60.4% (84 units) of the land units are accessed by a public road. At a distance of up to 0.5 km, the access road was available for 33.8% (47 units) of land units. Taking into account that the distance from the geometric center of the land unit to its border could also be added here, the access road provision was 94.2% of the total number of land units. Looking at the distances to the nearest inhabited places (detached houses), it can be seen that the weighted average distance of 0.5 km is greater than the minimum distance of 0.8 km, which is defined in the regulatory acts as the minimum distance in relation to the wind power plant. However, these were separate areas of rural homesteads and not a village. The measurement results of average and average weighted (the number of land units is taken as weight) geospatial distances are summarized in Table 2.

The distances to the nearest ST (0.4 – 20kV) and AST (110 – 330 kV) objects were measured in geospatial materials in the location of solar and wind power plants against the electric networks. Current regulations stipulate that power plants with a capacity of up to 14.99 MW are connected to distribution networks, but starting with a capacity of 15.0 MW, plants are connected to a high-voltage (110-330kV) network [18]. The results of the measurements showed that the location of the ground units in relation to the distribution networks is in a better position compared to the high-voltage

Table 2

Measurement results up to the road and settlements

Indicators	Distance, km				
	Public road	Inhabited Place	Parish center	County center	Riga
Kurzeme objects	0,14	0,45	5,94	24,51	123,93
Zemgale objects	0,15	0,6	5,99	22,82	78,54
Weighted average distance	0,14	0,5	5,96	23,96	117,71

networks. The average weighted distance from the border of the land unit to the nearest object of distribution networks is 0.49 km, which can be assessed as satisfactory. Wind and solar power plants with a capacity greater than 14.99 MW are built near high-voltage (110-330kV) networks. The average weighted distance to the high-voltage line (10.31 km) and the 110/20 kV substation (14.9 km) obtained in the study would not be satisfactory for the potential investor. However, this does not mean that you should not look for and find individual land units, where the distance to the electric network line is not greater than 0.5 km. However, in these cases, the area of the land unit should be taken into account. Swedish experience indicates that the minimum area that would be economically justified for the construction of a solar power plant is 2 ha [12]. The results of measurements up to the electric grids in the cross-section of regions are summarized in Table 3.

Table 3

Measurement results to electrical networks

Objects of electrical networks	Distance, km			
	Kurzeme objects	Zemgale objects	Average distance	Weighted average distance
0.4 - 20kV line	0,42	0,64	0,46	0,49
110 -330 kV line	7,72	15,56	6,68	10,31
110/20 kV substation	17,2	9,72	15,56	14,9

When conducting a geospatial analysis of the location of land units in relation to nature protection territories, it was found that 22% (31 obj.) of land units had protection zones of nature protection objects, which impose restrictions on economic activity. The average distance from the boundary of the land unit to the nature protection object outside was 1.87 km in the Zemgale region, 3.94 km in the Kurzeme region. The average results of the study initially show a sufficiently large margin of distance to nature protection objects. However, this does not allow us to draw the conclusion that there could not be obstacles in the construction of power plants, because the study included only the open data of nature protection objects, and also did not look at bird migration routes. According to the methodology determined in the study, 10 units suitable for electricity production were found. (7.2%) land units with a total area of 81.13 ha and a degraded area of 68.13 ha, for which electricity generation potential calculations were made. The calculated results of 80.44 GWh of solar and 112.48 GWh of wind energy potential for electricity production are considered sufficient to continue research. Estimates of electricity produced by wind should be further analyzed, as they look very optimistic in a relatively small area. The results were compared with the annual electricity consumption of Bauska, a separate Latvian county town of 58.4 GWh [4]. From the obtained results, it can be concluded that up to 10% of degraded areas have potential for electricity production. Considering that the average values of solar and wind power (W/m^2) in the country were taken into account in the calculations, further studies should take into account the values characterizing the geography of a specific land unit. For each land unit found, more detailed analysis and calculations may be made in the future.

Conclusions and proposals

The state and the municipality own 61% of the total number of land units in which degraded areas are located.

According to the analysis of Kurzeme and Zemgale objects, up to 10% of the total territories would be suitable for electricity production with solar and wind energy.

In order to clarify the possible potential of electricity production, it is necessary to look in detail at each land unit found in the study separately.

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EFFECTIVENESS OF EXTRA-ROOT NUTRITION OF NATURAL REGENERATION OF SCOTS PINE

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Abstract
The natural regeneration of Scots pine in a fresh oak-pine forest is more successful in conditions of soil loosening. A one-time event in the form of foliar feeding with solutions of preparations (Stimulate and Bioforge) increases the stability of Scots pine regeneration and its growth. The survival rate of regeneration in the variants of foliar feeding with drug solutions ranged from 75-90%, and the number of plants was 119.6-202.6 thousand (2021). In the control, the survival rate of renewal was 43%, and the density was 71.2 thousand units/ha.
Key words: Scots pine, natural regeneration, forest-cultivated area, preparations.

Introduction

In modern conditions, the reproduction of Ukrainian forests is carried out in accordance with theoretical provisions and current regulations [2, 3, 5]. Some of them do not fully take into account recent global trends and requirements for reforestation and afforestation.

The progressive deterioration of forest plantations of artificial origin led to the urgent need to preserve natural plantations at the end of the last millennium. The insufficient use of ecologically oriented methods of forest reproduction in Ukraine is to some extent due to the lack of theoretical foundations and modern scientific and practical recommendations that would take into account zonal ecological features, structure and condition of forests, as well as modern approaches to forest management [4].

Restoration of plantations at any level is the key to the creation and cultivation of biologically sustainable, highly productive plantations, such as those of natural seed origin. In this regard, the reproduction of indigenous stands of the main forest-forming species is one of the key issues of sustainable development of the forest industry in the context of economic activity. The technological schemes existing in forestry for the reproduction of pine plantations are at odds with the biological and ecological properties of forest-forming species, and the processes of natural regeneration are assessed using typical methodological approaches, which is at odds with natural processes of forest regeneration, because the activation of natural regeneration processes occurs under a set of mandatory conditions related to the reproductive capacity of plantations and a number of coinciding environmental factors. The combination of these factors activates natural regeneration processes and transitions self-seeding into the category of “undergrowth” and vice versa, which is lost with the introduction of traditional approaches to reforestation.

The emergence of natural regeneration is quite natural, as well as its subsequent disappearance, and requires careful study [1]. Only a favourable coincidence of environmental factors at certain stages of the development of natural regeneration of pine trees can ensure the success of natural regeneration and its growth. The presence of natural regeneration on forest-cultivated areas or outside it – under the canopy of mother plantations, indicates only the degree of success of the reproductive capacity of stands within the age group and does not guarantee its further existence.

Therefore, the study of natural regeneration processes should take into account the biological and ecological characteristics of the species and the conditions prevailing during the period of reproductive capacity, using methodological approaches to qualitative assessment of regeneration and taking into account the spatial structure within the age group. On the one hand, this will deepen the level of theoretical knowledge, and on the other hand, it will provide opportunities to improve the course of regeneration events with the subsequent development of measures to improve the conditions for its growth.

Successful fulfillment of this task depends on a set of factors that ensure high survival and preservation of pine trees, such as timely implementation of agro technical measures, use of agrochemicals and their solutions, in particular plant growth regulators [6].

It has been proved (Siryk, Veshytskyy&Mokrynskyy, 2006; Vedmid&Demchenko, 2004; Siryk, Veshytskyy&Mokrynskyy, 2006; Taranenko, 2017; Danylenko et al, 2021; Rumiantsev et al, 2022; Raspopina et al, 2022) that the use of growth preparations in silvicultural production has a positive effect on seed germination and germination energy, stress resistance of planting material to natural environment conditions, accompanied by more intensive growth compared to traditional methods.
The *aim of the research* is to evaluate the impact of foliar feeding of Scots pine renewal with solutions of stimulating (*Stimulate*) and anti-stress (*Bioforge*) preparations at the juvenile stage of its ontogeny.

Objects and methods of research

Objects of research is the state and growth of natural regeneration of Scots pine after foliar treatment with solutions of *Stimulate* and *Bioforge*, in the conditions of fresh oak-pine forest of the State Enterprise "Skrypaiivske NRFH", located in the southeastern part of the Left Bank Forest-Steppe, Kharkiv region.
The *subject of the study* is the growth and state of natural regeneration of Scots pine under the influence of foliar feeding.
Objectives of the study:

- to identify the optimal rates of the active substance of agrochemicals used in foliar treatment of natural regeneration of Scots pine;
- to establish the direct influence of agrochemical solutions on the growth and preservation of Scots pine regeneration;
- to establish the possibility and prospects of using stimulating (*Stimulate*) and anti-stress (*Bioforge*) preparations in reforestation.

Brief description of the preparations used in the experiment:
Option 1. *Stimulate* is a plant growth stimulator with an optimal combination of cytokinin, auxin and gibberellic acid. Stimulate helps to normalize vital processes, stimulate active tissue growth and plant rooting. It is used for a wide range of crops, including greenhouse crops, throughout the entire growing season (repeatedly) or as needed (once). Properties of the product: stimulates the overall development of plants; promotes rooting of seedlings and saplings; ensures simultaneous germination of seeds and emergence of seedlings; activates plant growth through cell division. Active ingredients: cytokinin (kinetin) – 0.009%; auxin – 0.005%; gibberellic acid –0.005%.
Option 2. *Bioforge mineral fertiliser* is an antistress preparation used to increase plant resistance to adverse conditions, faster recovery from damage, and enhanced root system growth. Environmental stresses affect the plant throughout the entire period of development: frost, heat, temperature changes, moisture deficit or excess, planting or transplanting seedlings, application of plant protection products (PPPs), etc. It contains the antioxidant diformyl (N – 2 %; K_2O – 3 %), which provides effective stimulation of plant defense systems at the level of enzymes and genes. It is used for a wide range of crops, including greenhouse crops, during the entire growing season (repeatedly) or as needed (once). Product properties: enhanced development of the root system (rooting of seedlings and saplings); increased resistance to stress factors; reduced stress on the plant in case of plant protection products. Faster recovery from stress or damage caused by hail, wind, pesticides, insects.

Fig. 1. Natural regeneration of Scots pine, as of the first year of the experiment (2019)

The experiment was conducted on a silvicultural area, forest crops created in 2019 with the presence of natural regeneration of Scots pine on the treated part of the soil. Agrochemicals were used in different variants of the aqueous solution, *Stimulate* – three variants of solution concentration, *Bioforge* – three variants of solution concentration. Additionally, one variant of the complex use of drugs in solution concentration (*Stimulate+Bioforge*) was used. Control – water treatment without drugs (Table 1).

Table 1

Variants of the used rates of drugs in the aqueous solution

№ of items	**Name of drugs**	**Variants**	**The content of the preparation, ml /2 l of water**
1	Stimulate	$St_{1/2}$	1
2	Stimulate	$St_{3/2}$	3
3	Stimulate	$St_{6/2}$	6
4	Bioforge	$Bf_{3/2}$	3
5	Bioforge	$Bf_{6/2}$	6
6	Bioforge	$Bf_{9/2}$	9
7	Stimulate+Bioforge	$St+Bf_{6+9/2}$	6+9
8	Control	C	-

The experimental sites covered about 200m^2 of the treated area and consisted of eight strips of treated soil (PKL-70) prepared for the creation of forest crops. Surface spraying of the natural regeneration of Scots pine was carried out with aqueous solutions of the preparations using a pneumatic sprayer "Forte OP-2.0 Lux" (2 litres of the preparation solution per 50 m linear).

The state of natural regeneration of Scots pine was assessed by height, which was measured with a measuring tape with an accuracy of 0.1 cm, and diameter at the root collar, which was measured with a caliper with an accuracy of 0.1 mm. The results of the research were processed using the method of mathematical statistics in MS Excel.

Fig. 2. Natural regeneration of Scots pine after foliar treatment, as of the third year of the experiment (2021)

Results and discussion

The results of the survey (2021) of the forest-cultivated area showed a rather significant amount of natural regeneration of Scots pine within the treated part of the soil – from 66-200 thousand plants/ha (Fig. 1-2), which indicates the intensification of natural reforestation processes under conditions of soil mineralisation [9].

The number of Scots pine regeneration in the variants of foliar treatment with preparations is represented by three "peaks", namely: variant $St_{3/2}$ – 202.6 thousand pcs/ha, $Bf_{6/2}$ – 175.8 and $Bf_{9/2}$ – 191.2 thousand pcs/ha. The control – 71.2 thousand plants/ha and variant $St_{1/2}$ – 65.6 thousand plants/ha had the lowest number of renewals. The latter is explained by the small amount of the preparation 1 ml/2 l of water (see Fig. 3) to increase the level of stress resistance to environmental conditions.

In other variants, as it turned out, at a high (low) concentration of preparations in an aqueous solution, although the amount of natural reforestation was recorded, it was lower than the maximum value and ranged from 119.6-148.0 thousand pcs/ha for variants $St+Bf_{(6+9/2)} \rightarrow St_{6/2} \rightarrow Bf_{3/2}$, control – 71.2 thousand pcs/ha.

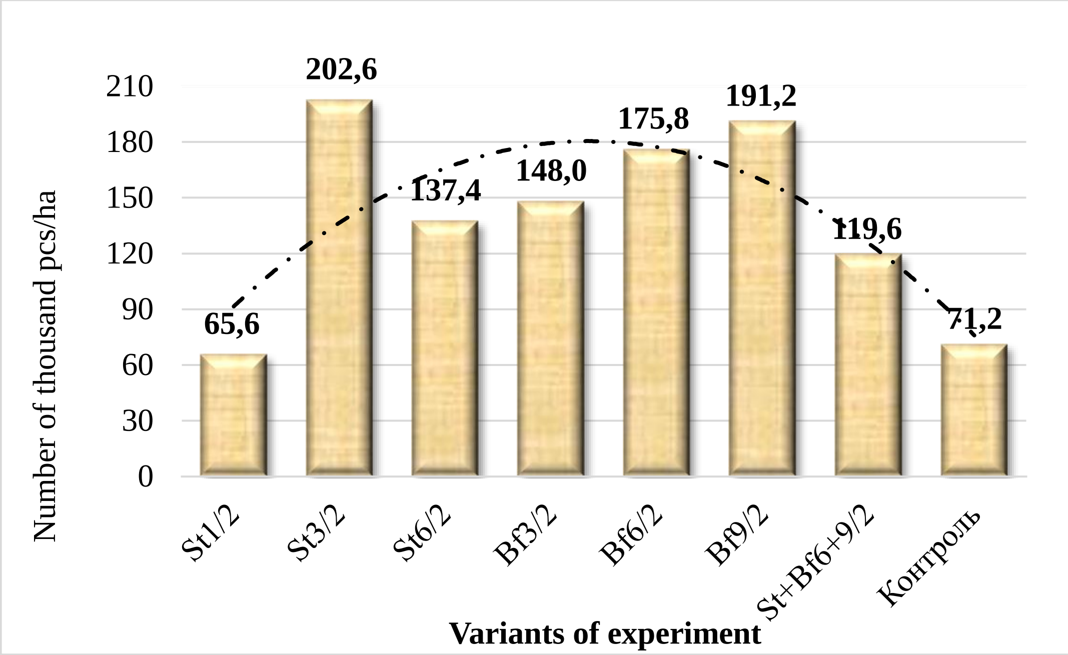

Fig. 3. The amount of natural regeneration of Scots pine in the experimental variants (after treatment)

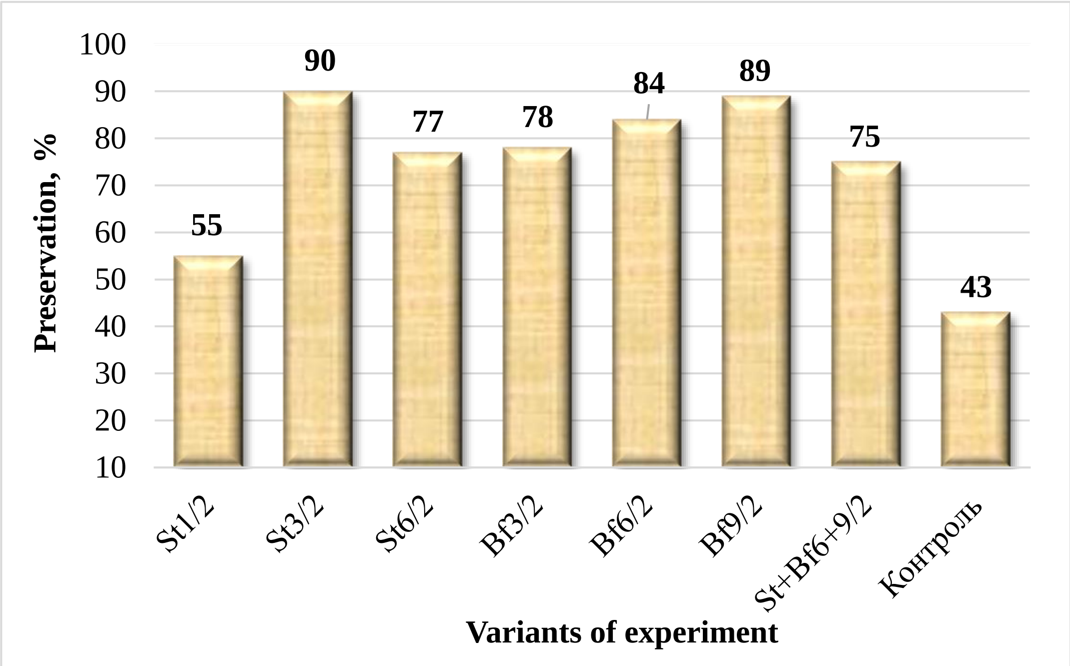

Fig. 4. Preservation of natural regeneration of Scots pine in the experimental variants (after treatment)

The preservation of natural regeneration of Scots pine within the experimental variants in the first year after foliar treatment with agrochemicals varied from 43-90%, with its minimum value recorded in the control variant (see Fig. 4). The remaining variants were characterised by relatively positive safety performance.

It was found that the variant with the use of a stimulating preparation *Stimulate* is characterised by a rather significant variation in the pine regeneration preservation rate from 55-90%, with the minimum value recorded in the variant with the use of the preparation solution $St_{1/2}$ (see Table 1). The optimal rate of the preparation in this variant was the concentration of the solution prepared from 3 ml of the preparation per 2 litres of water ($St_{3/2}$), at which the preservation of pine regeneration was 90%. With the increase in the amount of the preparation, the preservation of pine regeneration decreases – 77%. In the variant with the use of the anti-stress preparation (*Bioforge*), the dynamics of increasing the preservation rate with an increase in the concentration of the preparation in an aqueous solution from 78-89% is traced. The highest preservation was noted in the variant with foliar treatment with *Bioforge* ($Bf_{9/2}$) – 89%. In the variant $St+Bf_{(6+9/2)}$, with the complex use of drugs, a lower preservation was found compared to the previous variants of using solutions for foliar treatment of pine renewal – 75%.

It is well known that the safety of natural regeneration of pine is influenced by a fairly significant number of factors that ensure the quality of regeneration processes: droughts during the period of realisation of the reproductive capacity of plantations, location of the forest-cultivated area within the so-called "midday shadow", the influence of entomological and forest fauna, the presence of dense living ground cover, etc.

Among all of the above, it should be noted that the most significant factor in the conditions of the forest-cultivated area was the presence of dense living ground cover in the form of a lushly growing ground bentgrass (Calamagrostisepigejos (L.) Roth.), Fig. 5. Taking into account its uniform distribution within the site, the influence of this species can be considered homogeneous, i.e., it did not affect the reliability of the research results obtained within a particular variant, but rather created interest in the results of the direct effect of the used preparations when conducting research for this purpose.

Fig. 5. Ground bentgrass (Calamagrostisepigejos (L.) Roth.), photo 2021

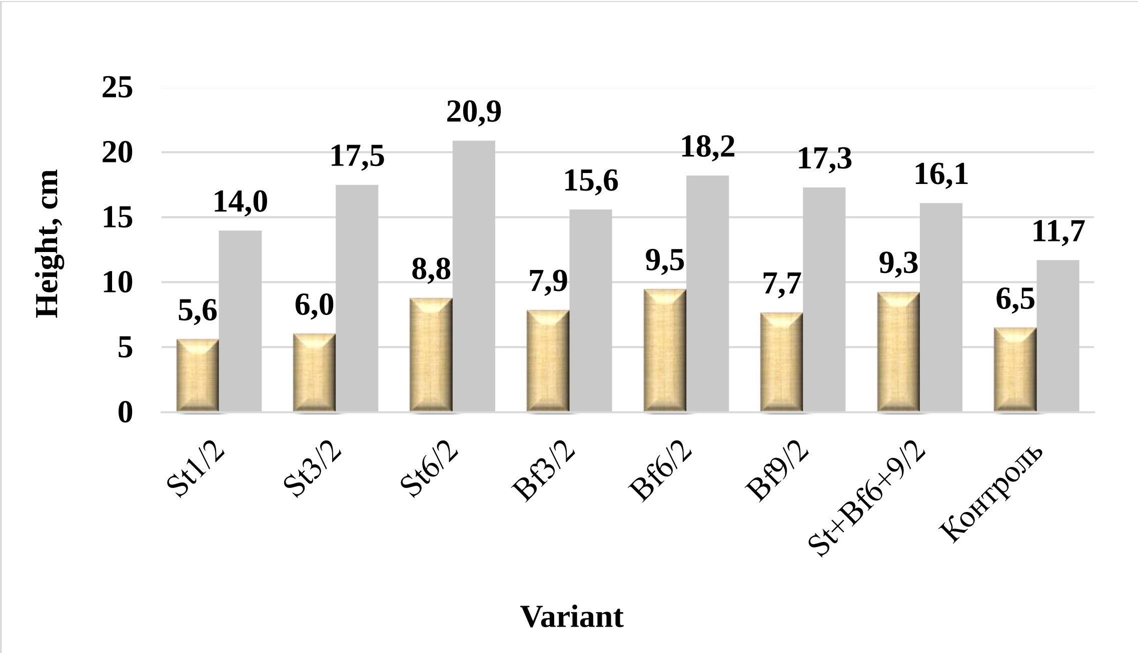

Fig. 6. Average regeneration height of Scots pine (2019-2021)

We note the positive effect of a single foliar treatment with agrochemical solutions on the biometric indicators of pine regeneration. Thus, in the variant with the use of the preparation of stimulating action (*Stimulate*), the growth of renewal by biometric indicators (height and diameter) increases, with the increase of the preparation in the solution, from 14.0-21.0 cm in height and 3.8-6.0 mm in diameter (see Fig. 6, 7). The highest average height value was noted in the variant of *Stimulate* ($St_{6/2}$) – 21 cm, and in diameter – $St_{3/2}$ – 6.0 mm, which is not significantly different from the indicated variant ($St_{6/2}$) – 5.7 mm. Low biometric parameters were presented by the variants with the smallest amount of *Stimulate* used, the variant – $St_{1/2}$ and the control pine height was 14.0 and 11.7 cm, diameter – 3.8 and 3.4 mm, respectively.

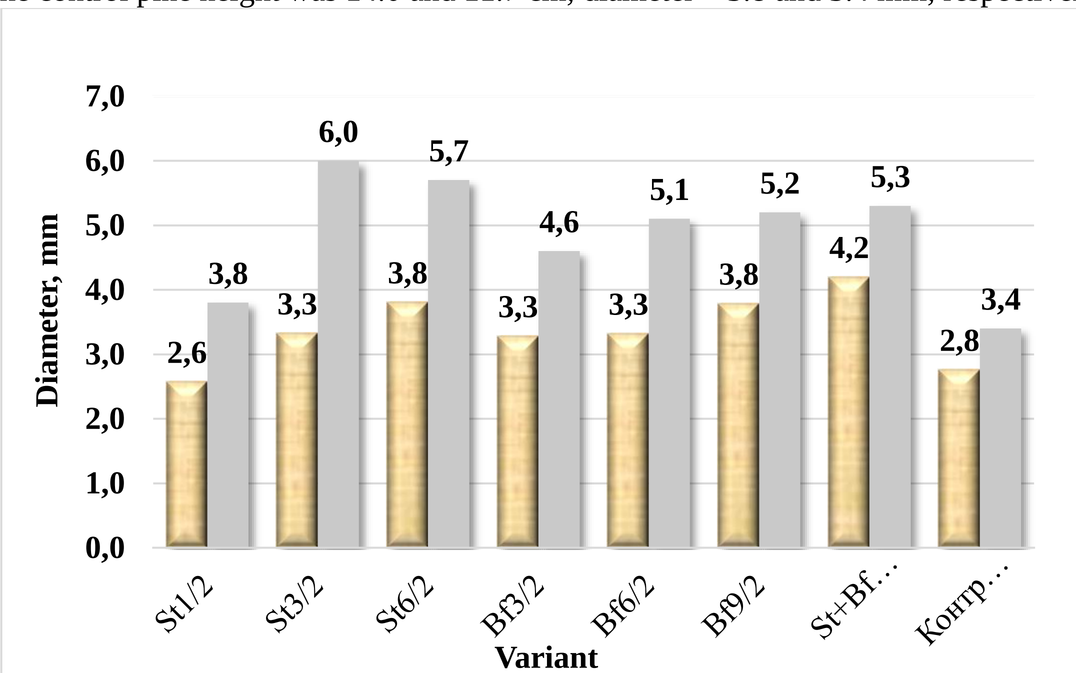

Fig. 7. Average diameter of Scots pine regeneration before and after foliar treatment with agrochemicals (2019-2021)

It should also be noted a more stable increase in the diameter of pine regeneration in the variant of using the anti-stress preparation (*Bioforge*) in the direction of increasing the amount of the preparation $Bf_{3/2}$–4,6 mm→$Bf_{3/2}$–5,1 mm→$Bf_{9/2}$–5,2 mm→St+$Bf_{(6+9/2)}$–5.3 mm, in the control variant – 3.4 mm.

In terms of height, on the contrary, a decrease in the height of pine regeneration was observed with an increase in the amount of the preparation, with the maximum size of pine regeneration in the $Bf_{6/2}$ variant – 18.2 cm, the smallest in the $Bf_{3/2}$ variant – 15.6 cm, control – 11.7 cm.

Conclusions

1. The processes of natural regeneration of Scots pine in a fresh oak-pine sub-forest are more intensive in the case of formation of a certain ecological niche, which is provided at certain stages of reforestation by disturbance of the aboveground cover.

2. Reforestation begins with the natural formation of the so-called “brush” of regeneration, the number of which can range from tens to several hundred thousand per hectare. Low sustainability of the natural population and dynamic changes in the quantitative and qualitative composition of regeneration largely depend on a set of anthropogenic and natural impacts. Due to their influence, several directions of events are possible - successful growth and development of the cenopopulation and its transition to the category of undergrowth or the emergence of a reforestation wave until its complete disappearance.

3. A one-time foliar treatment of the natural regeneration of Scots pine at the juvenile stage of its development with solutions of preparations proved to be sufficient for the preservation and growth of the natural regeneration of Scots pine at certain stages of its ontogeny.

4. The best growth of natural renewal of pine was noted in the variant of application of the preparation of stimulating action (*Stimulate*) – $St_{6/2}$ – 21 cm and 5.7 mm in height and diameter, respectively, with a preservation rate of 90%. More stable indicators of preservation and growth of natural renewal of pine were observed in almost all variants of application of the anti-stress preparation (*Bioforge*) from 78-89% and from 15.6-18.2 cm in height and from 4.6-5.3 mm in diameter.

5. In the variants with foliar treatment of Scots pine regeneration with solutions of *Stimulate*, the variation of biometric parameters (average height and diameter) is more pronounced than in the *Bioforge* variant, indicating a more sensitive reaction of Scots pine to the concentration of the solution of this preparation.

6. Taking into account the average number of regenerations in the variants of application of stimulating (*Stimulate*) and anti-stress (*Bioforge*) preparations, preference should be given to the latter, due to its more prolonged effect during the research period (2019-2021), which, in our opinion, is more important in the practice of reforestation.

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