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UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN (Poland)
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FOREWORD

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CONTENT

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METHODOLOGY OF ESTABLISHING THE LIMIT SIZES OF LOT LANDS FOR THE AGRICULTURAL USE

Zhildikbaeva Aizhan[1], Gurskiene Virginija[2], Yelemessov Serik[1], Ablaikhan Baukhan[1]
[1]Kazakh National Agrarian Research University, Kazakhstan,
[2]Vytautas Magnus University, Lithuania

Abstract
This study aims to develop a methodology for determining and calculating the limit size of agricultural land plots that can be leased by individuals and legal entities of the Republic of Kazakhstan. The article substantiates agricultural production after the current long-term lease terms end. The basic condition is the formation of land use, in which there is a close dependence on conditions and factors of production, where land, material resources, and labor are in certain proportions and balanced.
The main criteria for determining the limiting sizes of land are: land area, leased to a single entity should not exceed 1/3 of the area of farmland rural district specific administrative area, and the physical person no more than 15% of the area of agricultural enterprises of the same specialization. Emerging land uses should be subject to zonal specialization by natural and agricultural zoning; take into account the minimum thresholds for the area of crop rotation in the crop production sectors and the size of livestock in herds of different types of livestock by the breed composition in the livestock industry.
Key words: limiting size, land plot, natural and agricultural zone, specialization, competitiveness, efficiency

Introduction

The agrarian transformation in Kazakhstan associated with the privatization of state property has led to certain changes in the legal and organizational structure of farms, land redistribution, fragmentation of large enterprises, and the expansion of small-scale production. In developing countries, land use is mainly determined by food needs as well as land suitability (Ying Zhang, Hongqi Zhang, 2012). Land-use patterns do not provide sufficient land for certain farming activities (Burian, 2015; Bizikin 2015). The experience of most countries demonstrates the practice of limiting the maximum allowable size of agricultural land and land holdings (Rumyantsev, 2015; Stupen, 2015; Aleknavicius et al., 2016). The regulation of lease relations abroad is also the legislative establishment of land rent limits (Habóczky, 2013). According to research by M. Ritter et al. (2020), the complex relationship between land price and plot size cannot be captured by a simple functional form.

Much of agricultural land in foreign countries is in private ownership; however, most of the agricultural land is leased (Bandlerova, Lazíkova, 2014). Hartvigsen (2014) and Jurgenson (2016) investigated that land fragmentation often hampers agricultural development when land ownership and land use are highly fragmented.

As a result of land reforms, there has been a reduction in the level of concentration of production in the leading branches of agriculture in agricultural enterprises and the efficiency and competitiveness of small-scale peasant and farmer farms. At the same time, in the country's northern region, excessively large land uses have developed, mainly in structures that are part of grain agroholdings, as well as in the western and central regions, where desert rangelands predominate (Scientific Report, 2016). The size of land use varies considerably within one administrative area. At the same time, due to the lack of statutory norms in the formation of land use, the natural and agricultural conditions, the capacity of economic entities to ensure the rational use of land, and the indicators of diversification of agricultural production by the specialization of the region are not taken into account.

Land inventory materials for 2012-2014 show the irrational use of agricultural land and withdrawal of part of valuable types of land from agricultural turnover (Inventory materials, 2012-2014). In this regard, an urgent problem is the development of methodological approaches to determining the norms for setting the limit size of land use within the administrative district, which can be granted to individuals and legal entities of Kazakhstan, which will allow for a fair public policy in the public interest, taking into account local conditions and ensuring compliance with the rules of rational and efficient use of agricultural land.

The purpose of the study is to develop a methodology for determining and calculating the limit size of agricultural land plots that can be leased by individuals and legal entities of the Republic of Kazakhstan.

Methodology of research and materials

The object of the study – is administrative districts by natural-economic zones, large and extra-large agricultural formations of different specializations of the Republic of Kazakhstan.

Research methods: computational-constructive method, economic-mathematical method.

The methodology for calculating the limit size of land plots to be leased to a non-state legal entity is reduced to determining the area of crops under cereals, fruit, and fodder crops in the field cereal, fruit and fodder crop rotations according to 1 formula (Kaliyev et al., 2017):

$$S = [(S1 * N1) * K1 + (S2 * N2) * K2 + (S3 * N3) * K3] * Kr \qquad (1)$$

where are: S – the area of arable land in a cereal crop rotation, taking into account the plowing ratio,

S1 – an area of 1 field in a cereal fallow rotation,
N1– number of fields in a cereal fallow rotation,
K1– number of crop rotations in a grain and fallow crop rotation,
S2 – an area of 1 field in a crop rotation,
N2 – number of fields in a crop rotation,
K2 – number of crop arrays in a crop rotation,
S3 – the area of 1 field in the forage rotation,
N3 – number of fields in the forage rotation,
K3 – number of crop rotations in the forage rotation,
Kr – the rate of ploughing of the land area.

Research materials. The method of etymologization of the existing land structure, qualitative composition of arable land and cultural and technical condition of hay and pasture lands, their water availability, availability of labour resources, state of material and technical base, and investments were used to assess production indicators of administrative districts; potential opportunities of using available resources to form competitive agricultural formations were determined (Interim scientific report, 2017). The study used data from the state land cadastre, data, and statistical materials of the Land Resources Management Committee of the Republic of Kazakhstan.

Discussions and results

The main emphasis in the establishment of maximum land use limits for economic entities and leasing land was placed on the degree of land availability in the regions, qualitative state of arable land and soil fertility, degree of watering of pastures, application of innovative technologies in crop and livestock production sectors, etc. (Table 1).

Table 1

Assessment of the level of land availability, soil fertility, qualitative condition of the main types of land

Natural-agricultural zone	Land availability per 1 gricultural worker, ha*	Land occupancy per 1 rural inhabitant, ha/person **	Average bonitet score	The share of unconditionally arable land, %	The specific weight of watered waterlogged pastures, %	The specific gravity of pastures (Radical improvement), %
Forest-steppe	40.5	23.0	55	78.5	45.6	19.4
Steppe	39.1	21.2	45.6	45.4	37.2	29.6
Dry-steppe	49.3	28.5	26.6	51.7	32.2	9.2
Semi-desert	102.6	47.9	21.3	56.5	37.6	4.1
Desert	45.6	22.5	16	33.4	51.7	0.01
Foothill-desert-steppe	4.47	2.31	23	39.5	92.9	6.2
Foothill-desert	4.6	1.9	17.2	52.1	88.3	5.6
Mountain-steppe	26.5	12.7	37	75	35.5	4.1
Mountainous	8.1	4.0	38	53,8	42.6	1.1
*,** Note - Calculations based on data from the Statistics Agency of Kazakhstan, 2018						

These indicators are a limiting factor in the formation of extra-large farms to which farmland can be assigned. Thus, the indicator of high soil fertility and production structure with a predominance of arable land in forest-steppe, steppe, mountain-steppe, and mountain zones reflects the development of highly efficient production and determines the size of limiting large farms with smaller areas compared to dry steppe, semi-desert, desert, piedmont-steppe, and piedmont-desert zones, where farms can be formed with area 2 and more times larger.

Let us consider the methodology for establishing the limit size of land plots that can be leased for agricultural production to legal entities in the forest-steppe, steppe, and dry-steppe natural agricultural zones of Kazakhstan.

Accepted criteria:

1) choice of specialization by a long-term study of the development of crop and livestock branches in farms of these zones shows that their specialization is almost identical and forms grain, grain and livestock (dairy), grain and livestock (meat), grain and ovine, grain and livestock types of farms;

2) production structure: Rational combination of branches in the structure of commodity output value corresponds to a share of the crop sector – 70-65%, a share of the livestock sector – 30-35% while keeping diversification of grain-production based on the application of resource-saving technologies (minimum and zero), where the share of grain is not over 70%, including wheat – 65%, technical and oily crops - not less than 13%, forage - 17% (agricultural management systems, 1979-1982);

3) ploughability of land use, taking into account the share of arable lands in a total agricultural area, is taken: in forest-steppe and steppe natural-agricultural zones it will be within - 60-75%; in dry steppe - 25-50%;

4) The system of crop rotations in three natural-agricultural zones is accepted as four- and five-field fallow cereals, five-field alternating crops, six-field forage (grass-field);

5) the minimum threshold for rational use of arable lands, taking into account the effective use of highly productive machinery, is set at 400-500 hectares per field;

6) technological pattern in plant growing is established by the application of traditional, minimal, and zero tillage with the use of agricultural machines and towed implements with optimal terms of sowing and harvesting – 7-10 days with mechanics working ten hours;

7) several cattle in the forest-steppe zone are taken from 1200 to 1400 conditional heads of cattle (hereinafter – Cattle), in the steppe from 1600 to 2000 conditional heads of cattle, in the dry steppe from 2000 to 3000 conditional heads of cattle.

Determination of the maximum area of the land plot leased to the non-state legal entity with the optimal structure of production, where 70% is the cash crop production, 30% – is livestock, and contains from 1200 to 3000 conventional heads of cattle is connected with taking into account natural landscape and plough ability of the rural district. The plough ability of rural districts and natural-agricultural zones in the three zones under consideration ranges between 25% and 75% (Table 2).

The justification for the size of the crop rotations is based on the research and development work of technology institutes and centers. At present, in these natural-agricultural zones, four-field and five-field grain and pair crop rotations with a short rotation and a pure fallow field of 20% to 25% are used in grain production.

Table 2

Level and coefficient of the ploughed area of land use by natural-agricultural zone

The natural and economic zone	Number of areas	Number of districts, units	Area of agricultural land, thousand ha*	Number of rural districts	Arable land, thousand ha**	Ploughed area, %	Coefficient of plowing
Forest-steppe	1	2	624	29	414.4	66.4	1.34
Steppe	4	6	3464	75	2184.3	63.1	1.37
Dry-steppe	6	9	7656.2	153	2067.5	27.0	1.73
*,** Note - Calculations based on data from the Statistics Agency of Kazakhstan, 2018							

In recent years the grain-growing regions have switched to resource-saving technologies with minimum and zero tillage of soil in six-field crop rotations, which ensure the conservation of soil fertility. Fodder crop rotations with three fields of perennial (annual) grasses for the production of green and roughage are used for animal husbandry.
Based on the level of land availability of the administrative district of the grain-growing regions in the agricultural enterprises of grain and cattle breeding specialization the size of one field in the crop rotations is taken 450 hectares. The number of crop rotation arrays is taken depending on the area of the rural district and the maintenance of a rational ratio of crop and livestock sectors.
To calculate the land area of specialized grain and cattle breeding farms with dairy cattle, the coefficient of ploughed area for the forest-steppe and steppe zones was taken as 1.25 to 1.4; for the dry-steppe zone as 1.5 to 1.75.
The calculation of the maximum area to be leased to non-state legal entities is determined by the formula.
For the forest-steppe zone for agricultural enterprises of grain and cattle breeding type with livestock of 1200 conditional heads of cattle, the area of the land plot will be (2):

$$S = [(450*4) *5+ (450*5) *2+(450*6) * 1)]*1,34 = [(9000) + (4500) + (2700)]* 1,34 = 21700(ha) \quad (2)$$

For the steppe zone, for a grain and cattle breeding farm with 2,000 conditional cattle, the land area would be (3):

$$S = [(450*4) *6+ (450*5) *2+(450*6) * 2)]*1,37 = [(10800) + (4500) + (5400)]*1,37= 28400(ha) \quad (3)$$

For the dry-steppe zone, the maximum size of the farmland with 3,000 conditional cattle is (4):

$$S = [(450*4) *6+ (450*5) *2+(450*6) *2)]*1,73 = [(10800) + (4500) + (5400)] * 1,73=35800(ha) \quad (4)$$

By varying the number of cereal, fodder, and crop rotations, depending on the area of agricultural use in the rural district and the level of ploughing of the territory, the specialization of farms and the maintenance of livestock species, limit land use limits for legal entities in each specific administrative district are established.

Conclusions and proposals

The first option was to maintain the necessary diversification of production and introduction of resource-saving technologies by limiting grain crops and increasing the share of oilseeds and fodder crops.
The results of the optimization model identified multiple increases in the number of cattle in these natural-agricultural zones and a twofold increase in the output of cattle breeding per 100 hectares of agricultural land.
The second option optimizes the land of future grain and livestock farming entities in the same natural-agricultural zones under consideration.
As a result of the decision optimum parameters of the limiting sizes of the ground areas which can be given out in rent for legal bodies have been defined: for the agricultural enterprises of a grain and cattle breeding specialization the optimum size will be the ground area of 25.2 thousand hectares of arable land, 10 thousand hectares under natural forage lands, in total 35.2 thousand hectares of agricultural lands.
In the meat direction, the optimal size of land plots to be leased to legal entities is 21.8 thousand hectares of arable land, and 10 thousand hectares of natural grassland, in total 31.8 thousand hectares of agricultural land.

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Information about authors:
Aizhan Zhildikbayeva, Ph.D., associate professor. Department of Land Resources and Cadastre, Kazakh National Agrarian Research University. Tel. +7(701)3772255, e-mail: a.zhildikbaeva@mail.ru . Field of interests: cadastre and real estate valuation, economics, land use planning.
Virginija Gurskienė, dr. technological sciences, associate professor of the Department of Land Use Planning and Geomatics, Vytautas Magnus University, Lithuania. Address: K. Donelaičio str. 58, 44248, Kaunas city, Lithuania, phone: +370 614 17 853, e-mail: virginija.gurskiene@vdu.lt
Fields of interest: land use planning, real property cadastre, protected areas landscape.
Serik Yelemessov, doctoral student, Kazakh National Agrarian Research University. Tel.+7(707)2071827, e-mail: serik.yelemessov@bk.ru
Fields of interest: cadastre and land use planning
Baukhan Ablaikhan, doctoral student, Kazakh National Agrarian Research University. Tel. +7(701)9948622, e-mail: baukhan94@mail.ru
Fields of interest: economics, cadastre, and land use planning

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FEATURES OF CREATING AN INTERACTIVE MAPPING WEB APPLICATION FOR THE ANALYSIS OF SPACE IMAGES

Matviienko Oleksii, Kurach Tamara
Taras Shevchenko National University of Kyiv

Abstract
In the era of the high level of technological achievements of remote sensing of the Earth and the high level of development of web cartography, interactive web applications for the analysis of data of remote sensing of the Earth are gaining more and more popularity. Considering the large amount of space image data, and the complexity and heterogeneity of the analysis tools that need to be developed, the question arises of quickly and efficiently creating an interactive web application for the analysis of space images that will help scientists monitor and study changes in the Earth's surface and predict optimal ways of territory development with minimal expenditure of time and resources. In solving such a question, the specialized web platform Google Earth Engine (GEE) can help. The purpose of the article is to highlight the characteristics and advantages of the GEE platform by creating an interactive web application using the example of analyzing changes in the NDVI index. Analyzing GEE allows us to conclude that this web-platform provides a comprehensive solution for creating interactive cartographic web applications for the analysis of space images with a built-in IDE. It will help to significantly reduce development time and costs, allowing for quick and efficient analysis of Earth remote sensing data.
Key words: web cartography, interactive web application, aerospace images, integrated development environment

Introduction

In the modern world of web cartography, web mapping is considered as a scientifically based process and algorithm, creation or use and paperless distribution of cartographic works of various types and purposes. Web mapping focuses mainly on technological issues, while web cartography addresses theoretical aspects, including the use of web maps, evaluation and improvement of methods and workflows, usability of web maps, social aspects, etc. (Bondarenko, 2021; Kraak M.Y., 2020). The modern level of development of web cartography allows you to explore and interact with geospatial data from satellite images in real time. The emergence of mobile devices and big data played an important role in the formation and development of opportunities for creating web applications for analyzing Earth remote sensing data. (Kraak M. J., 2020; Krol K., 2020). Today, web applications for space image data analysis mainly consist of interactive web maps. The term "interactive web maps" can refer to a wide range of cartographic products, from simple online maps to complex cartographics information systems. In order for such interactive web maps to meet the needs of users, developers and designers of interactive maps must consider the goals, objectives and preferences of their users to create effective web maps. (Roth R. E., 2013). Accordingly, web cartography plays an important role as a tool for efficient and quick analysis of space image data. Thanks to various software products and web platforms, web applications are created that provide the opportunity to predict the potential ways of development of individual areas of the earth's surface, as well as to respond quickly to possible unforeseen natural disasters or cataclysms. (Bondarenko, 2021).

At the same time, the development of such web applications can be quite complex and time-consuming. The main problems may arise when searching or processing a large amount of geospatial data, developing specific analysis tools or low quality of the obtained data. Desktop software products will require additional customization and involvement of developer hardware resources to develop such web applications. Existing web platforms usually provide limited access to space image data and tools for their analysis. To solve the problems of resource-consuming, slow and inefficient development of a web application for the purpose of analysis and research of space image data, it is worth turning to the specialized web platform GEE. When developing interactive maps, it is necessary to take into account the property of interactivity and use a large number of interactive functions, the research of which is devoted to a recent work (Krakovskii, Kurach, 2022). This article aims to study the main features of creating an interactive mapping web application for the analysis of space images using the Google Earth Engine web mapping platform, which helps to reduce the time and resources required for the development of this type of web application. The focus will be on the analysis of the Normalized Difference Vegetation Index (NDVI) as an important tool for assessing the health of vegetation.

To achieve this aim, the methodology of this research involves a review of relevant literature on web cartography, interactive web applications, aerospace images, and integrated development environments. There was conducted an empirical study by developing an interactive mapping web application using the

Google Earth Engine cartographic web platform to analyze the NDVI index. This study will evaluate the platform's main features and functionality in terms of its ability to support interactive mapping web applications for space image analysis.
The materials for this research consist of various aerospace images and datasets that will be used to create the interactive mapping web application. The research methods applied will include software development, data analysis, and evaluation of the platform's features and functionality.
This research is significant because it highlights the benefits of using specialized cartographic web platform with built-in IDE for creating interactive mapping web applications. By examining the main features and functionality of the Google Earth Engine cartographic web platform, there will be provided insights into how this platform can be used to create interactive mapping web applications for analyzing space images. Moreover, this research will contribute to the development of innovative technologies for remote sensing and analysis of the earth's surface, which can have important applications in various fields, such as environmental monitoring, agriculture, and urban planning.
In summary, this article will examine the features of creating an interactive mapping web application for the analysis of space images, with a focus on the Google Earth Engine cartographic web platform. The article will justify the rationale of the study by providing appropriate theoretical and empirical backgrounds and materials. The article will also describe the research methodology and highlight the significance of this research for the development of innovative technologies for remote sensing and analysis of the earth's surface.

Methodology of research and materials

The research was conducted to demonstrate the features of creating an interactive mapping web application for the analysis of space images using Google Earth Engine (GEE) cartographic web platform. The study focused on creating an interactive cartographic web application for the analysis of the Normalized Difference Vegetation Index (NDVI) data for Ukraine territory as an example to highlight the main characteristics, functionality and advantages of GEE.
The NDVI is a measure of vegetation greenness and is calculated using near-infrared and visible red light reflectance from satellite imagery. (Remote Sensing of Environment, 1988) The NDVI data used in this study were obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on board the Terra satellite. Data were obtained with an average value for each season for the years 2000 and 2022 with a spatial resolution of 500 meters and a temporal resolution of 16 days (MODIS/Terra Vegetation Indices…, 2023).
To create an interactive mapping web application for the analysis of NDVI data, the GEE platform was used with the JavaScript programming language and GEE API for it. The GEE platform provides a wide range of tools and algorithms for analyzing satellite geospatial data and allows for the creation of interactive web applications (Google Earth Engine: Planetary-scale…, 2017). In addition, the platform provides access to a vast repository of satellite imagery and other geospatial data, which can be processed and visualized using JavaScript API code.
The NDVI data for Ukraine were imported from the satellite imagery library of GEE platform and were processed using the GEE API to calculate the mean NDVI value for each season for the specified years for the territory of the entire country (Google Earth Engine. Platform overview, 2023). As a result, the interactive web application was created with a web-based user interface that allows users to visualize and analyze the NDVI data within the Ukraine territory for specified period of time.
Overall, the methodology used in this study demonstrates the features and advantages of creating an interactive mapping web application for the analysis of space images using Google Earth Engine cartographic web platform. As an example, the study shows how interactive web applications created by GEE can be used to visualize and analyze NDVI data to analyze vegetation growth patterns within a region.

Discussions and results

The Google Earth Engine web platform is a powerful tool for analyzing and visualizing geospatial data of satellite imagery. It could be used for scientific and commercial purposes. It provides a wide range of functionality, including data processing and analysis, cloud-based storage, and visualization tools (Google Earth Engine: Planetary-scale…, 2017). GEE allows users to access and analyze massive amounts of satellite data, such as Landsat, MODIS, and Sentinel-2, which is particularly useful for monitoring land cover changes, analyzing agricultural patterns, and assessing ecosystem health (Exploring the Google Earth Engine…, 2018).

Researchers around the world are actively using Google Earth Engine to study various aspects of the environment. For example, the study (Fernández, Gil, 2022) examines the functional capabilities of the Google Earth Engine web platform for creating a web application for mapping, assessing and monitoring forest areas. The results presented in (Gorelick et al., 2017, Zhao et al., 2021) confirm that the GEE web platform has significant progress in solving global challenges associated with the processing of large volumes of geodata, which allows users to attract a minimum of resources without using supercomputers or specialized equipment. At the same time, the development of GEE does not stand still. The study (Yang et al., 2022) provides a comprehensive overview of the features and challenges of integrating artificial intelligence with GEE, which will further improve and automate the solution of major scientific and social problems, such as climate change and natural disaster risk management. Additionally, based on the following studies (Hamud et al., 2021, Varghese et al., 2021, Jaafa, Mourad, 2021), we can see that GEE can be used for various tasks: to monitor the effects of urbanization on changes in land use, to assess soil moisture, to monitor growth dynamics and to calculate the yield of various cultivated plants necessary areas. As we can see, scientists and researchers around the world are taking advantage of GEE, using it as the main platform for developing their web applications, or as an auxiliary tool for accessing a catalog of space imagery data and tools for their analysis.

To highlight the basic functionality and advantages of the platform, a small web application was created for the analysis and comparison of the NDVI index for the relevant years of the territory of Ukraine. (Fig. 1.)

The GEE web platform provided a range of tools and functionality that helped effectively and quickly create the interactive web application. For example, GEE's data processing capabilities made it possible to analyze and extract NDVI data from satellite imagery, while its visualization tools allowed for the creation of interactive map that could be easily navigated and manipulated by users. The cloud-based storage provided by GEE made it possible to store and access large amounts of data, and the platform's programming interface (integrated development environment) allowed developers to customize and extend the functionality of the web application

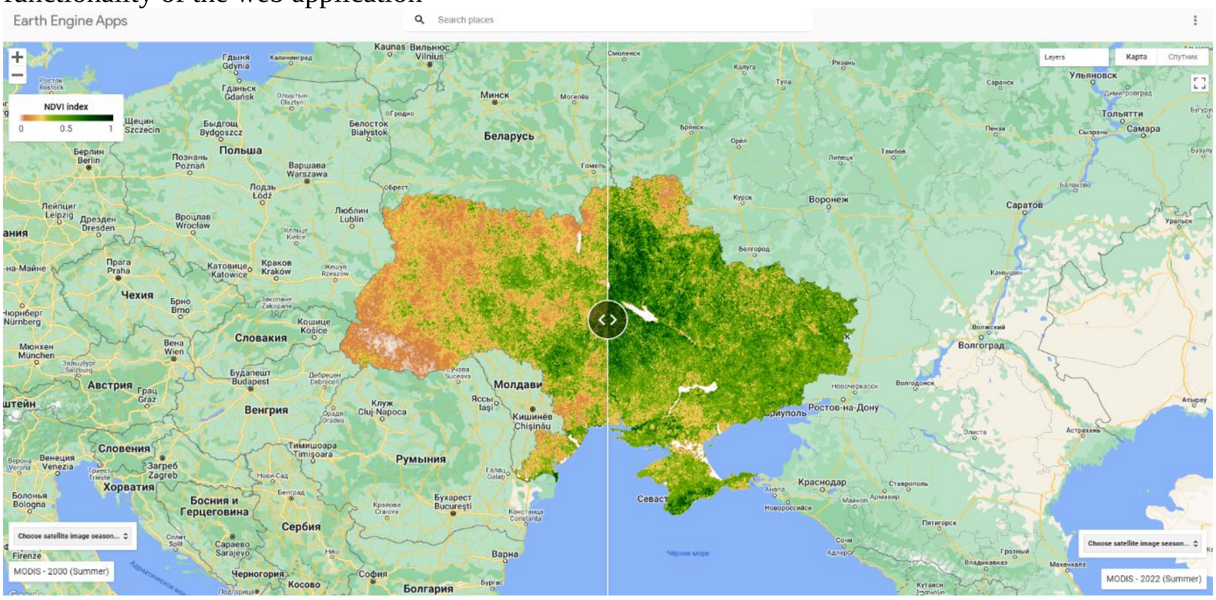

Fig.1. View of web-application for analyzing NDVI within Ukraine territory for the relevant years

The developed application allows users to explore different NDVI values across the Ukraine and compare data for the corresponding seasons of 2000 and 2022 years. The program is available to anyone with the appropriate link (https://work-folder-0.users.earthengine.app/view/ndvisplit-maps) to it and an Internet connection. In addition, if necessary (for example, in the case of crowdsourcing), the developer can provide direct access to the application code through a separate link, which is generated using the GEE functionality. The display of the NDVI index of the territory of Ukraine was reproduced on two separate maps, for the years 2000 and 2022, and it was also possible to obtain NDVI data for different seasons within the specified years, for a more detailed comparison of changes and development of vegetation cover territory of Ukraine over the past 22 years. Between the two separately created maps, an element of the user interface was reproduced - a partition panel that allows dynamically changing the received datasets from one year to another, which in turn allows for interactive analysis of changes in vegetation cover. Added web app legend to match color to NDVI values on maps. Directly, such a web application can be renewed and filled with

various tools or interactive components of the user interface provided by GEE for even more detailed analysis and research of the development of the vegetation cover of the territory of Ukraine based on the values of the NDVI index.
Thanks to the capabilities of the GEE web platform, it is possible to create a web application of this level in a short term, without involving third-party resources for obtaining satellite image data. All data, their processing, visualization and presentation in the form of a ready-made web program are executed and stored on Google servers. This makes the GEE web platform quite convenient, mobile in use and efficient in the development of web applications for the analysis and research of geospatial data of space images.
One of the main features and advantages of the GEE web platform is the built-in web-oriented integrated development environment (IDE), which allows developers to quickly and efficiently develop, test and publish a web application right in the browser, using built-in JavaScript API classes and methods. This IDE is structured around several core components, including the Code Editor, the Catalog, and the Assets (Fig. 2.).

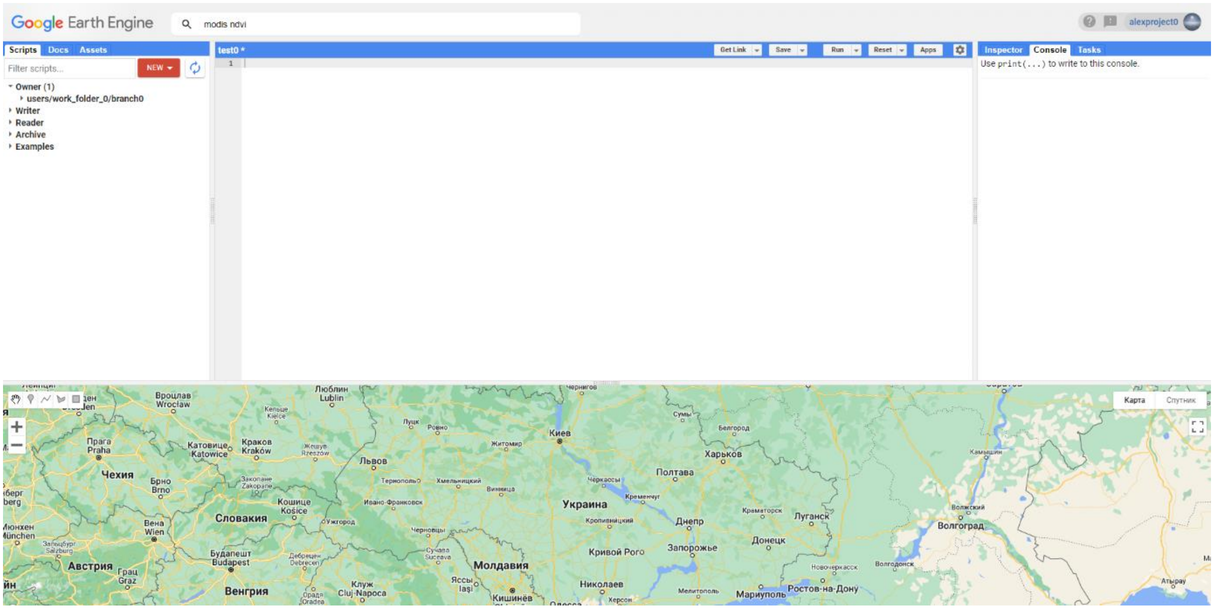

Fig.2. View window Google Earth Engine web-based IDE

The Code Editor is the central hub for writing and executing code on the GEE platform. It allows users to write JavaScript code that can access GEE's vast library of geospatial data and apply various analysis techniques to that data. The Code Editor also includes tools for debugging code and visualizing results. The Catalog is a repository of geospatial data available on the GEE platform. This includes satellite imagery, terrain data, climate data, and more. The Catalog allows users to search for and discover relevant data sets, as well as preview the data and explore its properties. Assets are user-uploaded geospatial data that can be stored and processed on the GEE platform. Users can upload their own data to the platform and access it within their own code, allowing them to perform custom analyses on their own data sets. In addition to these core components of GEE`s IDE, it also includes a number of built-in tools for performing geospatial analysis. These for example include tools for image processing, spatial filtering, machine learning and time-series analysis (Earth Engine Code Editor Overview, 2023).
One of the main advantages of the GEE platform is its scalability. The platform is designed to handle large-scale geospatial analysis tasks, and can process data sets that would be too large to handle using traditional desktop-based analysis tools. The platform also includes powerful tools for parallel processing, allowing users to distribute analysis tasks across multiple machines to speed up processing times.
Overall, GEE provides as a powerful platform for geospatial analysis, which can be applied to a variety of fields, including environmental science, agriculture, forestry, and urban planning. Based on the research of the main characteristic features of the GEE web platform, while creating a web application for the analysis of NDVI, it is worth highlighting the following types of geospatial analysis that can be performed using GEE:
- image classification: GEE can classify images based on spectral signatures and other features, such as texture and shape;
- time-series analysis: GEE can analyze temporal trends in imagery and data, such as changes in land cover, vegetation, or climate variables over time;

- land cover mapping: GEE can create detailed maps of land cover using various image processing techniques;
- vegetation monitoring: GEE can monitor changes in vegetation health, such as the Normalized Difference Vegetation Index (NDVI), and detect areas affected by drought, pests, or other stress factors;
- climate change analysis: GEE can analyze the impacts of climate change on different environmental variables, such as temperature, precipitation, and sea level rise;
- data fusion: GEE can integrate data from multiple sources, such as satellite imagery, weather data, and ground observations, to provide a comprehensive view of the environment.

There are several web platforms that are similar to Google Earth Engine (GEE) in terms of their functionality, for example such as QGIS Cloud and ArcGIS Online. Despite some similarities between these platforms in their functionality, Google Earth Engine has advantages over other web platforms with similar functionality. In general, the following advantages of the GEE web platform for the analysis of space images over other web platforms with similar functionality should be highlighted (Google Earth Engine as a planetary-scale platform…, 2023):
- large data repository: Google Earth Engine provides access to an extensive collection of satellite imagery and other geospatial data, including Landsat, MODIS, Sentinel, and more. This vast data repository allows users to perform complex geospatial analysis, such as time-series analysis and change detection, on a global scale.
- scalability: Google Earth Engine is built on Google's cloud infrastructure, which allows for the processing of large amounts of data in a short amount of time. This scalability makes it ideal for processing and analyzing large datasets, which is often a challenge for other web platforms.
- code editor: GEE includes a code editor as part of IDE that allows users to write, test, and run JavaScript code directly in the browser. The code editor provides a range of features such as autocompletion, syntax highlighting, and debugging tools.
- JavaScript API: GEE provides a JavaScript API that allows users to interactively explore and visualize geospatial data on a map. Users can also create custom applications and workflows using the API.
- Python API: in addition to the JavaScript API, GEE also provides a Python API for users who prefer to work in a Python environment. The Python API allows users to access and manipulate GEE data using familiar Python libraries such as NumPy and Pandas.
- machine learning capabilities: Google Earth Engine has built-in machine learning algorithms that can be used for tasks such as object detection, image classification, and land cover mapping. This makes it possible to automate many aspects of geospatial analysis and increase the efficiency of data processing.
- open access: Google Earth Engine is freely accessible to researchers, scientists, and developers around the world. This makes it possible for anyone with an internet connection to perform complex geospatial analysis and contribute to global research efforts.

These advantages and features make GEE an ideal platform for large-scale geospatial data analysis and visualization, as well as for developing customized applications for specific environmental or social challenges.

Conclusions and proposals

Web platforms for creating mapping web applications for analyzing satellite imagery have revolutionized the way we interact with geospatial data. These platforms allow users to access and process large amounts of satellite imagery, creating maps and visualizations that can be used to monitor changes in land cover, vegetation, weather patterns, and other environmental factors.

One of the most powerful web platforms for creating mapping web applications for analyzing satellite imagery is Google Earth Engine (GEE). GEE is a cloud-based platform that provides access to a vast amount of satellite imagery and geospatial data, including historical and real-time data from Landsat, Sentinel, MODIS, and other satellites. GEE also provides a variety of tools and functions for processing and analyzing this data, including machine learning algorithms and image processing techniques.

To highlight the main advantages and characteristic features of the GEE web platform, an interactive web application was created for the analysis and comparison of the NDVI index of the territory of Ukraine. According to the results of the reproduced web application, in general, we can observe a decrease in the value of NDVI for 20 years. However, at the same time, the average value of NDVI for the summer of 2022 in some regions of Ukraine exceeds the value of 2000. This may be related to certain climatic anomalies, such as an increase in the amount and frequency of precipitation during the corresponding period of time, which led to a deterioration in the definition and calculation of the NDVI value.

The following main advantages of GEE can be distinguished: built-in web-oriented integrated development environment, which helps developers get comprehensive facilities for web-application development in the browser, withouth using any additional software; cloud-based architecture with ability to handle large-scale data processing and analysis; providing real-time data processing and analysis, which allows users to monitor changes in environmental factors in near real-time; user-friendly interface that allows users to create and share mapping web applications with ease; provides a variety of templates and widgets that users can use to create custom mapping applications, which can be shared with other users or embedded on websites.

Overall, GEE is one of the most powerful and versatile web platforms for creating mapping web applications for analyzing satellite imagery for researchers, scie ntists, and anyone else interested in geospatial data analysis. Its ability to handle large-scale data processing and analysis, real-time data processing, user-friendly interface, and constant evolution make it an ideal platform for anyone interested in analyzing geospatial data from satellite images.

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Information about authors:

Oleksii Matviienko, Bachelor, Student of the Department of Geodesy and Cartography of Taras Shevchenko Kyiv National University. Address: 2 Akademika Glushkova Avenue, Kyiv, 03022, Ukraine; phone: +380631398679; e-mail: matvich1999@gmail.com; Fields of interest: GIS technologies, web cartography, geospatial analysis.

Tamara Kurach, PhD in Geography, Associate Professor of the Department of Geodesy and Cartography of Taras Shevchenko Kyiv National University. Address: 2 Akademika Glushkova Avenue, Kyiv, 03022, Ukraine; phone: + 380501688197; e-mail: tnkurach@ukr.net; Fields of interest: Remote sensing, thematic mapping, GIS technologies.

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THE AGRARIAN LANDSCAPE AND THE CHANGE IN ITS SUBDIVISION OF PLOTS

Krasinskaitė Karina, Valčiukienė Jolanta, Juknelienė Daiva
Vytautas Magnus University Agriculture Academy

Abstract
The article presents an analysis of changes in the agrarian landscape and the subdivision of its plots, using three Lithuanian municipalities as examples (Kaunas, Trakai and Šilutė). Statistical, comparative and multicriteria analysis methods were applied in the study. It was found that in all the studied municipalities, the area of the agrarian landscape was decreasing during the study period. The largest decreasing trends were in the municipality of Šilutė district, where the area covered by agrarian landscape decreased by more than 3%. At the same time, in the municipalities of Kaunas and Trakai districts, the area of agrarian landscape decreased quite evenly and did not reach 3%. It was also found that the number of agricultural holdings also decreased: by 27% in Kaunas district municipality and by over 33% in Trakai district municipality, but the area of agricultural holdings increased in all of the studied municipalities: in Kaunas district by over 5%, in Trakai district by over 37% and in Šilutė district by over 8%. The average size of a farm in Kaunas district remained rather stable, increasing by only 1%, in Šilutė district municipality the average farm size increased by more than 71% and in Trakai district municipality the tendency was the opposite, i.e. the average farm size decreased by more than 36%. The multicriteria analysis shows that the most common factors influencing changes in the agrarian landscape and its subdivision of plots vary between municipalities, but in general the following factors influence the changes in the agrarian landscape and its subdivision of plots: the land productivity score, the number of inhabitants, the distance to the centre of the city, the average size of the farms, the number of holdings, and the amount of land area occupied by bodies of water. The information collected and the results obtained show that in the municipalities analysed, the causes of change in the agrarian landscape and its subdivision of plots have a positive impact on the sustainable development of agriculture and rural areas.
Key words: landscape, agrarian landscape, subdivision of plots, change.

Introduction
Landscape is an important spatial resource of the country, encompassing urban and rural areas, forests, water bodies and fields and creating conditions for people to live and work. Preserving the uniqueness of the landscape, managing and shaping it to meet the economic, social, cultural, environmental and aesthetic needs of society is one of the most important tasks of the Lithuanian state (Dėl Lietuvos..., 2014).
Climate and population change, as well as the use of various natural resources, have been the main factors that have changed the visual landscape. If natural processes were the only cause of landscape change, there would be very little change in the landscape, but humans are involved in the whole process of change, so the visual appearance of the landscape changes quite significantly. And the biggest influence on landscape change is the fact that people are involved in agriculture. Thus, it can be argued that landscape change is an interaction between nature and humans (Thoren, 2014; Hartvingsen, 2014). It is through people respecting nature, the inevitable changes that occur in nature, and developing a sense of responsibility for their actions affecting and changing the landscape that the negative consequences that follow changes in nature can be reduced (Heyd, 2008).
Other authors, such as Azevedo and Perera (2014), argue that landscapes are the result of the interaction between nature and humans, and that their condition is influenced by various natural factors and human activities. One of the strongest drivers of landscape change is farming, which strongly influences agrarian landscapes.
An agrarian landscape is a type of landscape shaped by natural processes and human activities. This type of landscape retains the most important features of the natural structure (Dėl Lietuvos..., 2014).
The agricultural areas that make up the agrarian landscape are characterised by the subdivision of plots of various sizes and configurations and are an integral part of the mosaic of the agrarian landscape. Plot fragmentation is linked to problems of landscape optimality and agricultural efficiency (Orlonas and Veteikis, 2016). The subdivision of agricultural land affects both agricultural production possibilities and the visual quality of the countryside (Brabec, Smith, 2002).
The subdivision of the agrarian landscape may indicate that the existing land tenure structure is problematic. This can be a serious problem in many regions as it limits sustainable agricultural development and reduces the potential for sustainable rural development. A reliable assessment of the current situation is needed to combat land subdivision, as existing indicators of subdivision may also have shortcomings. They ignore

important spatial variables, such as the shape of the plots, as well as non-spatial variables, such as the type of ownership and the presence or absence of road access for each plot of land (Demeriou et al. 2013).
The agrarian landscape type covers more than half of Lithuania's territory and is characterised by different sizes and shapes of agricultural plots. With more than 93 000 people engaged in agriculture, especially in rural areas, it is very important and relevant to analyse in more detail the agrarian landscape and the changes in its subdivision of plots and to clarify the causality of these changes, to reveal whether they may, in fact, be limiting the rational development of agriculture and undermining the possibilities for sustainable rural development.
The aim of the study is to examine changes in the agrarian landscape and the subdivision of its plots in selected areas.
To achieve this, the following **objectives** are being pursued:

1. To analyze the changes in the agrarian landscape in selected areas.
2. To analyse the changes in the agrarian landscape subdivision of plots.
3. To identify the causes of change in the agrarian landscape and its subdivision of plots as well as its potential impact on the rational process of agricultural and rural development.

Methodology of research and materials

The areas (study sites) were chosen for the study based on different aspects that could be used to identify the variation and causality of the agrarian landscape and its subdivision of plots, irrespective of whether the sites are similar, i.e., the aim was to select sites with different characteristics. Thus, 3 study sites were selected:

- Kaunas district municipality is one of the most developing municipalities in central Lithuania. The municipality is undergoing a rapid process of urbanisation and population growth. Kaunas district municipality has an agricultural productivity score of 48, which is higher than the average for Lithuania (43.2), the land is fertile, and the agrarian landscape accounts for half of the municipality's total area (50.06%).
- Located in the south-eastern part of the territory of Lithuania, the municipality of Trakai district has one of the lowest productivity scores (28.70) in the whole territory of Lithuania, and the area of the agrarian landscape accounts for only 32.64% of the municipality's area. Urbanisation processes in the municipality are gradual, as the population is rather stable. The municipality focuses more on the renewal and renovation of already urbanised areas than on development.
- Šilutė district municipality is located in the western part of Lithuania and is environmentally sensitive, with protected areas occupying more than 51% of the municipality's area, while the area of the agrarian landscape also accounts for a significant (48.57%) part of the municipality's area. The productivity score for agricultural land in the district is 33.13. There is no need for urbanisation as the population of the municipality is decreasing significantly.

Thus, taking into account the above-mentioned criteria of the municipalities selected for the object of the study (different productivity scores, the extent and pace of urbanisation, and the rather different structural composition of the landscape), the study further analyses in detail the changes in the agrarian landscape and its subdivision of plots of the three municipalities of Lithuania (the districts of Kaunas, Trakai, and Šilutė).
Statistical, comparative and multicriteria analysis methods were used to analyse the changes in the agrarian landscape and its subdivision of plots, as well as the causes of change and their impact on rational agricultural and rural development in the selected districts. The following data for the period 2013-2022 were used for the analysis:

- Data from the Land Fund of the Republic of Lithuania (hereinafter referred to as "LR") (as of 1 January);
- Data from the Lithuanian Land Information System (www.zis.lt);
- Data from the Cadastre of Protected Areas of the Republic of Lithuania (as of 1 January 2022);
- Portal of the Registers of Agriculture and Rural Business and Farmers' Farms provides statistics on agricultural holdings. The choice was made to analyse the data as at 1 January of each year.

A multicriteria analysis was used to identify the main causes of change in the agrarian landscape and its subdivision of plots. This analysis was carried out using PROMETHEE software. This software can be used to identify the most significant aspects that determine the subdivision of plots of the agrarian landscape. Six criteria were set for the multicriteria analysis (Table 1).

Table 1

Criteria for multicriteria analysis to identify the causes of subdivision of plots in agrarian landscapes (compiled by the authors)

No	Criterion	Justification of the criterion	Criterion direction
1	Agricultural land area, ha	The larger the area of agricultural land, the lower the likely subdivision of plots in agrarian landscapes.	MAX
2	Productivity score	The higher the productivity score, the more fertile the land, the more intensive the farming activity and, presumably, the larger the area of agrarian landscape.	MAX
3	Distance to city centre, km	The shorter the distance to the city centre, the higher the subdivision of plots is likely to be.	MIN
4	The area of protected areas, ha	The smaller the area of protected areas, the greater the area of agricultural land is likely to be.	MIN
5	Average farm size, ha	The larger the size of the farm, the smaller the subdivision of plots is likely to be.	MAX
6	Number of farms, units	The larger the number of farms, the higher the number of agrarian plots is likely to be.	MAX
7	Number of inhabitants, units	The larger the number of inhabitants, the more likely it is that the subdivision of plots will be higher.	MAX
8	Number of agricultural holdings, units	The larger the number of agricultural holdings, the higher the subdivision of plots.	MAX
9	Roads, km	The more roads, the more likely the higher the subdivision of plots.	MAX
10	Water bodies, ha	The larger the area of land covered by water bodies, the higher the subdivision of plots is likely to be.	MAX

The values of the criteria were assessed from the data sources listed above and collected for the study, and the criteria were weighted according to their usefulness or uselessness for achieving the objective of the multicriteria analysis. The data matrix (Table 2) was therefore developed to carry out the multicriteria analysis (Table 2).

Table 2

Data matrix for multicriteria analysis and directions of criteria for multicriteria analysis (Compiled by the authors)

	Agricultu-ral land area	Productivity score	Distance to the city centre	Protected areas	Average farm size	Number of farms	Number of inhabitants	Number of agricultu-ral holdings	Roads	Water bodies
Criteria direction	MAX	MAX	MIN	MIN	MAX	MAX	MAX	MAX	MAX	MAX
Kaunas district municipality	74855.73	48.00	23.60	23782.65	5.49	2373	105032	3034	3143.76	7537.60
Trakai district municipality	39404.06	28.70	15.40	40876.66	4.53	1632	35864	1922	2209.04	5634.02
Šilutė district municipality	81718.19	33.13	12.50	82310.98	11.89	2789	42330	5138	2234.13	31958.75

The linear priority function (Linear) recommended by PROMETHEE was used for the multi-criteria analysis, as well as thresholds for identity status Q and strict priority P (Table 3). When a linear priority function is chosen, the values Q and P are included and there is a linear relationship between them. It is therefore not the fact that one indicator is higher or lower than another, but the magnitude of the change between the indicators that matter. Therefore, for favourable criteria, the programme assigns coefficient values between 0.1 and 1.0, depending on the selected Q and P values.

Table 3

Thresholds for criteria Q and P (compiled by the authors)

	Agricultural land area	Productivity score	Distance to the city centre	Protected areas	Average farm size	Number of farms	Number of inhabitants	Number of agricultural holdings	Roads	Water bodies
Q value	15352.37	6.23	3.40	17001.50	2.82	303	28158	859	423.01	11090.82
P value	43561.79	19.10	10.80	56020.39	7.72	1075	74270	3003	1046.16	28640.64

The study identified trends and causes of change in the agrarian landscape plot subdivision of municipalities and based on the findings, made assumptions about the possible consequences for sustainable agricultural and rural development.

Discussions and results

The change in the agrarian landscape between 2013 and 2022 in the municipalities analysed is presented in Figure 1.

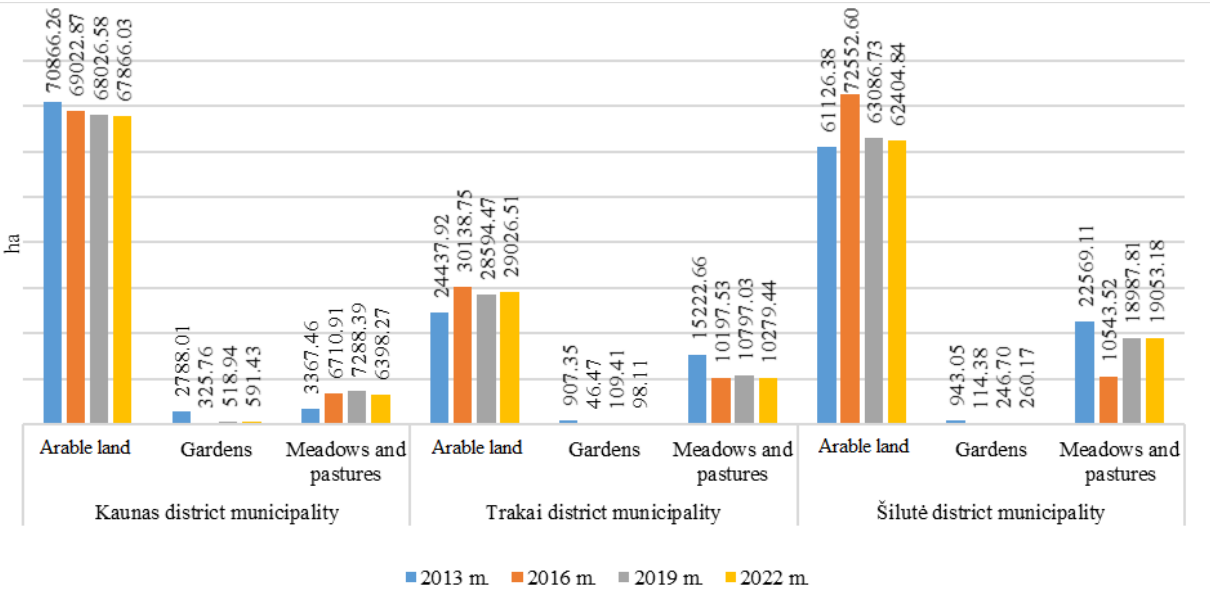

Figure 1. Change in the area of agricultural land in Kaunas, Trakai and Šilutė district municipalities in ha (Source: compiled by the authors on the basis of data from the Land Fund of the Republic of Lithuania)

It has been established that in Kaunas district municipality the agrarian landscape accounts for 50.05% of the total area of the municipality (the area of the municipality is 149548.33 ha, agricultural land – is 74855.73 ha). During the period under analysis, the area of arable land decreased by 3000.28 ha (about 4%), as did the area of gardens - 2196.58 ha (almost 79%). Meanwhile, the area of meadows and natural pastures increased by 3030.81 ha, i.e. by 90%.

In Trakai district municipality, the agrarian landscape accounted for 32.64% of the total area of the municipality (the total area of the municipality is 120732.73 ha, and agricultural land – is 39404.06 ha). During the period under analysis (2013 to 2022), the area of arable land in Trakai district municipality increased by 4588.59 ha (almost 19%). Meanwhile, the area of gardens, meadows and pastures decreased by 809.24 ha (about 89%) and 943.22 ha (about 32%) respectively.

In Šilutė district municipality, the agrarian landscape covered 48.57% of the total area of the municipality (municipal area 168245.05 ha and agricultural land area - 81718.19 ha). It was found that the area of arable land in the district increased by 1278.46 ha (about 2%), the area of gardens decreased by 682.88 ha (over 72%) and the area of meadows and pastures also decreased by 3515.93 ha, i.e. by over 15%.

The results of the analysis of the changes in the agrarian landscape are illustrated in Figures 2,3,4 and 5.

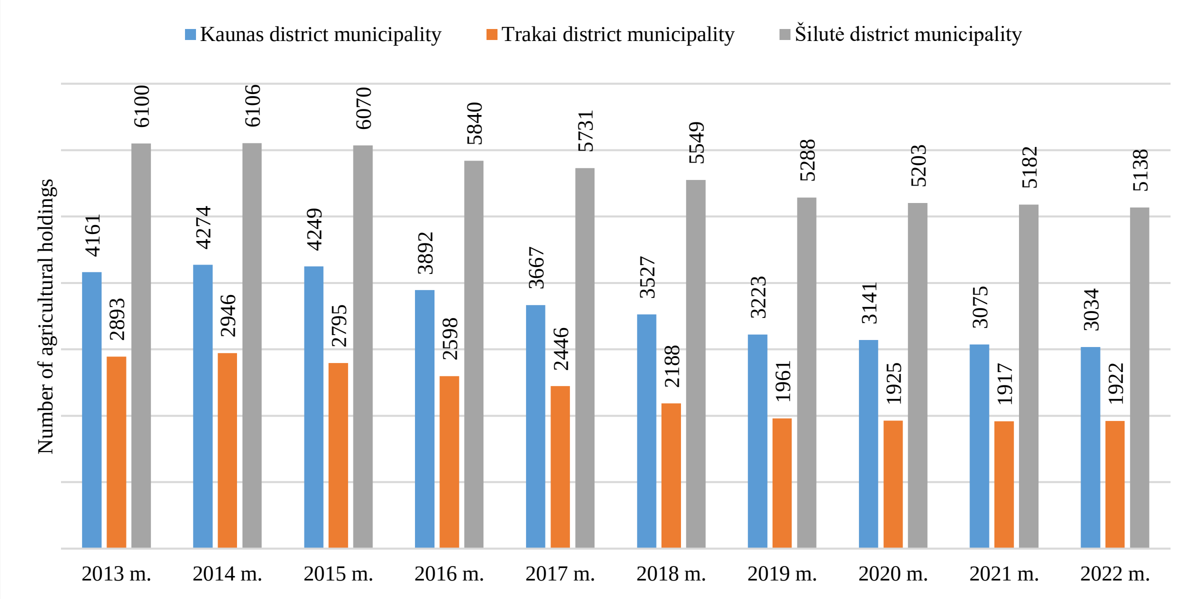

Figure 2. Change in the number of agricultural holdings in Kaunas, Trakai and Šilutė district municipalities (Source: compiled by the authors on the basis of the data of the Agricultural Holdings Portal - 1 January)

As of 1 January 2022, there were 3034 agricultural holdings in Kaunas district municipality, the average size of an agricultural holding was 93.57 ha. The distribution of the area of agricultural holdings by purpose was:

- Areas used for agricultural purposes amounted to 39982.54 ha;
- Areas used for forestry purposes - 229264.92 ha;
- Areas used for water purposes - 2311.26 ha;
- Areas used for other purposes - 10099.45 ha.

It was found that the number of agricultural holdings in Kaunas district municipality has been steadily decreasing during the period under study. From 2013 to 2022, the number of agricultural holdings in the district decreased by 1127 units, i.e. by 27.08%.
As of 1 January 2022, there were 1.922 agricultural holdings in Trakai district municipality, with an average farm size of 11.63 ha. The distribution of the area of agricultural holdings by purpose was:

- Areas used for agricultural purposes amounted to 18417.08 ha;
- Areas used for forestry purposes – 1800.85 ha;
- Areas used for water purposes – 349.58 ha;
- Areas used for other purposes – 1445.21 ha.

It was found that the number of agricultural holdings in Trakai district also decreased by 971 units, i.e. by 33.56%.
As of 1 January 2022, there were 5138 agricultural holdings in Šilutė district municipality, with an average farm size of 13.01 ha. The distribution of the area of agricultural holdings by purpose was:

- Areas used for agricultural purposes amounted to 60126.42 ha;
- Areas used for forestry purposes – 2471.62 ha;
- Areas used for water purposes – 837.47 ha;
- Areas used for other purposes – 2944.90 ha.

It was found that, as in the other two municipalities, the number of agricultural holdings in Šilutė district was also decreasing. Although from 2013 to 2015, it can be said that this indicator was steady and did not change significantly, from 2015 to 2022, there was a marked decrease in the number of agricultural holdings. During the whole period under study, the number of agricultural holdings in Šilutė district municipality decreased by 962 units, i.e. by 15.77%.
The study also analysed the evolution of the size of agricultural holdings (Figure 3).

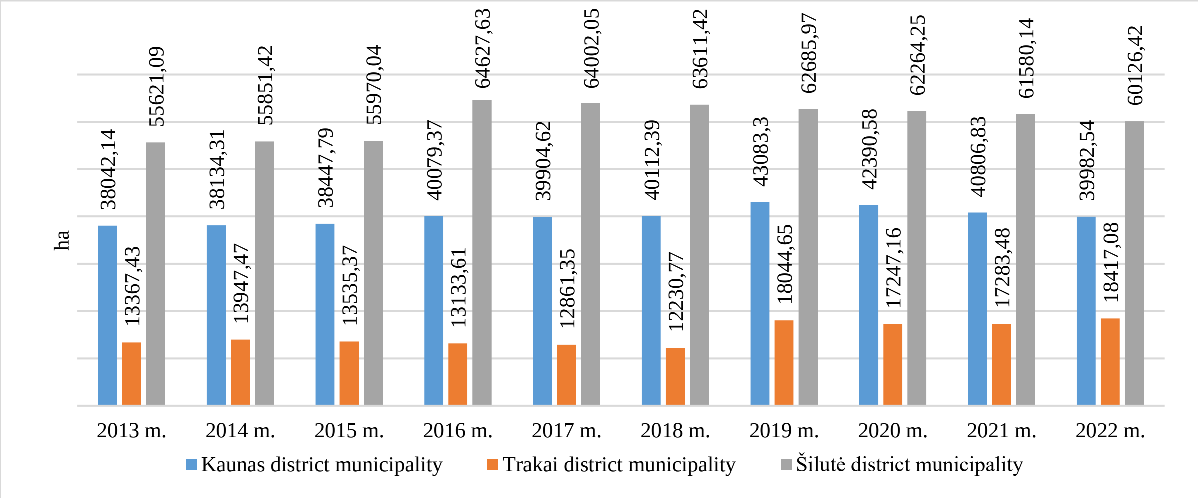

Figure 3. Area of agricultural holdings in Kaunas, Trakai and Šilutė district municipalities in ha (Source: compiled by the authors on the basis of the data of the Agricultural Holdings Portal - 1 January)

It was found that the area of agricultural holdings in Kaunas District was uneven. From 2013 to 2019, there was an increase of 5041.16 ha (more than 13%), while from 2019 to 2022, these areas decreased by 3100.76 ha, i.e. more than 7%. Summing up the whole period under study, it can be stated that the area of agricultural holdings in Kaunas district municipality increased by 1940.40 ha, i.e. by 5.10%.

Meanwhile, the area of agricultural holdings in Šilutė District remained fairly stable in 2013-2015, with a sharp increase of 8657.59 ha (more than 15%) between 2015 and 2016. Meanwhile, between 2016 and 2022, a rather steady decrease of 4501.21 ha (almost 7%) was observed. However, summarising the whole period under study, it can be stated that the size of agricultural holdings in Šilutė district increased by 4505.33 ha, i.e. by 8.10%.

The area occupied by agricultural holdings in the municipality of Trakai district has been unevenly distributed. It can be seen that from 2013 to 2018, the area decreased quite steadily by 1136.66 ha (more than 8%). Later, between 2018 and 2019, a sharp increase of 5,813.88 ha was observed, i.e. 47.53%. And between 2019 and 2022, the area can be said to have remained fairly even, with a change of only 372.43 ha, i.e. an increase of only 2.06%. Summarising the whole period under study, it can be stated that the size of agricultural holdings in the municipality of Trakai district increased by 5049.65 ha, i.e. by 37.78%, which is the highest increase among the 3 municipalities studied.

The change in the number of farms in the analysed municipalities was also studied (Figure 4).

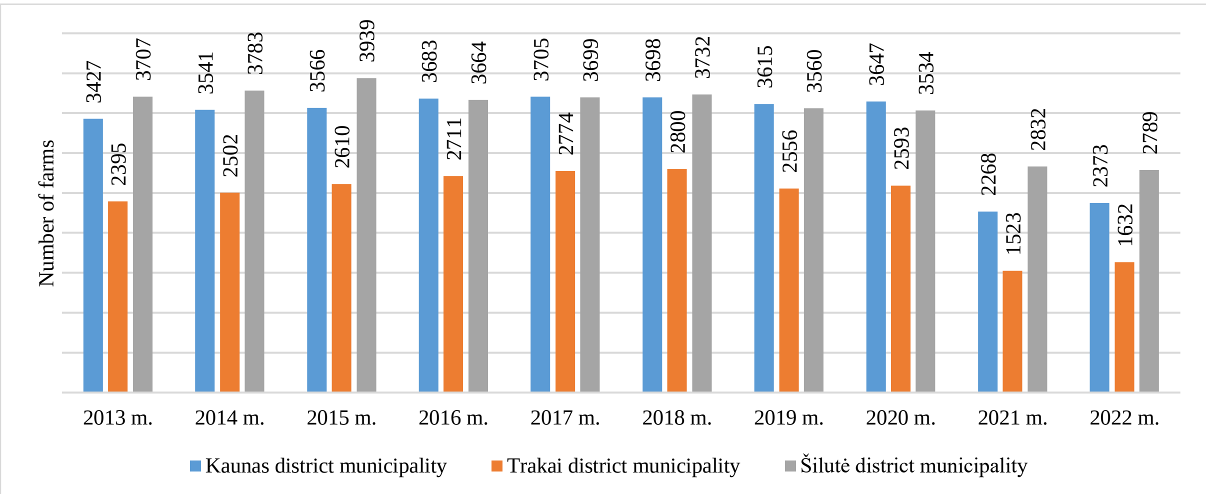

Figure 4. Change in the number of farms in Kaunas, Trakai and Šilutė district municipalities (Source: compiled by the authors on the basis of the data of the Agricultural Holdings Portal - 1 January)

The analysis of the change in the number of farms in the selected municipalities of the districts shows that the number of farms has been decreasing in all the municipalities analysed. The number of farms in Kaunas

district decreased by 1054 (30.76%) between 2013 and 2022, in Trakai district by 763 (31.86%) and in Šilutė district by 918 (24.76%).
The change in the size of the average farm is presented in Figure 5.

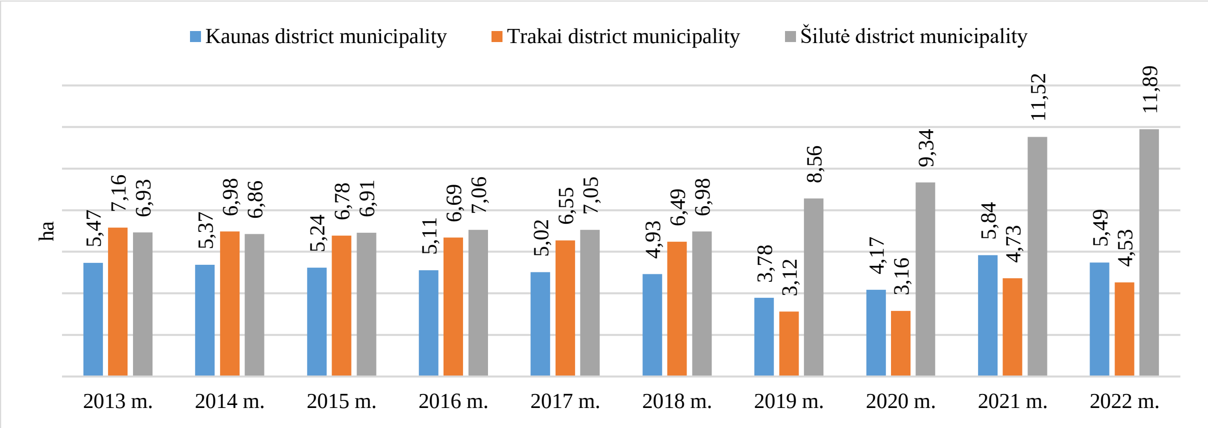

Figure 5. Change in the size of the average farm in Kaunas, Trakai and Šilutė district municipalities, ha (Source: compiled by the authors on the basis of the data of the Agricultural Holdings Portal - 1 January)

As can be seen from the figure, the average farm size in Kaunas district municipality remained fairly stable during the period under study. Between 2013 and 2022, the average farm size increased by only 0.02 ha, i.e. by only 0.36%. Meanwhile, in Trakai district municipality, the average farm size decreased by 2.63 ha (36.73%), and in Šilutė district municipality, the average farm size almost doubled, i.e. from 6.93 to 11.89 ha, i.e. an increase of 4.96 ha (71.57%).
To identify the causes of changes in the agrarian landscape and its plot subdivision, the above-mentioned multicriteria analysis was carried out, whereby the criteria were evaluated in order to determine which criterion is the strongest and which one is the weakest one of the changes in the agrarian landscape and its plot subdivision in the particular municipality under study.
The study has shown that in Kaunas district municipality the most influential factors on changes in the agrarian landscape and its plot subdivision are land productivity score, number of inhabitants and road area, and the least influential is the distance to the city centre (Figure 6).

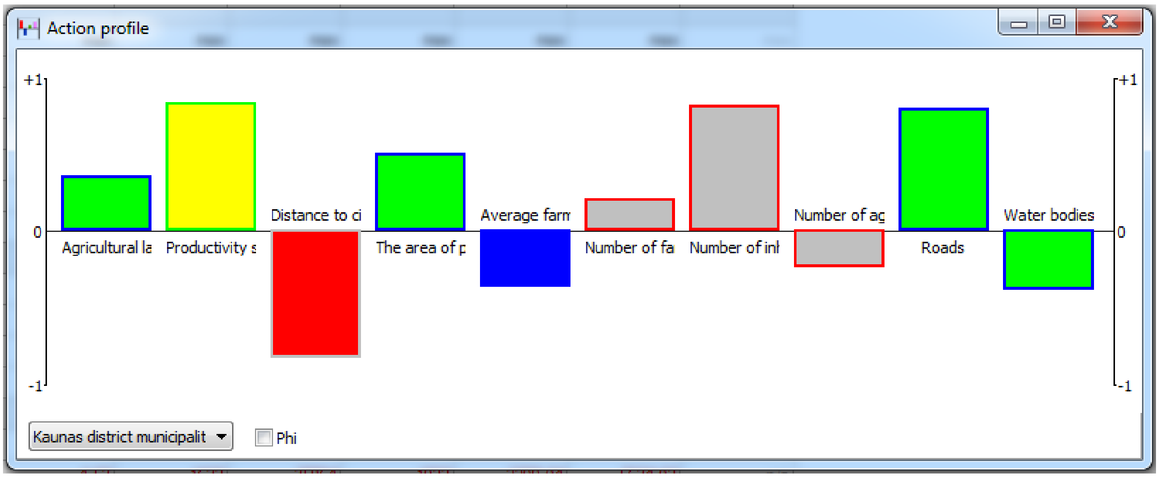

Figure 6. Analysis of Kaunas district municipality criteria by PROMETHEE Action profile test (Source: compiled by authors using PROMETHEE software)

In the municipality of Trakai district, however, there are no fundamentally exceptional indicators that influence the change of the agrarian landscape and its subdivision of plots. This change is only slightly influenced by the distance to the city centre and the area covered by protected areas, but it is clear that the area covered by agricultural land and the number of farms in the district do not have any influence at all on the change in the agrarian landscape and its subdivision of plots (Figure 7).

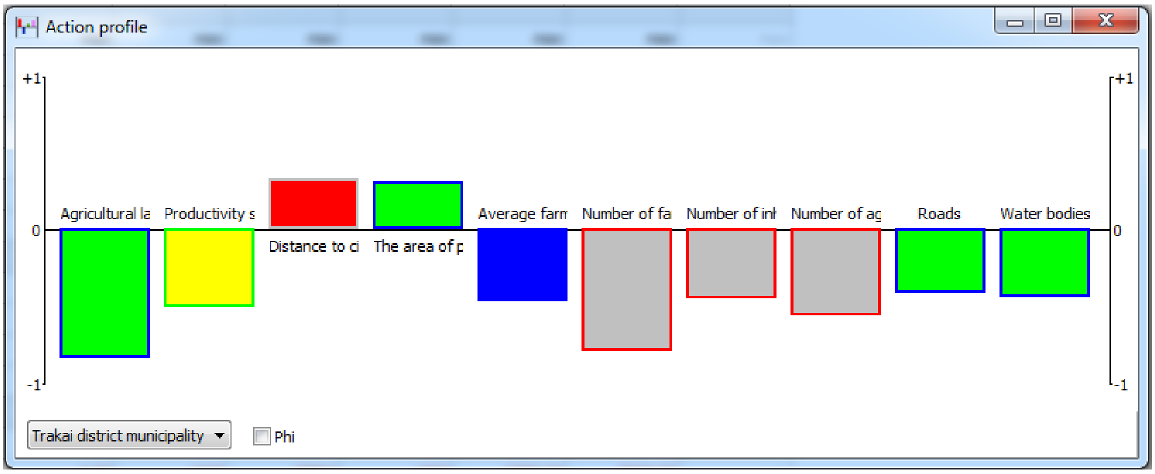

Figure 7. Analysis of Trakai district municipality criteria by PROMETHEE Action profile test (Source: compiled by authors using PROMETHEE software)

In Šilutė district municipality, almost all of the analyzed criteria have a significant influence on the change of the agrarian landscape and its subdivision of plots (Figure 8).

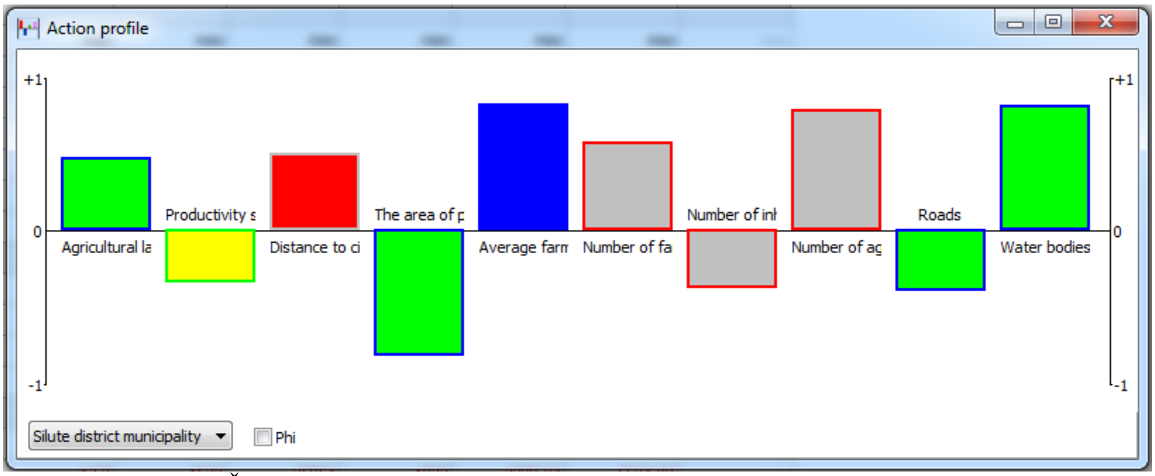

Figure 8. Analysis of Šilutė district municipality criteria by PROMETHEE Action profile test (Source: compiled by authors using PROMETHEE software)

The most significant criteria that have the greatest influence on the change of the agrarian landscape and its subdivision of plots in Šilutė district are the average size of farms, the number of agricultural holdings and the area of land occupied by water bodies. However, the size of the agricultural area, the distance to the city centre and the number of farms also contribute quite significantly to the changes in the agrarian landscape and its subdivision of plots in the district. Meanwhile, the area covered by protected areas has no influence on this change.

Summarising the information gathered and the results obtained, it can be stated that the change in the agrarian landscape and its subdivision of plots in the municipalities analysed has a positive impact on the sustainable agricultural and rural development process. As it was found that, although the number of agricultural holdings has been decreasing, the area of agricultural holdings has been increasing. It was also found that the number of farms was decreasing, but the average farm size was increasing. This means that agricultural plots have become larger, leading to a more rational and competitive process of agricultural development. It was also found that in Kaunas district municipality the changes in the agrarian landscape and its subdivision of plots are strongly influenced by the growing population. This is also a positive aspect, as an increasing population leads to the development of rural settlements, especially in this district. In the municipality of Šilutė district, the change in the agrarian landscape and its subdivision of plots is strongly influenced by the average size of farms, which has increased by more than 71% in the municipality, which is also a positive factor for sustainable agricultural development. Of the municipalities analysed, only the municipality of Trakai district was unable to identify the most influential indicator for the change in the agrarian landscape and its plot subdivision, but it was found that the area of agricultural holdings in the municipality is increasing, which is still indicative of ongoing agricultural development.

Conclusions and proposals

1. The results of the study showed that in all the municipalities studied (Kaunas, Trakai and Šilutė districts) the agrarian landscape areas have been decreasing during the study period. The most pronounced decreasing tendencies are observed in the municipality of Šilutė district, i.e. the area occupied by agrarian landscape decreased by more than 3%, while in the municipalities of Kaunas and Trakai districts, these areas decreased quite evenly and were less than 3%. In the municipality of Šilutė district, the most pronounced decreases were observed in the area of gardens - by more than 72% - and in the area of pastures and meadows - by more than 15%, while the area of arable lands increased by more than 2%. However, the most pronounced decrease in arable land was in Kaunas district - about 4%, while in Trakai district the opposite process was observed - the area of arable land increased by almost 19%. The same reverse process was observed in the change of meadows and natural pastures, where the area of meadows and natural pastures increased by 90% in the Kaunas district during the period of study. Meanwhile, the area occupied by gardens in both Kaunas and Trakai district municipalities decreased by 79% and 89%, respectively.
2. The analysis of the changes in the agrarian landscape subdivision of plots shows that the number of agricultural holdings has been decreasing in all the municipalities studied. The largest decrease in the number of agricultural holdings took place in Trakai district, with a decrease of more than 33%, while the smallest decrease took place in Šilutė district, with a decrease of more than 15%. The largest increase was observed in Trakai district - more than 37%, and the smallest in Kaunas district - just over 5%. The average size of a farm in Kaunas district municipality remained practically stable - it increased by only 0.02 ha, i.e. by only 0.36%. Meanwhile, in Trakai district municipality the average size of a farm decreased by 2.63 ha (36.73%), while in Šilutė district municipality the average size of a farm doubled from 6.93 ha to 11.89 ha, i.e. by 4.96 ha (by as much as 71.57%).
3. After multicriteria analysis, it was found that land productivity score, population and road area have the greatest influence on the subdivision of plots of agrarian landscape and its change in Kaunas district municipality. The municipality of Trakai district, on the other hand, does not have a strong indicator, but the distance to the city centre and the area covered by protected areas have a slight influence on the change in the agrarian landscape and its subdivision of plots in this district. In Šilutė district municipality, meanwhile, the average size of farms, the number of agricultural holdings and the area covered by land and water bodies are the main factors influencing the change in the agrarian landscape and its subdivision of plots. It has also been found that changes in the agrarian landscape and its subdivision of plots in the municipalities analysed have a positive impact on the rational process of agricultural and rural development. This leads to an increase in the area of agricultural holdings and the size of the average farm and, in some cases (such as in Kaunas district), the population. The increase in these indicators leads to a competitive agricultural and rural development process.

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Information about authors:
Karina, Krasinskaitė, master student, Departament of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, karina.krasinskaite@stud.vdu.lt.
Jolanta, Valčiukienė, doctor of technology science, assoc. prof., Departament of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, jolanta.valciukiene@vdu.lt. Fields of interest: sustainable development of rural and urban areas, land use planning, land administration.
Daiva, Juknelienė, doctor of technology science, lect.dr., Departament of Land Use Planning and Geomatics, Vytautas Magnus University Agriculture Academy. Address: Universiteto str. 10, LT-53361, Akademija, Kaunas district, +37037752372, daiva.jukneliene@vdu.lt. Fields of interest: sustainable development of rural and urban areas, land law, land administration.

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THE STRUCTURE OF GEODESIC MONITORING IMPROVEMENT BY HORIZONTAL AND VERTICAL DISPLACEMENTS BY APPLYING COMBINATION OF METHODS

Vynohradenko Serhii[1], Makieieva Liudmyla[2], Ryasnyanska Alona[3], Kriauciunaite-Neklejonoviene Vilma[4], Balevicius Giedrius[5]

[1, 2, 3] State Biotechnological University, [4, 5] Vytautas Magnus University

Abstract

The purpose of the article is to present a combined approach that connects several methods and algorithms to increase the effectiveness of the geodetic network measurement structure for determining horizontal and vertical displacements of engineering objects. Determining the deformation of commercial objects and objects of practical value allows to assess their technical condition. In case of critical changes at such objects, appropriate planning of protection, reconstruction and modernization works is also provided and the negative impact of the environment and weather conditions is indicated. Regardless of the methods used, the measurement of movements and deformations of structures is always preceded by an analysis of the prevailing conditions, as well as a network of geodetic measurement determination and control. These analyses are carried out taking into account manufacturability, economy, safe use of objects, human safety and environmental protection. The target function was defined, which in this case was chosen as the entropy of the geodesic observation network through the measurement of the parameters vector with true values. Analysing the structure of the control and measurement network and improving its efficiency by the number of necessary observations becomes important for determining reliable changes occurring at the object and the ability to conduct the necessary measurements in the shortest possible time. At the same time, the improved network structure should ensure the redundancy of observations made to match the geodetic network with the modified methods. The optimal number of observations in the geodetic network depended on the observation structure informativeness. During the research, it was noticed that the use of a combined approach will allow selecting only those observations that are the most informative. This will reduce the measurement time without reducing the accuracy of the received movements. The obtained results of the numerical analysis showed the performance of the offered solution for increasing the efficiency of the geodetic network structure formation. It also allows faster and more economical performance of engineering structures geodetic measurements.

Key words: geodetic network, geodetic monitoring, combined approach, parameter vector

Introduction

Geodetic monitoring of buildings includes measurement of vertical and horizontal displacements using appropriate measurement methods and results interpretation. The results interpretation is preceded by the construction of movements geometric model, which makes it possible to identify benchmark base points (Gil, 2003; Abellan et. al., 2009). Conducting geodetic monitoring can be continuous or periodic, taking into account the need to monitor the dynamics of changes occurring at the object. Systems for monitoring and diagnosing the state of construction objects can take into account the load of individual structural elements with the influence analysis of external factors, such as winds, environmental pollution and thermal and chemical interactions (Suchocki, Blaszczak-Bak, 2009). Correctly carried out measurements and determination of movements make it possible to identify the technical condition of the object and predict its behavior in the long term. This, in turn, allows to plan the optimal use of the object and carry out measures aimed at maintaining the object and preventing its deterioration (Tretyak et. al., 2015; Dvulit et. al., 2019; Sztubecki et. al., 2022).

A wide range of measurement methods and techniques can be used to measure movements and deformations. However, measurement should always be preceded by an analysis of the measurement conditions at the facility, development of the optimal architecture of the measurement and control network and determination of a possible calculation method (Marsella, 2020). All analyses must take into account technological, numerical, economic, ecological aspects, environmental protection and the safety of people who work at and use the facility (Gridan, Grecea, 2013). When optimizing the placement of a geodetic network for monitoring changes occurring in construction objects, the possibility of performing measurements, the correctness of calculations to determine movements and the possibility of recording the changes occurring should be taken into account. These elements depend on the average measurement error, which is the result of the technological decisions made (Afonin, 2011). The measurement results are subject to geometric interpretation, which consists of determining the parameters of the object's body movements and the approximation of the vector field of movements (Xu et. al., 2022). Thereby, the influence of random factors characterized by changes in time and different intensity, deformation measurements performed during the operation of objects are of great importance for ensuring the buildings and engineering structures' safety. The periodic measurements' results of control networks, intended to determine the movement of construction objects, are compared with the results obtained during the initial measurement (Abdalla, Mustafa, 2021). One of the methods that can be used in the alignment of measurement and control networks is the free alignment method, which may be necessary to study the movements of various parts of the object, thus analysing its deformation. Free alignment allows you to optimally fit the aligned network into the approximate network, using additional conditions (compared to the classical method of least squares), superimposing the values of the covariance matrix C_X on the vector of d_x increment estimates to the approximate coordinates imposing on the vector of growth estimates d_x (Filipiak-Kowszyk, Kaminski, 2016).

The aim of the article is to improve the structure of geodetic monitoring of horizontal and vertical displacements by using free alignment in combination with classical methods of geodetic network alignment.

The main tasks are structured in such a way as to present the possibility of using free alignment to determine the horizontal displacements of a construction object:

- based on the cyclic monitoring of a building structure by investigating the possibility of using free alignment to determine horizontal displacements. The approach is implemented in the Matrix Laboratory environment;
- to analyse the results and perform quantitative analysis to verify the accuracy of the obtained displacements to the horizontal displacements of the measuring and control network points.

Displacements were obtained using classical computational methods used in geodetic analysis of deformations and changes in buildings.

Methodology of research and materials

In the classical alignment of geodesic networks by the method of least squares with minimal restrictions on degrees of freedom, the vector of corrections is subject to the following condition (Tretenkov, 2016):

$$V^T PV = \min, \tag{1}$$

where: V is the corrections matrix to be paid attention to, P is the weight matrix. When using free alignment, additional conditions arise that are imposed on the Euclidean norm of the vector of approximate coordinate increments d_x and on the covariance matrix C_X, these conditions are following:

$$d_X P d_X = \min \tag{2}$$

$$\mathrm{trace}(C_X) = \min. \tag{3}$$

In the process of free alignment, no minimum restrictions on the degrees of freedom are assumed. Therefore, it was determined that the increments of coordinates of all points of the geodetic network are subject to alignment. This procedure leads to the origin of an external network defect, which is equal to the number of degrees of freedom and is calculated as:

$$\mathrm{def} = \mathrm{cols}(A) - \mathrm{rank}(A), \tag{4}$$

where: A is a matrix of coefficients for unknown values. Using formula (4), it is possible to determine the external disconnection, which is def = 1 for vertical networks and def = 3 for horizontal networks. In practice, the external disconnection of geodetic networks is eliminated by condensing the network to points with known coordinates or by defining a local coordinate system (for example, considering the coordinates of one of the points of the vertical networks to be constant). The principle of free alignment assumes a non-zero external decoupling. According to this assumption, the system of observation equations will have the following form:

$$Ad_X = L + V, \tag{5}$$

where: L is the interpolation matrix. In the group of possible solutions of equation (5), there is one specific solution, which is subject to the classical condition of network alignment by the method of least squares (1) and the condition (2). However, it should be noted that with non-zero external network incoherence, the matrix of coefficients A of the system of correction equations $V = Ad_X + L$ is a column matrix of incomplete order. That is, the matrix of coefficients of the system of standard equations

$A^T PAd_x + A^T PL = 0$ is a singular matrix, and its classical inverse form does not exist. The solution can be obtained using the Moore-Penrose pseudo-inverse matrix, that is, the generalized inverse matrix. For the generalized inverse matrix A^+, the evaluation vector of the increments to the approximate coordinates, which satisfies the solution of the contradictory system of equations $Ad_x + L = 0$, will have the following form :

$$d_x = -A^+ L. \tag{6}$$

The vector d_x satisfies the following conditions:

$$(Ad_x + L)^T P(Ad_x + L) = \min \tag{7}$$

$$d_x^T M d_x = \min, \tag{8}$$

where: P is the weight matrix of the vector of measurement results, while the weight matrix is known before the alignment of the coordinates of the points. Under these conditions, solution (6) is a solution of the system of correction equations for which conditions (1) – (3) are fulfilled.
After determining the d_x vector that satisfies condition (1), it is necessary to formulate another alignment problem. It is an additional optimization problem compared to classical alignment methods. The optimization problem (Gierski et. al., 2016) refers to the conditional method known in the theory of equations and has the following form:

$$Bd_x + \Delta = 0 \tag{9}$$

$$\min\left\{V^T MV\right\} = d_x^T M d_x, \tag{10}$$

where: B is a matrix of coefficients with unknowns, and the matrix Δ contains intercepts. The optimization problem (10) is a primary problem with constraints that admit solutions from the $\{d_x : Bd_x + \Delta = 0\}$. While solving this problem, the primary problem turns into a dual problem without restrictions, in this case it can be expressed by the following expression:

$$\min\left\{V^T MV - 2k^T (Bd_x + \Delta)\right\} = d_x^T M d_x. \tag{11}$$

The solution of the dual problem (11) is the estimation:

$$d_x = M^{-1} B^T k, \tag{12}$$

where: k is the correlation vector, and is defined as:

$$k = -(BM^{-1}B^T)^{-1}\Delta. \tag{13}$$

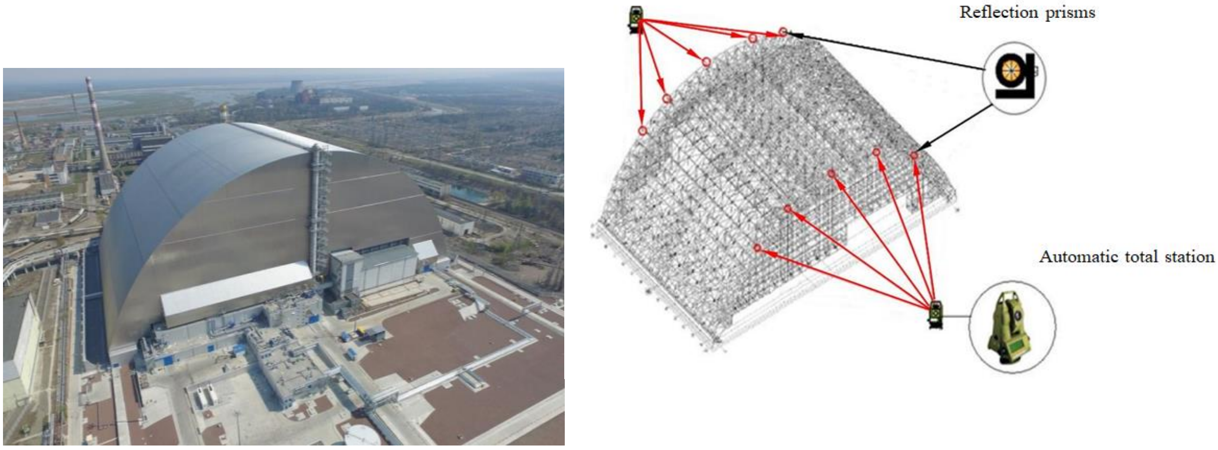
Thus, summarizing the calculation method, the estimation of approximate coordinate increments will be determined by the following formula:

$$d_x = -M^{-1}B^T (BM^{-1}B^T)^{-1} A^T PL. \tag{14}$$

Discussions and results

As an example of the offered approach application, actual data obtained from the results of geodetic monitoring of the building structure were used. The object of monitoring was the complex of the new safe confinement (NSC) of the Chornobyl NPP, located in the north of the Kyiv region in the territory of the exclusion zone directly in the center of 10 km. zones of special radiation danger. The object of measurement and analysis was represented by the final sets of deformation, control marks and subject to periodic observation for four years. Measurements of movements of points of the geodetic control network were used for the tests; the principle of determining the plan-height position of reflector prisms is presented in Figures 1a and 1b. The measurements of the network were carried out with an electronic total station of the TC 1800 type from the "Leica" company and Ni 002 and DINI 010 levels from the "Zeiss" company. The device is characterized by the root mean square error of distance measurement ± 3mm and root mean square error of angle measurement as for wall marks and for marks on the pitched roof. Angular net measurements were taken from each net position using the directional measurement method and the lengths of each side were taken in both directions. Geodetic monitoring at the facility included four cycles of periodic measurements in the form of angular and linear observations. The baseline measurement was labeled Cycle

No.1, and the individual periodic measurements were labeled Cycle No.2, Cycle No.3, and Cycle No.4. The structure of settlement deformation marks is shown in Figure 2.



a) **b)**

Figure 1. General view of the complex of the NSC of the

Figures 1a and 1b. Chornobyl NPP buildings (a) and the scheme of the prism reflectors installation on the structures of the NSC (b)

The discretization of the object in the form of control marks selection (figure 3) and the conducted observations made it possible to determine the horizontal movements of the control marks, which, in turn, became the basis for conducting direct geodetic monitoring on the analysed object.

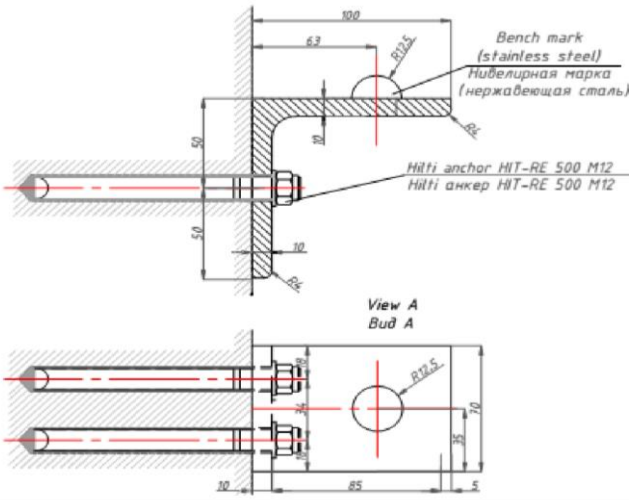
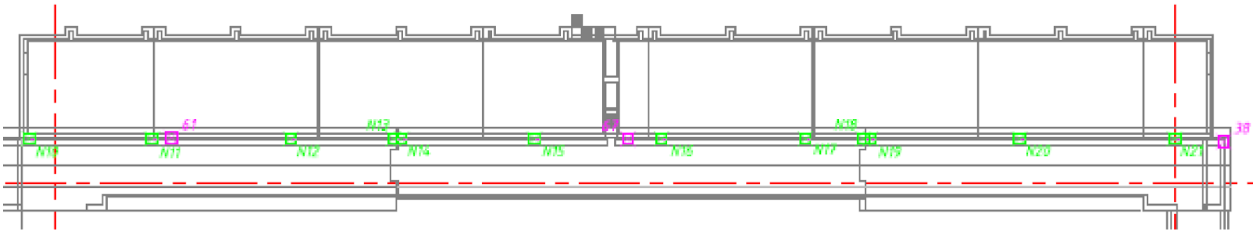
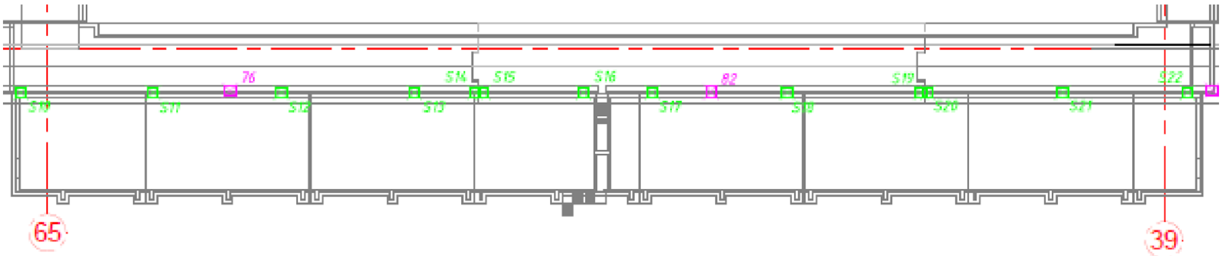


Figure 2. The construction of a settling deformation mark

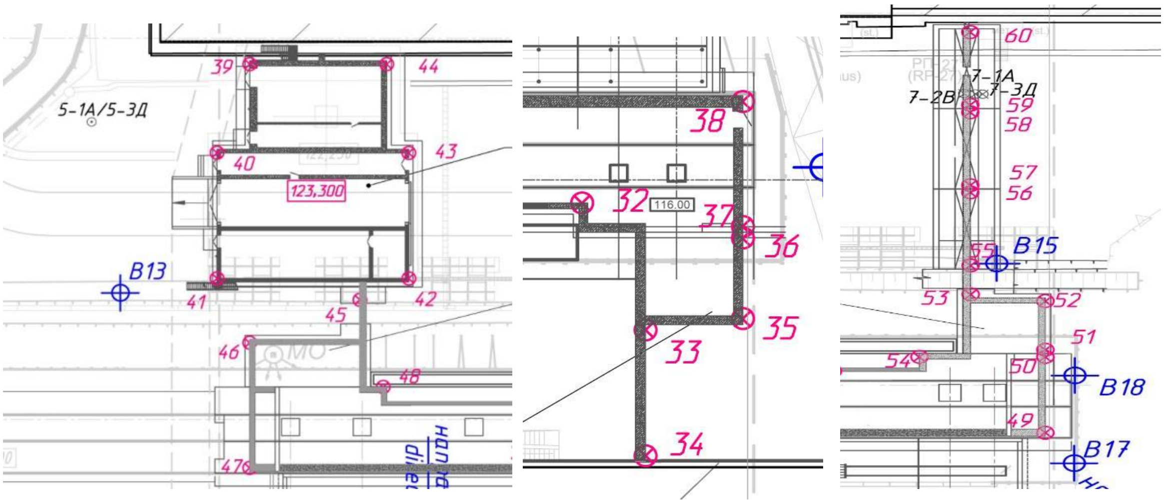
Calculations of control mark displacements were performed using the free alignment method as presented in the section above and the geometric model definition of displacements based on classical least squares alignment.



a) Northern basement of the NSC Service Zone



b) Southern basement of the NSC Service Zone



c) **d)** **e)**

Figure 3. Installation scheme of control marks on the Northern **(a)** and Southern **(b)** basements of the NSC Service Zone, settlement deformation marks on the southwestern end wall **(c)** Arches of the NSC (marks 39 – 48), settlement deformation marks on the north-eastern **(d)** (marks 32 – 38) and south-eastern **(e)** (marks 49 – 60) end walls of the Arch of the NSC

The obtained results of free alignment were compared with the results obtained when measuring the network using the classical engineering-geodesic approach, performed by the method of least squares. The root mean square error was used for comparison (Vynohradenko et. al., 2022, Виноградenko, 2023), which was calculated for separate calculation options in separate measurement cycles. While comparing, differences in the obtained aligned coordinates are considered (table 1). A graphical presentation of the obtained results in the form of resulting vertical movements for four cycles of measurements is presented in the figure 4.

Table 1

Root mean square values of correction errors to coordinates for four cycles of observations

Observation cycle	Root mean square value by the method of free alignment, mm	Root mean square value by the method of least squares, mm
Cycle No.1	3.5	3.3
Cycle No.2	3.3	3.6
Cycle No.3	3.4	3.2
Cycle No.4	2.5	2.3

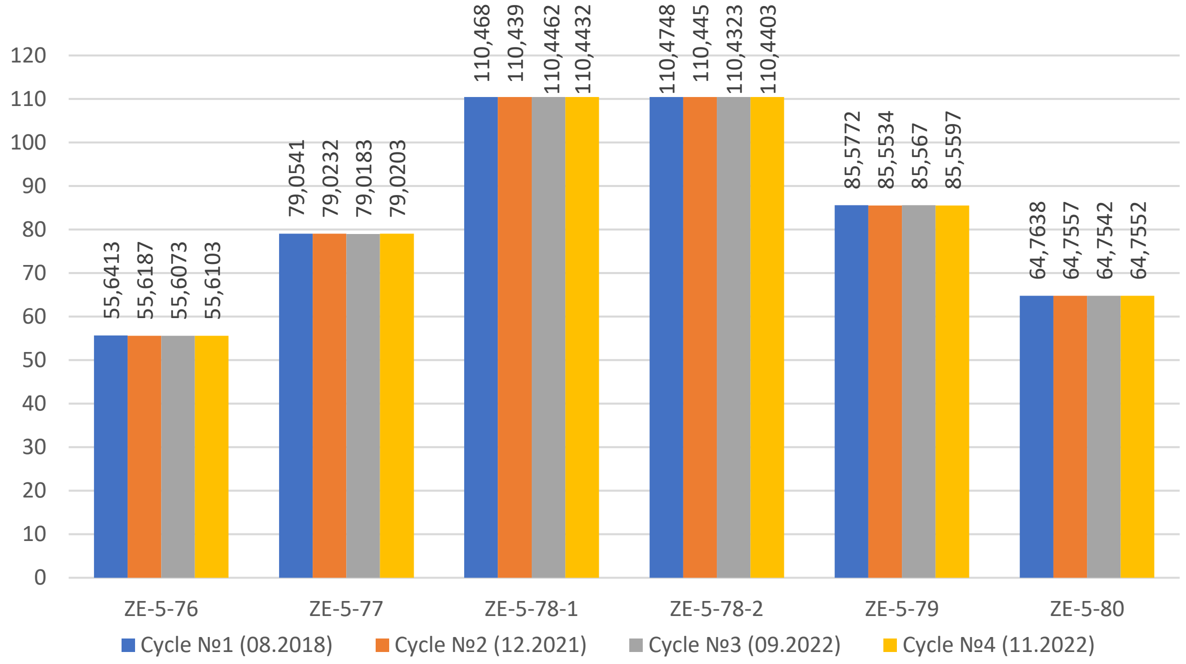


Figure 4. Vertical displacements for four cycles of measuring control marks of the NSC Arch structures, m

Analyzing the results shown in the table 1, it can be seen that the obtained Root mean square values corrections and horizontal movements in separate measurement cycles differ within a range that does not exceed the average error of the performed measurements. The largest difference in the coordinate values obtained during free alignment and least squares alignment was obtained in cycle 2 and was 0.3 mm. The obtained results indicate the possibility of using the offered approach, avoiding the need to use fixed points in the alignment process.

Conclusions and proposals

To determine the movements of engineering structures, buildings, you can use a network of arbitrary shape with a non-zero external deviation, using a free reference system. While measuring movements and deformations, such a network is a full-fledged geodetic system that allows determining internal changes in the shape of the object under investigation. The offered solution allows to determine the aligned values of the points coordinates of the measuring and control network, thus determining the magnitudes of the horizontal and vertical movements that the object undergoes.

The obtained results have several clear consequences that indicate the direction of measurement and calculation methods development used in monitoring building structures. The following are the most important consequences of the presented research:

- while using the free alignment method, it was possible to avoid the subjective assumptions associated with the use of fixed points in the alignment process, while maintaining a pattern of movements similar to that which can be obtained by the method of least squares alignment,
- based on the conducted numerical experiments, it can be seen that the offered approach allows obtaining results similar to the classical methods of alignment performed by the method of least squares, and simulating the phenomena and processes occurring on buildings that are subject to geodetic monitoring,
- the offered method can be used both for the alignment of observations obtained using classical measurement methods (for example, tacheometric measurements) and methods based on GNSS observations.

The offered approach to the alignment of observations made during geodetic monitoring refers to modern measurement methods. It has an important engineering significance for assessing the safe operation of buildings. Due to the satisfactory results of the analyzed studies and the current work carried out, we offer to use the presented approach for the alignment of observations made in more extensive measurement networks created for large engineering objects (for example, areas under mining, earth dams and areas, where, for example, waste dumps are located). This approach can also be used to align observations obtained by other measurement methods (for example, obtained using GNSS measurements) and detect observations with gross errors.

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Information about authors:

Serhii Vynohradenko, Ph.D in economic sciences, associate professor, associate professor of Department of Land Management and Cadastre, State Biotechnological University. Alchevskykh str. 44, 61002, Kharkiv, Ukraine, phone +380984650418, e-mail: s.vinogradenko15@gmail.com. Fields of interest: all similar surveying and technology studies.

Liudmyla Makieieva, Ph.D in sciences in public administration, associate professor, associate professor of Department of Land Management and Cadastre, State Biotechnological University. Alchevskykh str. 44, 61002, Kharkiv, Ukraine, phone +380979431467, e-mail: Makeevafiz2017@gmail.com. Fields of interest: state management of land resources, land management of territories.

Alona Riasnianska, Ph.D in economic sciences, senior lecturer of Department of Land Management and Cadastre, State Biotechnological University. Alchevskykh str. 44, 61002, Kharkiv, Ukraine, phone +380660749808, e-mail: alona.ryasnyanska@gmail.com. Fields of interest: all similar technology studies and issues of land recourses.
Vilma Kriauciunaite-Neklejonoviene, doctor of technological sciences, lecturer, Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, Universiteto str. 10, LT–53361 Akademija, Kaunas, Lithuania, phone +370 37 752372, e-mail: vilma.kriauciunaite-neklejonoviene@vdu.lt . Fields of interest: geodetic measurements, accuracy of surveying, land use planning.
Giedrius Balevicius, lecturer, Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, Universiteto str. 10, LT–53361 Akademija, Kaunas, Lithuania, phone +370 37 752372, e-mail: giedrius.balevicius@vdu.lt. Fields of interest: land use planning, geodetic measurements

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AGRICULTURAL LANDS TRANSFORMATION AND THEIR USE IN LAND PLANNING PROJECTS IN UKRAINE

Koshkalda Iryna[1], Sadovyy Ivan[2], Dombrovska Olena[3], Gurskiene Virginija[4], Maliene Vida[5].

[1,2,3]State Biotechnological University, [4,5]Vytautas Magnus University

Abstract

Aspects and factors of agricultural land transformation are analyzed in the work. Taking into account the world experience of land transformation, directions for improving the development and control system of land management projects implementation in Ukraine are offered. The compliance issue by land users with established types of agricultural land according to the data of state registers is highlighted. Nowadays, land management projects that provide ecological and economic substantiation of crop rotation and land management make it possible to develop environmentally safe and economically feasible land use projects. In production, the above-mentioned projects are sometimes used to transfer ecologically stabilizing lands (pastures and hayfields) to arable land. This is contraversial to all recommendations, conventions and programs that emphasize the need for reduced plowing of the territory. It is necessary to improve the control mechanisms of crop rotation and agrotechnical environmental protection measures. The introduction of land plots agricultural passports is an important but insufficient measure. The remote sensing data of the earth and the use of modern geoinformation technologies should become part of the state control over compliance with land management projects. There is already experience of using various indices at the state level to decipher agricultural crops. As a result of the research, we came to the conclusion that the use of land remote sensing data and modern geoinformation technologies in land management will make it possible to bring the indicators of plowed areas to a rational level, while not creating artificial restrictions on economic activity. The methodical and regulatory acts for the development of land management projects, which regulate the size of the ecologically safe land area need improvement.

Key words: agricultural lands transformation, land management project, pastures, hayfields, arable land.

Introduction

The purpose of the work is an attempt to analyze the aspects of agricultural land transformation and, taking into account the world experience of land transformation, to offer ways of improving the existing development system of land management projects in Ukraine, to highlight the trends of compliance by land users with the types of agricultural land according to the data of state registers To achieve the set goal, the following tasks were solved:

- to consider the main groups of factors influencing the transformation of land in Ukraine;

-to analyse the land management documentation types and determine the general steps of its development;

-to identify positive and negative characteristics of land transforming;

-to develop measures for increasing the effectiveness of the land management projects development related to the transformation of agricultural lands. In particular, control over compliance with land management projects The suboptimal structure of agricultural land can have various effects depending on the context and scale, such as plowed territory, agricultural development, anthropogenic load, ecological stabilization effect, etc. Plowing can lead to soil erosion and nutrient runoff, which can reduce soil fertility, reduce yields and degrade soil quality (Keesstra, 2018). Land imbalances can also contribute to water pollution. High agricultural development can lead to a decrease in biodiversity, which means the loss of natural environments and habitats for many species of animals and plants. Land ratio can also affect climate influencing water balance, air circulation and other climate factors (Cowiea, 2018). The way land resources are used affects the energy costs associated with the production and transportation of agricultural products. One of the tools for influencing the balance of lands is transformation (Popov et. al., 2022). In order to legally transfer one type of land to another, it is necessary to develop land management documentation.

Groundless transformation of agricultural land is a path to soil degradation and erosion. The problem of land degradation in Ukraine affects more than 20% of arable land (FAO, 2018). From 300 to 600 million tons of soil is lost annually from erosion, and the yield can be reduced by 50%, depending on the level of degradation. In Ukraine, water erosion affects 13.4 million hectares, including 10.6 million hectares of arable land. Erosion can lead to significant economic losses exceeding UAH 20 billion per year. Losses of agricultural products from erosion exceed 9-12 million tons of grain units per year. Due to land degradation from 1990 to 2010, the humus content in the chernozems of Ukraine decreased by 0.22% (Кирієнко, 2020).

Land use is an important component of sustainable development and ensuring environmental safety. To ensure environmental safety and economic feasibility of land use, it is necessary to take into account a number of factors:

- determination of ecological criteria for land use. For example, it is important to consider the impact of agricultural land structure on biodiversity, water resources, soil, atmosphere and other environmental components (Koshkalda, Panukhnyk et. al., 2022; Koshkalda, Vynohradenko et. al., 2022);
- ensuring the economic feasibility of land use. For example, the land structure should be properly planned and organized taking into account market needs, potential profitability and resource recovery opportunities;
- when determining the structure of agricultural land, it is important to take into account the possibility of providing the vital needs of the population and other social factors.
- use of energy-efficient technologies and organic fertilizers (Gustafson, 2014).

Therefore, in order to ensure the optimal ratio of lands, it is necessary to carefully study all factors and use effective methods and technologies. Modern GIS technologies are a powerful tool for analysing information related to land structure (Sadovyy et. al., 2022; Jouma, 2021). But in addition to the study tool, it is necessary to have a legally established algorithm for land transformation as development of land management projects. In production, the above-mentioned projects are sometimes used to increase arable land and agricultural development. This is contrary to all recommendations, conventions and programs that emphasize the need for reduced plowing of the territory.

Methodology of research and materials

The article uses the dialectical method of scientific knowledge, which considers phenomena (land transformation) and processes in the world (agriculture) as interconnected, existing in a system of interaction and dependence on each other. The method of comparison is used, which consists of comparing phenomena, processes and indicators that characterize them in order to identify common features and differences between them. The actual indicators comparison of land management projects with regulations, standards and norms demonstrates the extent to which land users adhere to the established ecologically safe and economically expedient use of land. The monographic research method made it possible to collect, analyse and interpret information on the transformation of agricultural land, as well as draw conclusions based on this information. The results of the conducted research are demonstrated and illustrated by the graphic method in the form of diagrams and figures. Analysis includes the study of plowing, vegetation and other characteristics of land plots. Induction includes the study of the different types characteristics of agricultural land and the selection of general patterns of influence on ecological and economic indicators. Deduction is the process of deriving specific recommendations for the development of land management projects that use land transformation. In the context of land management, an analogy is a comparison of land plots from different regions or countries in order to study different methods of land management and their effectiveness. Abstraction and generalization are two key steps in land management that help reduce the complexity and size of land management documentation and make it more understandable and accessible to various stakeholders. This made it possible to comprehensively investigate the main factors affecting the transformation of agricultural land, and based on this analysis, recommendations can be developed for more effective creation of land management documentation in Ukraine. The following materials are used in the work: works of scientists, regulatory and legal documents of Ukraine, the European Union, the United Nations Organization regarding the transformation of agricultural lands. The services reg.dar.gov.ua, kadastr.live, e.land.gov.ua were used.

Discussions and results

Regarding land transformation, international programs and conventions call for: reduction of human impact on the environment (UNEP, 2022), conservation and protection of landscapes (States of the Council of Europe,2000), fight against dehydration and land depletion, conservation of natural resources (United Nations, 1996) and maintaining soil fertility (WOCAT, 1992; Global Soil Partnership, 2018). Similarly, these documents point to a reduction in the rate of plowing and soil erosion, which directly depends on rational actions regarding land transformation.

The transfer of one type of agricultural land to another can be carried out with the help of a corresponding change in land management documentation: land management projects regarding the allocation of land plots, land management projects that provide ecological and economic justification for crop rotation and land management, technical land management documentation regarding land inventory, land management work projects (reclamation, preservation). The general steps of the transformation can be as follows:
- determining the need to change the type of agricultural land: before starting the transformation process, it is necessary to determine what consequences such a change will have;
- preparation of necessary materials, such as economic and ecological indicators, cartographic materials and others;

- impact assessment on the environment, therefore it is necessary to conduct an appropriate assessment of the impact on the ecosystem and ensure the necessary measures to minimize the negative impact;
- decision of the relevant subject of land relations regarding land transformation;
- making changes to the State Land Cadastre.

There are many factors that influence design decisions on changing the type of agricultural land. Some of them may be related to the management level, while others may be external factors depending on the specific situation. Several groups of factors that can influence the transformation of land are listed below (Fig. 1).

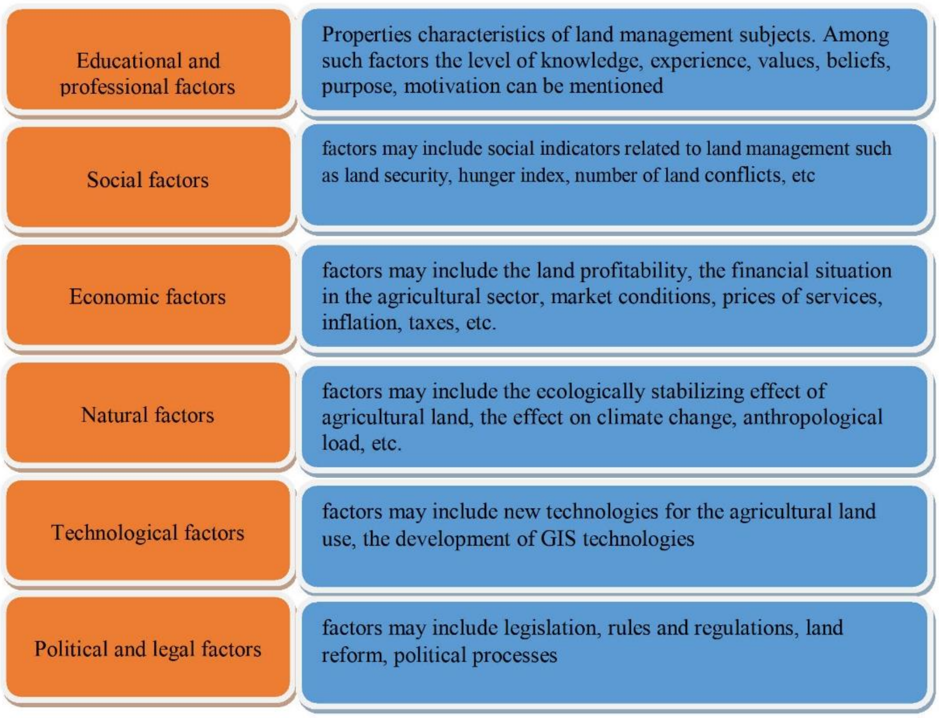


Fig. 1. Groups of factors influencing the transformation of agricultural lands (Source: author's development)

As it is seen from Fig. 1. regulatory and legal acts are among the factors influencing the transformation of lands. It should be noted that there are cases of a non-systematic approach to the development of the regulatory framework for land transformation in Ukraine. For example, amendments were made to the Land Code (Земельний кодекс України, 2001), approved resolutions of the Cabinet of Ministers of Ukraine, and developed methodological recommendations for the development of land management projects that provide ecological and economic justification for crop rotation and land management (Про затвердження Методичних…, 2013). But later, due to the trend of deregulation of economic activity, almost all efforts on this issue were abolished. A negative consequence is that land management projects regarding crop rotation began to be used to transfer ecologically stabilizing lands (hayfields, pastures) to lands that are intensively used (arable land). This leads to negative phenomena that have the environmental and economic consequences listed above.

Looking for a balance between the creation of regulated conditions for rational land use and the removal of artificial restrictions on economic activity, legislative bodies created mechanisms for the development of land management projects that have both positive and ambiguous characteristics. The ability to transform land by drawing up and registering land management documentation may include the following positive effects:
- ensuring environmental safety standards through a scientifically based change in the type of land;
- reduction of costs for farms, which is associated with the optimal structure of land;
- stimulating investments in land use with balanced land types.

However, negative consequences of unjustified land transformation may include:
- decrease in the economic opportunities of obtaining profit by land users (transformation into less productive lands);
- increase expenses for farms, which is connected with the suboptimal structure of land;

 - decrease in the market value of land plots (transformation into less productive lands).
Therefore, the transformation of land can have both positive and negative consequences, and it is important to ensure a balance between the need to comply with environmental standards and the preservation of a competitive and efficient market environment.
Land management projects are an important tool for ensuring the rational use of land resources and ensuring a balance between the needs of people and nature. However, like any tool, they have their advantages and disadvantages. Land management projects can help ensure rational use of land, in particular by structuring land according to its natural conditions and the needs of economic entities. Also, land management projects can help ensure environmental security, for example, protecting water resources from pollution.
However, one of the disadvantages of land management projects is the high cost, in particular, when large-scale changes in land use need to be carried out. If the land management project does not have the support of the community, then its implementation may become more difficult. Communities often put profitability above the stability of the ecological system and vote for the de-soldering and transformation of natural fodder lands into arable land. In the case of strict adherence to the crop rotation scheme in land management projects, a situation may arise when business entities will lose profits. In modern conditions, it is necessary to apply "dynamic crop rotations". Currently, land management projects that provide ecological and economic substantiation of crop rotation and land management make it possible to develop environmentally safe and economically feasible land use projects. But there are a number of economic and regulatory issues that require clarification.
International conventions and programs aimed at creating an optimal land structure encourage the improvement of land transformation mechanisms, the creation of a clear monitoring and reporting system that allows timely detection of deviations from land management projects.. A variety of tools and approaches can be used to improve control mechanisms.
As mentioned above, it is necessary to introduce innovative technologies and software for monitoring the use of agricultural land, which will allow collecting and analysing data on the performance of certain works and tracking their dynamics over time. One of the tools for monitoring the use of agricultural land in Ukraine is the agro technical passport of the land plot. This document contains information about soil characteristics, its resource potential, as well as recommendations for land use and application of various types of fertilizers to achieve high yields. But the characteristics of the land can change over time, which requires regular updating of the agricultural passport. The data of remote sensing of the earth and the use of modern geoinformation technologies should become part of the state control over compliance with land management projects. There is already experience of using various vegetation indices at the state level to decipher agricultural crops. For example, on the Public Cadastral Map of Ukraine, the layer "Classification of crops 2019 (Spring) and (Winter) was added)". But this layer was only informative and was not updated afterwards. In contrast to the State Agrarian Register, where, in accordance with the best European practices and experience, the latest satellite map information about the sowing of the winter and spring crops of 2022 and the possibility of entering the effective date of the land use contract have been added to the functionality (Fig. 2).

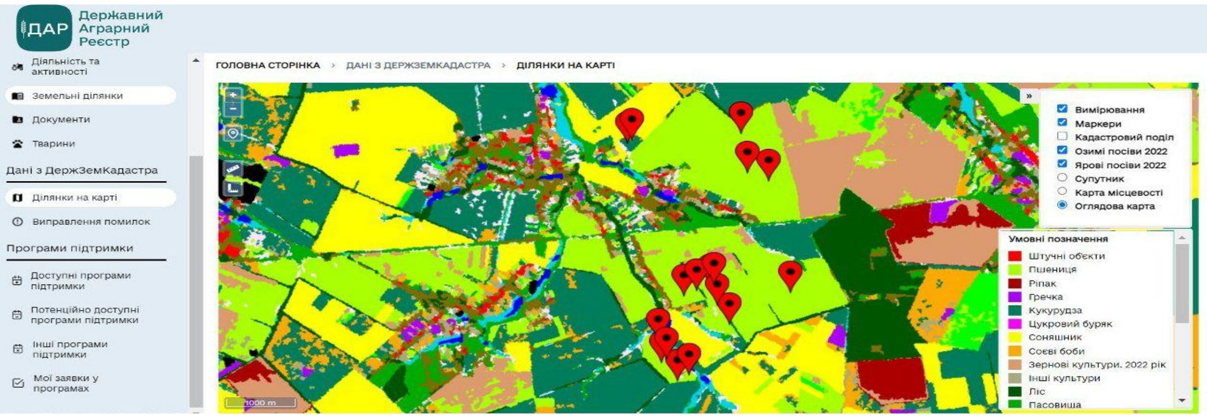
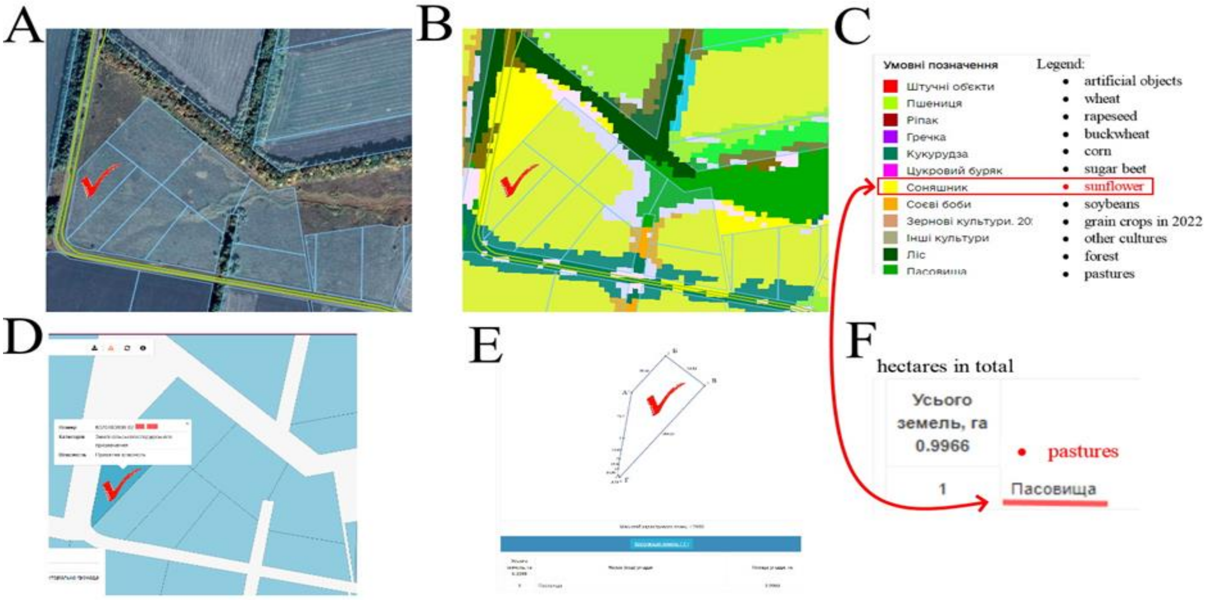


Fig. 2. An example of information from satellite maps about the sowing of winter and spring crops in 2022. (Source: State Agrarian Register data).

The possibility of using state GIS services to determine land plots that require the development or clarification of land management documentation was investigated. The investigated land plot itself is marked with a red tick (Fig. 3). According to satellite data, it was established that in 2022, sunflowers were grown on the experimental land plot (Fig. 3, C), and according to the state cadastre data, the land plot has pastures (Fig. 3, F). In order to legally grow sunflowers on this plot of land, it is necessary to transform the land on the basis of land management projects or use a plot of land according to a pre-prepared land management project (organization of the territory of land plots (shares)), i.e. for livestock grazing.



LEGEND
The investigated area is marked with a red tick.
A – layer "cadastral division" reg.dar.gov.ua,
B – layer "spring crops 2022"reg.dar.gov.ua,
C – legend for the layer "spring crops 2022",
D – layer "geometry of plots"kadastr.live,
E – section "information about the land plot" cadastral plan e.land.gov.ua,
F – enlarged fragment of the Lands Explication.

Fig. 3. Conformity of registered land plots to the regime of actual use. (Source: author's development).

It was established that the state authorities have the technology, database and legislative authority to identify land plots, the use of which does not correspond to previously prepared land management projects. It is necessary to develop a system of incentives for compliance with land use requirements according to statistical reporting, compliance with crop rotation and agro technical environmental protection measures. This can be implemented with the help of significantly increasing fines for non-compliance, or involving participation in programs (grants) that contribute to the preservation of natural resources.

Providing an independent (public) examination of compliance with land management projects will increase trust in the control system and reduce the possibility of data falsification. It is important to raise the level of land users' awareness regarding the harmfulness of unjustified land transformation.

Conclusions and proposals

The imbalance of agricultural land leads to erosion and degradation of land plots. This brings environmental and economic damage. Transformation can bring both positive and negative effects. World experience reflected in UN and EU conventions and programs emphasizes the importance of land balance. To ensure rational land use, it is necessary to: consider the main groups of land transformation factors, determine the characteristics of land transformation, increase the effectiveness of the land management project's development .

Many types of land management documentation and projects use land transformation as a tool for creating rational land use. The common features of such projects are: determination of land changes expediency, preparation of necessary materials, assessment of the impact on the environment and making changes to the registers.

The introduction of agricultural field passports is an important, but not the only, method of influencing the balance of land. Modern GIS technologies are a powerful tool for developing land management projects for land transformation. Information support for decision-making regarding transformation can be based on data from remote sensing of the earth, satellite images and calculation of vegetation indices.

It was established and verified on individual land plots that the data of the State Register of Ukraine can be used to identify land uses that do not comply with land management projects. For example, according to the state cadastre, livestock should be grazed on the investigated land plot, but in fact, an agricultural crop is grown there - sunflower In particular, according to the land management project, there should be pasture, and in fact, agricultural land should be the arable land. Correction of violations is possible through the land transformation, or through a return to compliance with the previous land management project. The fact that landowners sometimes do not comply with land management projects indicates the need to improve methodological and legal acts regarding the development of land management projects related to land transformation.

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Information about authors:
Iryna Koshkalda, doctor of economic sciences, professor, Head of the Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, Ukraine, 61002, tel: +38 050 323-55-94, e-mail: irinavit1506@gmail.com Fields of interest: land management, urban planning, landscape management.
Ivan Sadovyy, doctor of philosophy in economic, senior lecturer, Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, Ukraine, 61002, tel: +38 097 655-50-77, e-mail: sadddd007@gmail.com Fields of interest: geodesy, land management, spatial planning, geoinformation systems
Olena Dombrovska, doctor of philosophy in economic, assoc. prof., Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, 61002, tel: +38 066 194-82-77, e-mail: domolena73@gmail.com Fields of interest: land management, urban planning, land consolidation
Virginija Gurskiene, doctor of technological sciences, assoc. prof., Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, K. Donelaicio g.58, Kaunas, Lithuania, phone +370 37 752372, e-mail: virginija.gurskiene@vdu.lt . Fields of interest: land use planning, urban planning, management of protected areas
Vida Maliene, doctor of technological sciences, professor., Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, K. Donelaicio g.58, Kaunas, Lithuania, phone +370 37 752372, e-mail: vida.maliene@vdu.lt . Fields of interest: urban planning, land consolidation, property valuation.

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ESTIMATION OF THE FOREST-GROWING POTENTIAL OF LANDS BY SOIL INDICATORS

Raspopina Svitlana, Suska Anastasiia, Nazarenko Vitalii, Opashniuk Anna
State Biotechnological University

Abstract. The indirect approach is mainly used to assess the forest-growing potential of lands in the forestry of Ukraine. For these purposes, a comparative ecological (forest typological) method is used to assess soil conditions according to their forest growth effect. The species composition of the forest stand and its productivity are the main indicators of the forest growth effect. The undoubted advantages of this method are high forestry value, low labor intensity and cost, and the main disadvantages are the subjectivity of determining the types of forest conditions (especially derivatives and artificial plantations), its insufficient environmental sensitivity, and the difficulty of applying to places where there is no forest vegetation. The aim of the study was to quantify the quality of forest land and develop markers of the forest-growing potential of soils. The studies were carried out by synthesizing two methodological approaches – forest typological as the leading method for assessing the potential of habitats and direct study of soils (field and analytical). The package of markers was developed to assess forest potential of soils based on the establishment of a correlation between the productivity of forest stands (height, quality class) and soil indicators (thickness of the humus part of the profile, pH, content of clay particles, humus, total and exchange forms of N, P, K, Ca, Mg). The package of markers depends on the soil type and consists of the following soil indicators: the content of particles of physical clay (d<0.01 mm), the thickness of the humus part, as well as the content of humus, N, Ca, K, Mg. A gradual increase in their quantitative values leads to increase in the forest productivity of the soil and, as a result, the productivity of the forest stand.
Keywords: productivity of forest soils, markers, tree stand

Introduction

The phytoindication (by the species composition and productivity of native forest plantations) is the leading method for determining the forest-growing potential of lands in Ukraine, the essence of which is clearly displayed in the classification model of forests and forest plots – in edaphic grid of Alekseev – Pogrebnyak's (Table 1) (Погребняк, 1955; Остапенко, Ткач, 2005). The edaphic grid is based on two main soil properties that determine its fertility – moisture and nutrient content (trophicity). The grid is a coordinate system: the abscissa shows habitats that differ in nutrient content – trophotopes (A, B, C, D) and the ordinate shows habitats with different humidity – hygrotopes (0, 1, 2, 3, 4, 5). The intersection of a hygrotope and a trophotope results in edaphotope (edatope) – the type of forest condition (TFC) indicating overall forest area productivity (Table 1).

The value of this method, which underlies the forest cadaster of Ukraine, is beyond doubt. The absolute advantages of the method are relatively low labor intensity, cost and high forestry value. However, a number of circumstances makes it difficult to use. First of all, rapid reduction of the virgin natural forest area (according to experts, only 16-35 thousand hectares remain in Ukraine). The characteristics of these forests (composition and productivity) used as the criteria for the level of forest-growing potential of lands. At the same time, the taxation characteristics and composition of artificial forests, especially with an imperfect forest management system, often differ significantly from the characteristics of natural forests and, therefore, cannot objectively reflect the forest productivity of the habitat. In this case, we are no longer assessing the natural fertility of the soil, but its anthropogenic component. In addition, it should be noted that the forest stand capacity class is only a consequence of a certain soil fertility level and does not indicate, which soil properties determine this level. For the most part, the forest vegetation is forming on soils with a low level of fertility. The assessment of the forest soil productivity has its own specifics and differs from the assessment of agrocenosis (Ponette et. al., 2014; Hansson et. al., 2020; Legout et. al., 2020; Gao et. al., 2022). This is primarily due to the fact, that the forest is a complex multicomponent and multifunctional ecosystem with a practically closed circulation of substances, functioning for a hundred years or more. Therefore, mobile forms of nutrients are used to assess the fertility of agricultural land on which the crop is forming during one growing season, while the total forms of nutrients are often used (Gao et. al., 2022; Zhao et. al., 2023) to assess the productivity of forest soils. In addition, the productivity of forest stands depends not only on the presence of nutrients in the soil, but also largely determined by the granulometric composition of the soil.

Table 1

The edaphic grid with indicator-species and their quality class, which indicates the forest lands productivity

Humidity types (Hygrotopes)		**Fertility types (Trophotopes)**			
		Increasing fertility levels →			
		A (poor habitats) *Bir*	B (relatively poor habitats) *Subir*	C (relatively rich habitats) *Sugru*d	D (rich habitats) *Grud*
0 (very dry)	Increasing humidity level ↓	*P – IV-V* A_0	*P – III/IV* B_0	*P– III* C_0	*Q–IV-V* D_0
1 (dry)		*P – III-IV* A_1	*P – II/IV ; Q –V* B_1	*P– II/I ;Q –III-V* C_1	*Q– III-IV* D_1
2 (moderately humid)		*P – II-I/III* A_2	*P– I-*I^a *; Q, Pc – III-IV, B–I* B_2	*P –*I^a*-*I^b *;Q –I-III; F, Pc –II* C_2	*Q, Fr –I-II; F-II-I; Pc– I-*I^a D_2
3 (humid)		*P – III/IV; Q -V; Pc-IV-V* A_3	*P –I-II; B – I; F, Q, Pc – IV-III* B_3	*P–I-*I^a*; Q, F– I-II ; Pc –I -II* C_3	*Q, Fr – I-*I^a*; F– I-II, Pc–* I^a*-*I^b D_3
4 (very humid)		*P – IV* A_4	*P –II-IV; B–II; Pc – IV-V* B_4	*P–I; B, Pp–I-II; Al–II; Q, Pc –II-III* C_4	*Q–I-II; B, Pp–I; Pc–I-II* D_4
5 (marshy ground)		*P– V* A_5	*P, B – IV-V; Al -IV-III* B_5	*P–II-IV; B-III-II; Al-I-III* C_5	*Al I-*I^a *;·Pp-I* D_5

Note: *P– Pinus sylvestris, Q – Quercus robur, Pc – Picea abies, B – Betula pendula, Fr – Fráxinus excelsior, Al – Alnus glutinosa, F – Fagus sylvatica, Pp – Populus tremula*.

Determining the marker system for the level of forest soil fertility and their quantitative parameters has a particular importance in the context of the prioritized tasks of forestry such as increasing the forest cover of Ukraine to a scientifically substantiated optimal level (20%). The planned increase of the forest cover is due to expanded afforestation, i.e. large-scale afforestation of lands previously unoccupied by forest vegetation. At the same time, it is planned to increase the level of forest cover in Ukraine in the short term (until 2035) up to 18% (Державна стратегія, 2021). It is impossible to determine the forest-growing potential of these soils by the productivity of forest vegetation. Under such conditions, the soil properties is the most objective criteria for the forest growth potential of lands and their forest suitability.

The purpose of the study is to quantify the main properties of forest soils in the flat part of Ukraine and develop a set of diagnostic indicators of the forest-growing potential of soils. The study is based on two methodological approaches - forest typological (phytoindication method), as the main method for assessing the productivity of Ukrainian forest lands, and assessment based on the soil research.

Methodology of research and materials

The study of the forest-growing potential of lands based on the principles of forest typology, comparative ecology, soil science, agrochemistry, and mathematical statistics and carried out in several stages. The first stage of research included experimental plots, which were laid in middle-aged primary (mostly natural) plantations in various types of growth, of natural and climatic zones of Ukraine (Polissya, Forest-Steppe, and Steppe), where the forest stand productivity (quality class) and soil covering were determined. There were at least 30 trees on the sample plot. A total of 170 sample plots were established. On the each sample plot, the soil profiles were laid, described (the depth depended on the type of soil and varied from 0.5 m to 2 m) and the samples were taken for the chemical analysis.

Further under laboratory conditions the following soil indicators were determined according to generally accepted methods: granulometric composition (pipette method in modification of N.A. Kachinskiy); humus

content (method of Tjurin in Kononova and Belchikova's updating); content of total forms N, P, K, Ca, Mg (in concentrated sulfate extract); permanent wilting of plants (calculation method); content of exchange forms Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} (in acetic-ammonia extract); acidity level (potentiometric method).
At the final stage, a correlation analysis of the dependence between the values of soil indicators and the height of the forest stand were carried out. Thus, those soil characteristics that have the greatest influence on the height of the stand were determined. This methodological approach made it possible to determine the indicators of the forest-growing potential of soils, as well as quantitatively characterize various types of habitats (Bir, Subir, Sugrud, Grud).
The studies covered sandy lands under pine forests in the main natural and climatic zones of Ukraine, in particular, in Polissya (within the Zhytomyr and Chernihiv regions), Forest-Steppe (Kharkiv region) and Northern Steppe (Kharkiv and Luhansk regions). The types of forest conditions for these lands are A_1, A_2, B_1, B_2, C_1, C_2. Trial plots were also laid on clay lands, on which broad-leaved, mainly oak, forests had been formed (Eastern Forest-Steppe, Kharkiv region). The type of forest conditions of these lands is D_2.

Discussions and results

The development of a diagnostic indicators system for assessing the forest growth potential of sandy lands was carried out for a consolidated group of sandy soils in Ukraine, which includes:
1) Soddy-podzolized (Leptic podzols) clayey-sandy and sandy loamy soils on rocks of various genesis, mainly on ancient alluvial pseudofibre sand (Fig. 2a). The soils of this group are not subject to deflation, as they are fixed by vegetation. They predominate in the Forest-Steppe, but also can be found in Polissya and Northern Steppe.
2) Soddy-slightly podzolic (hidden podzolic) sandy, clayey-sandy, sandy loamy soils on the fluvioglacial, moraine and ancient alluvial sands (Fig. 2b). Soil names are given in accordance to the Ukrainian soil classification and the FAO classification (Полупан et.al., 2005; World Reference Base, 2006).


a	b
Leptic podzols on ancient alluvial pseudofibre sands	Soddy-slightly podzolic soil on fluvioglacial

Fig. 1. Typical forest soil profiles under pine forests in Ukraine

These types of soils were combined into groups based on the significant homogeneity of the basic properties (water-physical, nutritional, etc.), which is due to their sandy granulometric composition (Table 2, Fig. 2.). This similarity of soil properties, in turn, determined their identical forest growth effect (forest stand productivity). The sandy soils characterized by a very low level of fertility relatively to agricultural crops, but forest plantations, pine in particular, reach high productivity on such soils.

Table 2

Average values of the main indicators for sandy soils under pine forests

Clay %	Humus horizon thickness, cm	pH (H_2O)	pH (KCl)	Humus	N	P	К
				%			
7.0±0.25 (n = 489)	24±2.7 (n = 145)	5.2±0.06 (n = 495)	4.3±0.07 (n = 245)	0.51±0.06 (n = 377)	0.04±0.003 (n = 449)	0.03±0.003 (n = 449)	0.06±0.005 (n = 449)

Note: Clay – total content of particles with a diameter of <0.01 mm; Humus, N, P, K – total content (significant difference, $p < 0.05$)

The fertility of forest soils under conditions of sufficient moisture is closely correlated with their granulometric composition. A straight-line correlation (significant difference, $p < 0.05$) was established between the height of pine stands and the content of physical clay particles in the upper (up to 50 cm) soil horizon. An increase in the content of clay particles in the soil enhances its ability to accumulate moisture and nutrients, which in turn leads to an increase of the forest stands productivity.

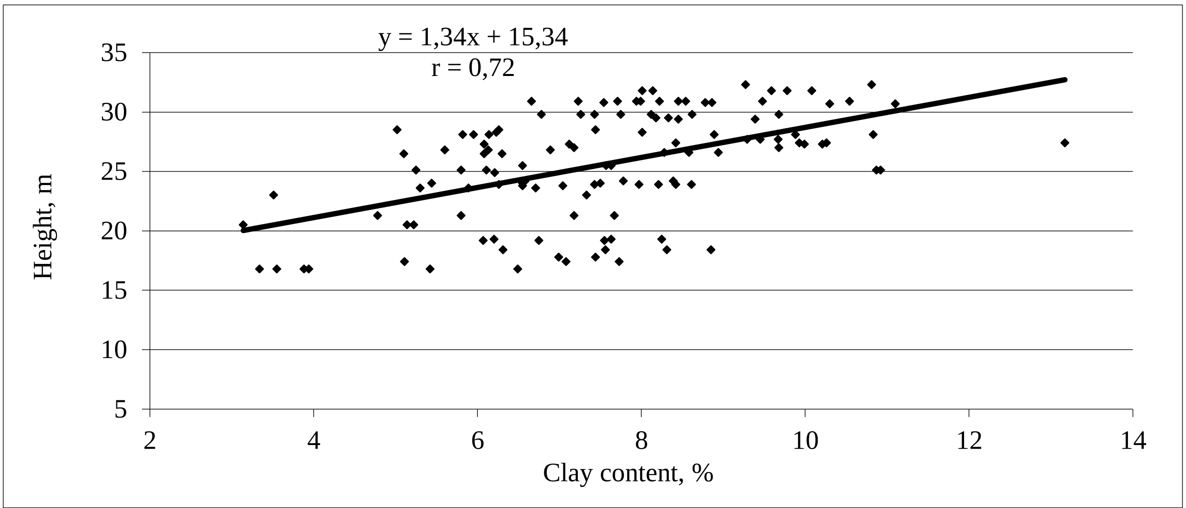

Fig. 2. Dependence of the height of pine stands on the clay particles content in the soil

The studied sandy soils of Ukraine are characterized by an acid reaction of the solution (pH_{H2O} –5.2), very low total content of nutrients (N – 0.04%, P – 0.03%, K – 0.06%), exchange bases (4 meq/ 100 g of soil) and humus (0.51%) with a gradual increase in values from Bir to Sugrud conditions (significant difference, $p < 0.05$). Among these indicators, the best indicator of the forest productivity of sandy soil is the content of total Potassium. Noted that the content of Potassium and exchange bases completely determined by the mineralogical composition of the parent rocks and the degree of the soil solid part dispersion, i.e., the granulometric composition.

In addition to the content of clay particles and total Potassium, the productivity of pine plantations is significantly ($p < 0.05$) affected by the thickness of the humus horizon. Other studied indicators had a lesser effect on productivity. Thus, content of silt particles, thickness of the humus horizon, and content of total Potassium are the markers of the forest growth potential of sandy soils and pine habitats. A gradual increase in their quantitative values leads to an increase in the forest lands productivity in the group Bir – Subir – Sugrud trophotopes (Table 3).

The forests of Ukraine formed by more than 30 types of trees dominated by pine (*Pinus silvestris* L.) – 33% and oak (*Quercus robur* L.) – 24%. In the Eastern Forest-Steppe of Ukraine, the main arrays of oak forests formed on watersheds, right side of river banks covered with significant thickness of loess. Oak forests in the vast majority are represented by D_2 conditions, which are replaced by D_1 conditions on the top of slopes and on the southern slopes, and in lowering are replaced by D_3 conditions.

Table 3

The markers of forest-growing potential of sandy soils by the types of forest-growing conditions

Soil type	**Clay %**	**Humus horizon thickness, cm**	**K_2O, %**
A			
Soddy-podzolized	4,9	11	0,03
Soddy-slightly podzolic	5,0	13	0,04
Average values	4,9	12	0,03
B			
Soddy-podzolized	6,5	18	0,04
Soddy-slightly podzolic	6,8	25	0,06
Average values	6,6	21	0,05
LSD_{05} (A_2–B_2)	0,5	3	0,01
C			
Soddy-podzolized	8,4	23	0,06
Soddy-slightly podzolic	9,8	71	0,12
Average values	9,2	39	0,09
LSD_{05} (B_2–C_2)	0,8	9	0,02

LSD_{05} – Least significant difference

The oak forests of the region are quite sparse with a developed grassy cover and formed on dark gray podzolized soils on loess (Greyic Phaeozems Albic) almost everywhere (Fig. 3).

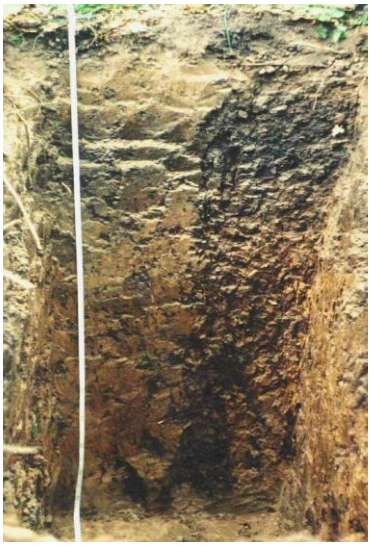

Fig. 3. Dark gray forest soil on loess

These soils characterized by an accumulative type of profile (with accumulation of humus in the upper part), which is superimposed by an illimerization process. The soils contain carbonates, which are usually concentrated in the parent rock.

According to the granulometric composition, the soils are classified as light clay soils with a high content of silt particles (diameter <0.001 mm). The average content of silt particles is 37.17±1.77% with a range of values from 13.68 to 62.83%. The content of particles with a diameter <0.01 mm averages 58.68±1.63% and ranges from 28.88% (light loam) to 90.5% (heavy clay). The ability of silty particles to absorb vaporous moisture, which becomes inaccessible to plants, is well known. In soils with a high content of clay fraction, a significant part of the moisture is in a bound state, which negatively affects the productivity of forest stands. This pattern is typical for the Eastern Forest-Steppe of Ukraine, where during the growing season there is a shortage of precipitation at high air temperatures. The productivity of oak stands is limited not only by the high (>31%) content of the clay fraction in the rhizosphere soil layer, but also by the salinization of loess rocks with Magnesium compounds (average content of Mg 1.7%).

An increase in the forest growth potential of dark gray podzolized soils, which leads to an increase in the productivity of oak stands by an average of one capacity class (from class II to class I), correlates with an increase in the thickness of the humus part of the profile (from 34 to 45 cm), of Ca^{2+} content (from 4.18 to 18.85 meq/100 g soil) and the ratio of Ca and Mg (Ca/Mg) (from 1:4 to 3:1) ($p<0.05$).

Conclusions and proposals

The content of physical clay, the thickness of the humus part of the profile, and the content of total Potassium are main diagnostic indicators in assessing the forest growth potential of sandy soils in Ukraine. Changes in parameters of the indicators determines the type of forest conditions and the productivity of pine plantations.

The granulometric and chemical composition of the parent rock are main diagnostic indicators of the forest growth potential of soils under the oak forests of the Eastern Forest-Steppe of Ukraine. Soils formed on light and medium clay loess, saturated with Calcium compounds characterized by the highest forest growth potential compared to soils formed on the heavy clay loess saturated with Magnesium.

The proposed markers characterize types of forest conditions of Alekseev – Pogrebnyak's edaphic grid providing a theoretical basis for assessing the forest growth potential of various soil types.

To increase the level of forest cover to a scientifically substantiated level (20%) on the territory of Ukraine, it is necessary to create forest plantations on an area of about 2 million hectares. To do this, it is planned to withdraw soils with a low level of fertility from agricultural circulation. It is impossible to determine the forest growth potential of these soils using the phytoindication method, i.e. according to the composition and productivity of the stand. Using the proposed package of markers, one can accurately assess both the forest suitability of lands transferred for afforestation and make a forecast of the productivity of the created forests.

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Information about authors:

Svitlana Raspopina, doctor of Agricultural Sciences, Senior Researcher, Head of the Department of Forest Plantations, Land Reclamation, Landscape architecture and Park Management, State Biotechnological University. Address: the village of Dokuchaevske - 2, Kharkiv region, Ukraine, phone: +38-068-459-64-23. e-mail: svitraspopina@gmail.comFields of interest: forest soil, indicators of productivity, afforestation, forest plantations.

Anastasiia Suska, doctor of Economic Sciences, professor, Dean of the Faculty of Forestry, Woodworking Technologies and Land Management, State Biotechnological University. Address: the village of Dokuchaevske - 2, Kharkiv region, Ukraine, phone:: +38-097-984-37-11. e-mail: n.suscka@gmail.com. Fields of interest: social and economic relations in the forestry branch, economic valuation of forest lands.
Vitalii Nazarenko, PhD in Agricultural Sciences, Associate Professor of the Department of Forestry, Land Reclamation and Horticulture, State Biotechnology University. Address: the village of Dokuchaevske - 2, Kharkiv region, Ukraine, phone: +38-099-730-10-84. e-mail: 0997301084@btu.kharkov.ua Fields of interest: soil typology, forest monitoring and certification, forest fund dynamics.
Anna Opashniuk, student of the Faculty of Forestry, Woodworking Technologies and Land Management, State Biotechnology University. Address: the village of Dokuchaevske - 2, Kharkiv region, Ukraine, phone: +38-068-314-33-29. e-mail: a.opashniuk@gmail.com. Fields of interest: forest soil, productivity of forest plantations.

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ADVANTAGES OF USING QGIS TO SOLVE SPATIAL PLANNING TASKS

Hoptsii Dmytro, Siedov Arkadii, Anopriienko Tetiana, Khainus Dmytro, Yaremko Denys
State Biotechnological University

Abstract
The article discusses the prospects and advantages of using QGIS for solving spatial planning tasks. Attention is focused on the strengths of QGIS compared to other geographic information system software and the programme's potential to eliminate the monopoly position in the market by well-known geographic information system software manufacturers. Even though QGIS is open-source software, this software product is generally not inferior to expensive geographic information system software. At the same time, the advantages of QGIS include cross-platform, rich functionality, the ability to use different geographic information databases, and the ability to connect and integrate various plug-ins into the programme. Particular attention should be paid to the ability to independently write plug-ins for solving specific highly specialised tasks in the Python programming language and their quick integration into the QGIS software environment. Examples of QGIS software for solving specific spatial planning problems are given. The possibilities of using QGIS in solving the issues of settlement planning, territory management, land management and environmental monitoring are considered. The conducted research gives grounds to recommend QGIS for wide application by developers of project documentation, as well as by executive authorities and local self-government bodies for analysing cartographic and project materials in making management decisions. This approach will help create a competitive environment among developers of urban planning and land management documentation. After all, today, many specialists cannot afford expensive commercial licenses of well-known geographic information system software developers. And any legislative requirements that oblige them to use them in practice lead to monopolisation of the market for these services by individual enterprises. At the same time, it has been proven that using the open-source geographic information system software QGIS will not lead to a deterioration in the quality of project documentation. The programme can ensure the proper quality, accuracy and interoperability of design and mapping materials created with its help and solve a wide range of tasks in spatial planning.
Key words: geographic information system software (GIS software), spatial planning, project documentation, cartographic materials, territory management

Introduction

Today, spatial planning is hard to imagine without modern geographic information systems. Geographic information systems are being improved daily and expanding their application scope. In addition to solving traditional problems of physics, geodesy, geography and geology, modern geographic information systems allow solving problems in other, seemingly unrelated areas, such as statistics, demography, medicine and ecology. The widespread use of geographic information systems in spatial planning in Ukraine is primarily driven by digital transformation and the development of cadastral systems, as well as the decentralisation reform and the empowerment of local communities to manage their territories. The Russian aggression and the full-scale war in Ukraine have stimulated the expansion of the scope of geographic information systems. For example, for military purposes, the use of geographic information systems is intended, among other things, to solve the problems of humanitarian demining, assessing the degree of soil contamination with heavy metals and chemical compounds, the degree of destruction of settlements caused by hostilities, etc.

In many cases, remote sensing data processing using geographic information systems remains almost the only way to obtain up-to-date information about specific areas. At the same time, in Ukraine, many users involved in spatial analysis, assessment and planning of territories are limited in using well-known commercial geographic information system software (GIS software). Therefore, the issue of using alternative software products arises, provided they are suitable for solving the above tasks without losing accuracy, quality and information content. In our opinion, QGIS is a promising GIS software in this regard. The advantages of using this software for solving spatial planning problems in the current conditions in Ukraine have determined the relevance of this study.

The study of the capabilities of free GIS software and their comparison with commercial software products is dedicated (Benduch, 2017; Khan, Aaqib, 2017; Khan, Mohiuddin, 2018). The use of QGIS and various plug-ins based on it for solving practical problems in various fields is discussed in the following works (Nowak et.al., 2023 ; Ajaj et al. 2023; Kpiebaya et al. 2022; Nielsen et al. 2021; Ellsäßer et al. 2020; Fang et al. 2020; Çalışkan, Anbaroğlu 2020; Blanco-Gómez et al. 2023; Zaki et al. 2023). While highly appreciating the contribution of scientists to solving this problem, it should be noted that the issue of using QGIS as a full-featured alternative to commercial GIS software has not been studied sufficiently.

Research methodology and materials

This paper aims to prove that QGIS is not inferior to commercial software in terms of functionality and accuracy of geospatial data analysis and processing. Also, to identify the strengths of QGIS and specific tasks that can be solved with the help of this software in spatial planning.

To achieve this goal, dialectical methods of cognition of processes and phenomena were applied. The empirical method was used to compare and identify similarities and differences between GIS software, their functioning, performing of specific tasks, etc. The method of analysis and synthesis was used to study the subject and object of the study. To illustrate the tasks related to the development of urban planning and land management documentation using QGIS, the graphical method was applied.

During the research, a critical analysis of scholars' positions on the advantages and disadvantages of using QGIS to solve spatial planning problems was carried out. Our own experience of using this GIS software was also taken into account. The main criteria for assessing the capabilities of the GIS software were: accuracy of calculations, information content of remote sensing data processed with the help of the GIS software, convenience of the interface and tools, speed of mastering the functionality of the GIS software for an average user, opportunities for improving and developing the software. Based on the conducted research, an unbiased assessment of the prospects of using QGIS to solve the tasks was provided, and specific examples of the GIS software application were given.

Discussions and results

Although GIS software is used in many areas today, its market remains relatively monopolised. Most large companies choose commercial software products, forming specific standards for exchange files and geospatial databases, often becoming official at the legislative level. The most famous developer of GIS software is Esri. As of 2023, the share of the company's most popular software product, ArcGIS, in the geographic information software market alone is 35.20% (according to 6sense.com). At the same time, the market value of the primary desktop version of the software in Ukraine (according to ua.softlist.com.ua) reaches $700. However, advanced software versions are required to solve specific applied tasks, which sometimes cost several times more. The cost of commercial software is prohibitive for small companies and private users, especially given that its basic versions are often insufficient to meet production needs. Due to the war in Ukraine, the property status of developers of land management and urban planning documentation, as well as territorial communities, has deteriorated significantly due to the lack of financial stability and, therefore, orders from designers, the closure of state registers in the area where active hostilities are ongoing, or the direct loss of equipment and software. At the same time, the need for geographic information software to solve spatial planning problems will only grow in the post-war period. Therefore, there is a need to find alternative non-commercial or free software. However, such GIS software should be able to solve spatial planning problems and meet the requirements of interoperability of geographic information data. In our opinion, QGIS is such software.

Since its creation in 2002 by the American geologist Gary Sherman, QGIS has developed rapidly as a promising and progressive GIS software. Today, QGIS is the main competitor of ArcGIS. A large team of volunteers and specialists worldwide, united by the idea of writing open-source software for creating, editing, visualising and publishing geospatial data, is developing and improving QGIS. The scientific community has repeatedly compared the capabilities of ArcGIS and QGIS in solving specific tasks related to geospatial information processing. For example, a study (Benduch, 2017) analysed the capabilities of ArcGIS and QGIS when working with vector and raster data. The author concluded that both programmes showed comparable results when analysing vector data, except for building buffers around objects, especially when such objects were complex polygons. According to the author, this is due to different buffering algorithms. However, it is impossible to answer the question of which programme has the best algorithm. Significant discrepancies in the results were observed when processing raster data, also due to the use of different data processing algorithms. The most notable differences were observed when building a slope map. However, assessing which results are more reliable without specialised knowledge is also impossible. As an alternative, the author suggests using the common part of the results of specific analyses to obtain the most reliable result. A study by (Khan, Aaqib, 2017) on the advantages and disadvantages of ArcGIS and open-source geospatial data processing software did not reveal any significant advantages of commercial software. With some conventionality, the authors include the data format standard, software product warranty and developed technical support as advantages of commercial software.

On the contrary, the study conducted by (Khan, Mohiuddin, 2018) on the evaluation of ArcGIS and QGIS parameters for GIS applications revealed the advantages of open-source software. In particular, the authors mentioned the advantages of QGIS, such as ease of use, better data visualisation capabilities, and multi-platform capabilities. Our experience with various GIS software (Опара В. et.al., 2020; Пілічева М. et.al., 2020; Ачасов, А. et.al., 2015) shows that perhaps the only advantage that commercial GIS systems have today compared to QGIS is access to better remote sensing data, not the software capabilities for their analysis and processing.

Summarising the results of research by scientists and relying on our own experience in the QGIS environment, we will identify the advantages of this GIS software.

1. QGIS is open-source software. Open-source software can be freely used, studied, copied and modified. This fact makes it an affordable option for small organisations and individuals who cannot afford expensive commercial software. In addition, the availability of open source code provides an opportunity to independently improve the programme and adapt it to your production tasks. Of course, the ability to make changes to the software requires specialised knowledge that ordinary users usually do not have. The disadvantage of such software is the possibility of

a large number of unstable builds, i.e. versions of the programme that may not work correctly or in test mode. However, in the case of QGIS, the official website (https://www.qgis.org/en/site/) offers both the latest release, which may interest potential software developers and experienced users, and a stable build of the software that has been comprehensively tested and is free of errors. Such software versions are labelled «long-term release» and should be chosen by the average user.
2. QGIS has a user-friendly and intuitive interface. This easy-to-understand interface makes it easier for beginners to learn and work with. Moreover, today there is a large number of training materials available in the public domain, both in the form of manuals and articles and in the form of videos. This fact provides ample opportunities for self-education and independent search for answers to questions that may arise when solving production problems.
3. QGIS has officially registered user groups. Today, there are officially registered QGIS user groups in 34 countries worldwide. The QGIS user community provides an opportunity to get help from experienced users in solving specific production problems or get advice on using the software more efficiently. The QGIS user community is being actively formed in Ukraine, but so far, it is represented at the level of a Telegram channel.
4. Availability of extensive QGIS functionality. The software has a wide range of functions that allow users to perform various geospatial data analysis and spatial planning tasks. These functions include database creation, data management, visualisation, geoprocessing and geocoding. For this purpose, the software has powerful tools for customising attribute forms, creating and configuring layer symbols, and an easy-to-use field calculator.
5. QGIS compatibility with other GIS software. QGIS supports a wide range of file and database formats, including shapefiles, GeoJSON, KML and many others. Thus, users can work with data from various sources and use them to analyse and solve production problems.
6. Extensive possibilities to customise QGIS and create your own working environment. QGIS has a modular architecture, which provides a wide range of options for customising and installing additional plug-ins to solve specific production tasks. Plug-ins are divided into core and external modules. The QGIS development team develops core plug-ins that are automatically included in each new software release. External plug-ins are located in external repositories and are maintained by their authors. The plug-ins are written in C++ and Python programming languages. Thus, provided you know the programming language, the user can write modules for their own needs. This fact makes QGIS a flexible tool that can be adapted to a wide range of spatial planning tasks.
The above advantages make it possible to use QGIS to solve scientific problems in various fields. For example, (Nowak et.al., 2023) investigated the use of QGIS to design forest belts. The authors note that the QGIS Tree Belt Designer plug-in allows for the design of forest belts and the assessment of the effect of design decisions, taking into account the choice of tree and shrub species; their height, width and crown shape; and the suitability of the habitat represented by soil type, topography and vegetation cover. A study by (Ajaj et.al., 2023) assessed the impact of cement plant emissions on land cover by modelling a Gaussian plume using QGIS. The authors used Python to write a plug-in that allowed them to build maps of the distribution of emissions from the cement plant depending on the season and wind strength, as well as to measure the area of the territory affected by pollution. In the study (Kpiebaya et.al., 2022), QGIS was used to assess groundwater potential spatially. Based on the analysis results, the study area was divided into zones depending on the volume of groundwater. Based on the analysis, test drilling of wells in the aquifers was carried out, confirming the calculations' high accuracy. The study (Nielsen et.al., 2021) proved the QGIS Water Ecosystems Tool plug-in's high efficiency for modelling aquatic ecosystems. In the study (Ellsäßer et.al., 2020) the QWaterModel plug-in was used to predict evaporation based on the ground surface temperature. The authors also proved the high representativeness and reliability of the data obtained. The study (Fang et.al., 2020) was aimed at solving tectonic geodesy problems using QGIS. The authors note that QGIS-based tectonic mapping software has the advantages of ease of use, low training costs, and a user-friendly interface. According to the authors, the software has a high potential for mapping geological features, seismicity and deformation of the earth's crust and coseismic deformation. The study (Çalışkan, Anbaroğlu, 2020) proposed the use of a plug-in for QGIS that determines the MST (Minimum Spanning Tree) on geographic data using the Kruskal algorithm. Minimum spanning tree is used in many areas, particularly when assessing the optimal cost and complexity of building engineering networks or logistics systems. The authors note that using the QGIS plug-in allows for much faster MST determination. In addition, it provides the ability to work with raster data. Thus, continuous geographical characteristics can be considered when estimating the cost of edges in addition to discrete distance measurement. The plug-in also allows for barrier (obstacle) prediction to ensure that the MST is fit for purpose, as political boundaries or other limiting socio-economic factors can be taken into account. In a study (Blanco-Gómez et.al., 2023), the Colour Pattern Regression (CPR) algorithm for QGIS was considered to identify and quantify the relationship between aerial images and raster maps. Using this plug-in in QGIS allows studying the relationship between aerial images and objects on the earth's surface, such as soil moisture content, vegetation cover, vegetation and forest conditions, soils, urban heat islands, etc.
As we can see, the scope of application of QGIS is vast. However, the capabilities of QGIS are best revealed when solving spatial planning tasks. For example, Object-based Image Analysis (OBIA) based on QGIS, which was studied in (Zaki et.al., 2023), has a high potential for solving spatial planning problems. This method is promising for a comprehensive assessment and forecast of territory use based on a progressive raster image analysis algorithm. All of the above confirms the expediency of using QGIS in spatial planning, as it makes it possible to analyse and provide substantiated conclusions on a wide range of issues and tasks. Thus, QGIS allows to successfully perform routine tasks related to urban planning and land management documentation development. One of these tasks is creating buffers around objects. Buffering is a tool widely used in territorial planning to define protection zones, sanitary

protection zones, urban planning restrictions and other areas with a particular legal regime. Buffer zones are created automatically according to the specified parameters, and QGIS allows you to build them around objects of any type and shape (Fig. 1).

Fig. 1. River vector with a constructed buffer of the 100 m coastal protection zone.

QGIS provides convenient functionality for creating map layouts for printing and visualisation at a given scale. Layouts can be saved, modified, and supplemented. This is especially convenient when attribute information changes periodically, for example, when the structure of sown areas in crop rotation changes (Fig. 2).

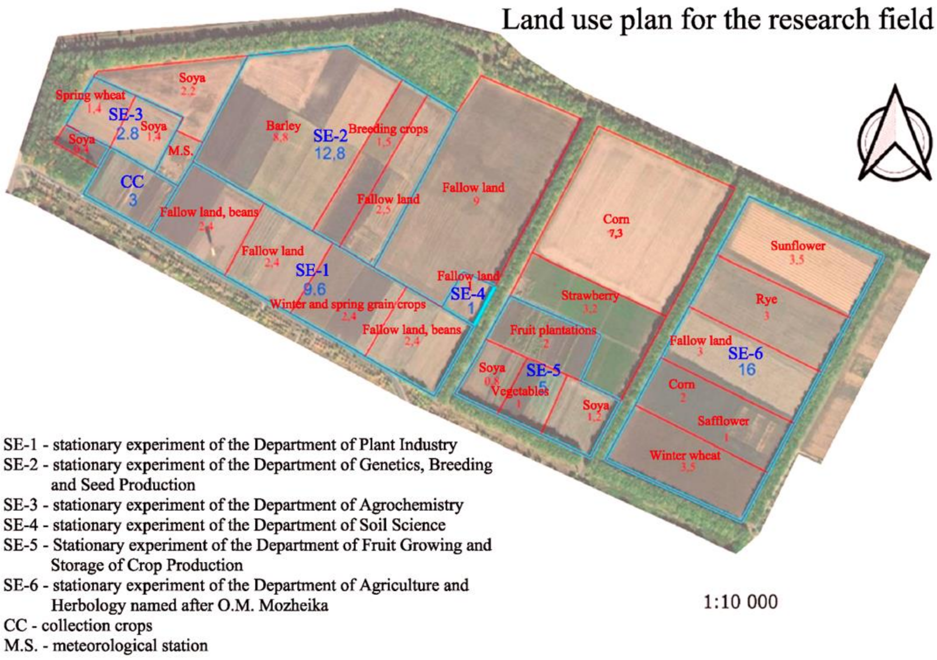

Fig. 2. Plan of the experimental field of the State Biotechnological University.

QGIS allows to work with various geospatial databases. In particular, connecting a layer of the public cadastral map enables to obtain information on the location and parameters of objects of the State Land Cadastre. At the same time, the wide range of options for setting up attribute tables and data processing algorithms using the field calculator allows you to systematise and summarise information according to the specified parameters (Fig. 3).

Fig. 3. Search and display of newly formed land plots on the public cadastral map layer (newly formed land plots are coloured red, existing land plots are coloured green)

QGIS provides the ability to connect and use dynamic WMS such as Sentinel Hub and Planet Explorer. This feature allows to track changes in the territory with a particular frequency, which has become especially relevant in connection with active hostilities in Ukraine. By connecting these services and comparing their data with the public cadastral map, the areas that have been shelled can be recorded. This allows for spatial analysis to identify areas in need of humanitarian demining, as well as agricultural areas that have been chemically contaminated by explosives, etc. (Fig. 4).

Fig. 4. Land plots that have been shelled and may contain explosive ordnance and chemical contamination (red marks craters from explosions)

Conclusions and proposals

The rapid development of geographic information systems and their widespread use in all spheres of life requires equal access to high-quality and functional software. Our research has shown that QGIS is almost as good as expensive commercial GIS systems, while it has even more significant potential in many respects. First, QGIS is an open-source GIS software that allows users to create, edit, visualise, analyse and publish geospatial data and constantly improve the software itself. But even among the open source software, QGIS occupies a particular place due to its extensive officially registered community of users worldwide, which ensures the correct operation and continuous improvement of the programme. Another essential advantage of QGIS is its modular architecture, which provides ample opportunities for solving ordinary and highly specialised tasks. The potential of QGIS for solving spatial planning tasks is undeniable, including planning and organisation of territories at different levels; identification of territories with a particular legal regime; assessment of environmental impact from individual objects or modelling the consequences of natural disasters and emergencies; calculation of parameters of the transport network and other engineering networks, etc. QGIS has great potential in overcoming the effects of hostilities, particularly in solving humanitarian demining tasks and assessing the level of land and environmental pollution. Thus, QGIS is a full-featured alternative to commercial GIS software and can be used by local governments and specialists in land management and urban planning to solve any spatial planning problems.

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Information about authors:

Dmytro Hoptsii, doctor of philosophy in economic, assoc. prof., Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, 61002, tel: +38 050 976-05-80,
e-mail: dmytro.goptsii@gmail.com Fields of interest: spatial planning, GIS, land law.
Arkadii Siedov, senior lecture, Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, 61002, tel: +38 066 464-68-15,
e-mail: shakhmet1985@gmail.com Fields of interest: GIS, remote sensing, UAV’s, GNSS.
Tetiana Anopriienko, doctor of philosophy in economic, assoc. prof., Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, 61002, tel: +38 067 957-54-00,

e-mail: atatyanav2017@gmail.com Fields of interest: all similar surveying and technology studies, economic.
Dmytro Khainus, doctor of philosophy in economic, assoc. prof., Department of Land Management and Cadastre, State Biotechnological University, Alchevskykh St., 44. Kharkiv, 61002, tel: +38 095 926-61-19,
e-mail: Dmitry.khainus@gmail.com Fields of interest: all similar surveying and technology studies.
research.
Denys Yaremko, first master's degree student, State Biotechnology University, 44 Alchevskikh str., Kharkiv, 62002. Kharkiv, 61002, tel.: +38 095 218-26-99,
e-mail: yaremko.deniska@gmail.com Fields of interest: all similar geodetic and technological studies.

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EFFECTIVE USE OF DEGRADED AND UNPRODUCTIVE AGRICULTURAL LAND: PLANNING ASPECT

Suska Anastasiia[1], Shevchenko Serhii[2], Valčiukiene Jolanta[3], Jukneliene Daiva[4], Opashniuk Anna[5]
[1,2,5]State Biotechnological University, [3,4]Vytautas Magnus University

Abstract
In Ukraine, intensive agricultural use involves a significant area of land with degraded and unproductive soils, which is economically impractical and ecologically dangerous. Part of the land was impacted by military activities. One of the tasks of sustainable development in Ukraine is to stop the process of land degradation, achieve a neutral level of land cover degradation, and promote the restoration of their productivity. This can be achieved by growing energy crops on degraded soils. Energy crops can grow on infertile soils and accumulate a significant amount of biomass, which is an important argument in favour of the development of green energy.
The purpose of this study is to determine the specifics of planning work on the phytoremediation of degraded lands when using energy plants and the subsequent production of fuel pellets and briquettes. The focus is on measures to comply with the requirements for the content of pollutants in solid biofuels, which will be made from energetic plants used in the process of phytoremediation of degraded soils. The ratio of pollutant concentrations in soil and plants to their maximum permissible concentration in biofuel is proposed to be used at phytoremediation planning.
This study substantiates recommendations for planning the phytoremediation of soils impacted by military activities using energy plants. These recommendations, in particular, concern: the choice of plant species; estimates of the duration of the phytoremediation process; application of precision farming methods in phytoremediation of lands; use of stochastic models of the phytoremediation process.
Key words: Soil, Phytoremediation, Technogenically Polluted Soils, Energy Crops.

Introduction

Plants absorb heavy metals intensively from the soil. This is one of the reasons for the legal limitation of heavy metal content in the soil of agricultural land since they enter the bodies of people and animals with plant products. At the same time, this property makes it possible to use plants for phytoremediation – soil purification from pollutants. A significant reduction in the concentration of pollutants can already be observed after a few years.
The intensive development of phytoremediation research began in the 1970s, to a large extent, due to the growing attention of society to ecology and large-scale studies of land pollution by industrial emissions and emissions of power plants and transport. Plantations of such energy crops as Salix (Capuana, 2020) and poplar (Stolarski et.al., 2020) have gained considerable popularity
An overview of the current situation with land pollution in the European Union (EU) is given in (Panagos et.al., 2013). According to the Thematic Strategy for EU Soil Protection, the European Commission has identified soil contamination as a priority task for soil data collection on a European scale. This review presents the results of an analysis of the contaminated soil data provided by the participating countries. It was determined that household and industrial waste enters the soil the most (38%), and the main pollutants are mineral oil and heavy metals (60% of soil pollution).
In the work (Vasarevičius et.al., 2013), a comparison of the requirements of the regulatory documents of European countries regarding environmental protection was carried out and a model for the assessment of polluted places in Lithuania was proposed. This model consists of two main stages – preliminary and detailed research. In the first stage, preliminary information about the contaminated site is collected and the need for detailed analysis is determined. In the second stage, a comprehensive assessment of the risks caused by contamination with organic chemical materials (in particular, oil products) and heavy metals is carried out. The equation for determining the level of pollution, which considers the specified factors and soil structure, has been substantiated.
A report (Buivydaite, 2005) contains soil survey results and available data on soils in Lithuania. Particularly, soil maps based on geoinformation systems, sampling locations and topsoil texture, soil classification, and soil degradation information (e.g., areas contaminated with heavy metals such as Cr, Cd, Pb, Ni, Cu, Zn) are provided. The directions of work on improving the condition of the soil have been determined.
Phytoremediation of contaminated soil in the cases of two sites in the Klaipeda region of Lithuania is discussed in a report (Liuiinas et.al., 2003). The list of plants most resistant to soil contamination with fuel oil is given. Notably, such plants have long taproots.

In the work (Sytar et.al., 2022), the influence of heavy metals (Pb, Ni, Cr, Cu) on soil and crop pollution in Ukraine because of military operations are investigated. The monitoring data of the main plant-growing areas of Ukraine are analyzed, heavy metal pollution is described, and the possible impact of pollution on productivity is characterized.
The study (Vasarevièius et.al., 2004) examines the specifics of pollution caused by military activities, such as abnormal pollution with heavy metals and petroleum products and remnants of explosive devices. This study provides data on the allocation of heavy metals characteristic of ammunition (Zn, Cu, Pb) in soil layers up to 1 meter deep and trends in such allocation.
A bibliometric analysis of 3,500 publications on the issue of chemical soil pollution due to military operations is presented in the work (Stadler et.al., 2022). The consequences of such pollution are considered. They are pollution of water resources and pollution entering the food chain. The main research topic is heavy metal pollution, related risk management, and soil remediation.
A critical review of publications from 2010 to 2020 on soil contamination in war-affected areas is given (Broomandi et.al., 2020). In particular, an overview of physicochemical disturbances of soils because of military operations, characteristics of contaminated military facilities, and achievements in the assessment of relevant risks to human health are presented. The list of chemical elements that are investigated for pollution includes Ag, As, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, V, and Zn.
The work (Shkvirko et.al., 2019) considers the peculiarities of the biological reclamation of disturbed land and identified promising types of energy crops for its implementation, particularly, Miscanthus, Populus, and Salix. Energy crops (herbaceous, bushy, and woody) that can be used as phytorecultivators are characterized according to growing conditions, and appropriate recommendations are given.
A review (Hauptvogl et.al., 2020) analyzes the prospects and challenges of using fast-growing energy plants for soil phytoremediation. It shows that the advantages of phytoremediation are low costs and low impact on the environment. This study focuses on elucidating the phytoremediation potential of the energy tree crops of Salix and Populus, as well as the energy grasses of Miscanthus and Arundo. Energetic plants can provide high yields of biomass in a short time. They are resistant to abiotic stress and can accumulate toxic substances, thus contributing to soil recovery. Attention is also drawn to the disadvantages of phytoremediation: the process is slower than physicochemical methods and can change the conditions for plant existence(regarding water, nutrients, and oxygen), as well as affect other factors (e. g., the structure of the soil profile, pH, and concentration of salts).
The study (Manzoni et.al., 2011) developed a stochastic model of land phytoremediation. The model deals with the leaching of pollutants by precipitation and the absorption of pollutants by vegetation under conditions of precipitationvariability. Analytical expressions for probabilistic estimation of the duration of phytoremediation were obtained according to statistical parameters of precipitation and characteristics of the soil and vegetation. The proposed model can be used in the optimization of phytoremediation projects according to various criteria (for example, minimizing the duration of remediation).
The work (Khodaverdiloo et.al., 2008) develops a mathematical model of the process of phytoextraction of cadmium and lead from contaminated soils. The basis of the model is an integrodifferential equation, which makes it possible to estimate the length of time required to achieve a given level of soil recovery. Among the given experimental data, it is advisable to pay special attention to the non-linear dependence of the transfer coefficient of lead and cadmium into plants according to their concentration in the soil.
The review (Solomou et.al., 2022) draws attention to the varieties of phytoremediation and its advantages and disadvantages. It is noted that phytoremediation is used to remove from the soil such metals as Ag, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, and Zn, as well as metalloids such as As, Se, and radionuclides. The reactions of higher plants to stress caused by heavy metals are considered. Factors affecting the success of phytoremediation were analyzed. Examples of plant species that are hyperaccumulators of the specified substances and the corresponding indicators of bioaccumulation are given. Socio-economic evaluation of phytoremediation is also carried out in this work.
The purpose of this study is to determine the specifics of planning work on the phytoremediation of lands, impacted by military activities, when using energy plants and the subsequent production of fuel pellets and briquettes.
Tasks of the research:
- to justify indicators of biofuel and soil pollution for use in phytoremediation planning, taking into account the requirements of regulatory documents;
- to determine the features of planning work on phytoremediation of lands impacted by military activities;
- to formulate recommendations regarding genuses of plants used in phytoremediation of degraded lands.

Methodology of research and materials

The methodology of this study is a systematic approach to determining the features of phytoremediation of Ukrainian soils, considering the experience of the EU and other countries. The study uses a comparative-analytical method. The focus is on measures to comply with the requirements for the content of pollutants in solid biofuels, which will be made from energetic plants used in the process of phytoremediation of degraded soils. At the same time, literature data on the content of pollutants in various environments are used. When analyzing data, a transition is made to dimensionless indicators, which are the ratio of pollutant concentrations in a certain environment with the basis for comparison – the maximum permissible concentration of the corresponding pollutant in solid biofuel. The use of dimensionless indicators makes it possible to obtain results in a form convenient for making managerial decisions.

Materials and numerical data were used in this study:

- permissible contents of pollutants in solid biofuel according to the standard EN 14961-1:2010;
- typical limits and average values of the content of pollutants in solid biofuel according to the standard EN 14961-1:2010;
- datas on abundance of elements in the earth's crust (CRC Handbook …, 2016–2017);
- permissible contents of pollutants in the soil according to the Decree by the Cabinet of Ministers of Ukraine dated December 15, 2021 No. 1325 "On approval of norms for maximum permissible concentrations of hazardous substances in soils, as well as a list of such substances";
- types of response to soil pollution depending on the content of pollutants (Assessment of Soil Contamination and Remediation Needs, 2007).

Phytoremediation is especially intensive when using energetic plants, which are characterized by rapid growth. At the same time, energy plants can intensively accumulate heavy metals. Thus, energy plants allow solving the initial task of making contaminated land suitable for agricultural use. However, the question arises regarding the further movement of pollutants accumulated in energy plants.

Among the chemical elements whose content in solid biofuel is regulated by EN 14961-1:2010, there are some very hazardous (Cd, As), medium-hazard (Hg, Pb), and low-hazard (Cu, Zn) elements. From an ecological perspective, the best option is to remove pollutants from the plants which they have accumulated during the phytoremediation process (or at least from those parts of the plants where the concentration of pollutants is the highest). This would make it possible to use pollutants as secondary raw materials and "break" the uncontrolled circulation of pollutants, preventing them from re-entering the soil with gaseous combustion products.

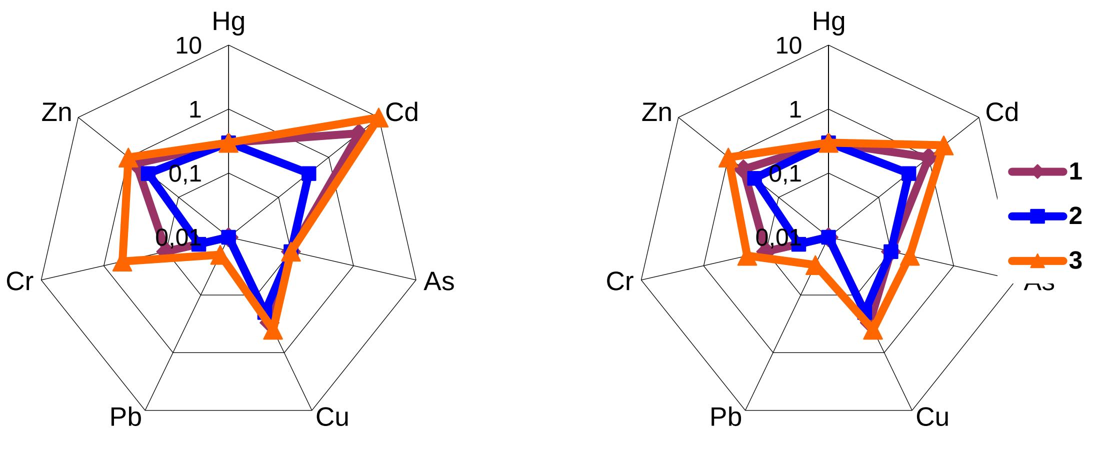
However, attention should be paid to the fact that when heavy metals enter plants from the soil, they form safer compounds, and when burned, they form oxides that are more stable and less harmful (Kyrienko et.al., 2020). Moreover, when solid biofuel is burned, at least part of the pollutants will remain in the ash, which is sent for disposal.

In this study, we will determine the organizational measures that should be implemented when planning phytoremediation to limit the content of heavy metals in fuel pellets and briquettes according toEN 14961-1:2010.

To do this, we will analyze several indicators that characterize the content of pollutants in solid biofuel from energy plants and the soil. At the same time, we will consider pollutants whose content in fuel pellets and briquettes is regulated by EN 14961-1:2010 – As and heavy metals (Hg, Cr, Zn, Cu, and Pb).It is convenient for the analysis to use relative indicators – namely, the ratio of the permissible content of pollutants in a certain environment to their permissible content according to the standard EN 14961-1:2010. It is worth noting that the maximum content of heavy metals is the same for solid biofuel both in the form of granules and in the form of briquettes. The maximum content of heavy metals does not differ for fuels of different classes (A1, A2, and B).

Discussions and results

First, consider the ratio of the average and typical content of pollutants in fuel pellets and briquettes from Salix and Populus (plantation of a short growth period) to their permissible content according to EN 14961-1:2010. The results of calculations of this indicator are presented in Fig. 1. As can be seen from Fig. 1, the typical content of several elements approaches the acceptable level. Therefore, in the process of phytoremediation of soils intensively polluted with the specified elements, it is only possible to increase their content several times (compared to the typical one) to meet the requirements of EN 14961-1:2010.



a) b)

Fig. 1. The ratio of the average (1) and typical content diapason (2. 3) of pollutants in fuel pellets and briquettes from Salix (a) and Populus (b) to their permissible content

When choosing plants, you should also pay attention, to the content of cadmium in energy Salix can exceed the norm more significantly than it is inherent in energy Populus. One of the reasons for such an excess, as stated in the standard EN 14961-1:2010, is soil contamination of wood raw materials. This can be possible if the content of pollutants in the soil is many times higher than their content in plants.

For a more detailed study of this factor, compare the content of pollutants in soil and biofuel.

Second, consider the ratio of the content of pollutants in the soil and biofuel. Fig. 2 shows the results of calculating the ratio of the average content of hazardous elements in the earth's crust to their permissible content according to EN 14961-1:2010. As can be seen from Fig. 2, the most significant excess is characteristic of chromium. However, consider that the distribution of these elements, even due to exclusively natural factors, is uneven. Therefore, we will further analyze a similar ratio for soils (in particular, for agricultural purposes and those that require phytoremediation). Note that the requirements of national legislation regarding permissible soil contamination may differ significantly.

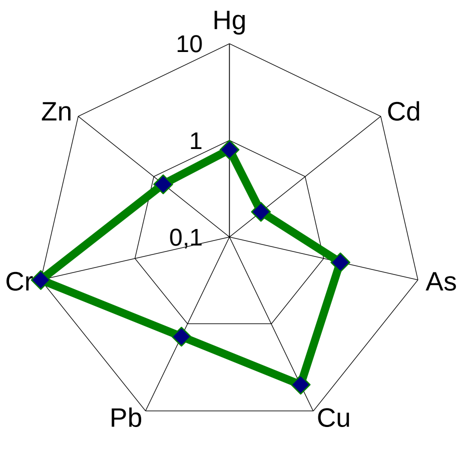


Fig. 2. The ratio of the average content of hazardous elements in the earth's crust to their permissible content in solid biofuel

In Ukraine, there is the Decree by the Cabinet of Ministers of Ukraine dated December 15, 2021 No. 1325 "On approval of norms for maximum permissible concentrations of hazardous substances in soils, as well as a list of such substances". This regulatory document specifies the requirements for the gross content of hazardous substances in soils and/or their mobile form. The results of calculations of the ratio of the maximum permissible concentrations of dangerous substances in the soil by the regulatory document of Ukraine to their permissible content in solid biofuel are shown in Fig. 3.

As can be seen from Fig. 3, this ratio is the largest for mercury. However, we note that the mercury content in biofuel from energy Salix and Populus does not significantly approach the permissible value established in the standards EN 14961-1:2010.

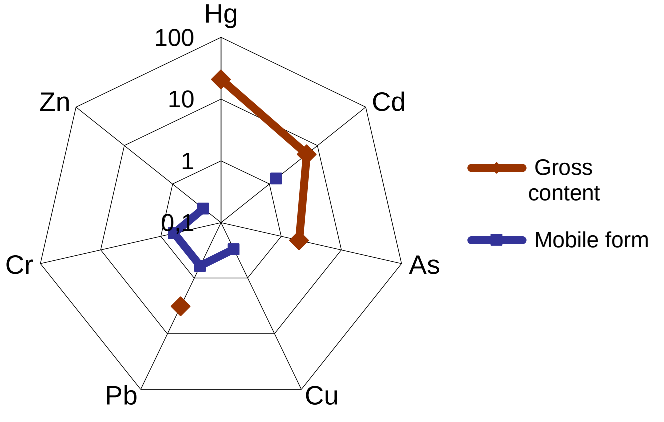


Fig. 3. The ratio of the maximum permissible concentrations of dangerous substances in the soil (1- the gross content, 2 - the mobile form) by the regulatory document of Ukraine to their permissible content in solid biofuel

Gradation of regulatory documentsaccording to the type of land use (different for urban, industrial, and agricultural soils) is a promising trend in improving the legal requirements for the content of hazardous substances in soil.Examples are the regulatory documents of Germany, Great Britain, and Finland.

In the Finnish regulatory document (Assessment of Soil Contamination and Remediation Needs, 2007), the regulatory pollution indicators have three levels: precautionary levels, maximum permissible concentration (trigger concentration), and intervention values. If the intervention values are exceeded, it is necessary to clean up contaminated soils or change the type of land use. There is a need to apply such gradation of pollution in Ukraine, as well, and to harmonize measurement methods to ensure comparability of results. Fig. 4 shows the results of calculating the ratio of the norms of the content of hazardous substances, defined in the Finnish regulatory document, to their permissible content in biofuel.

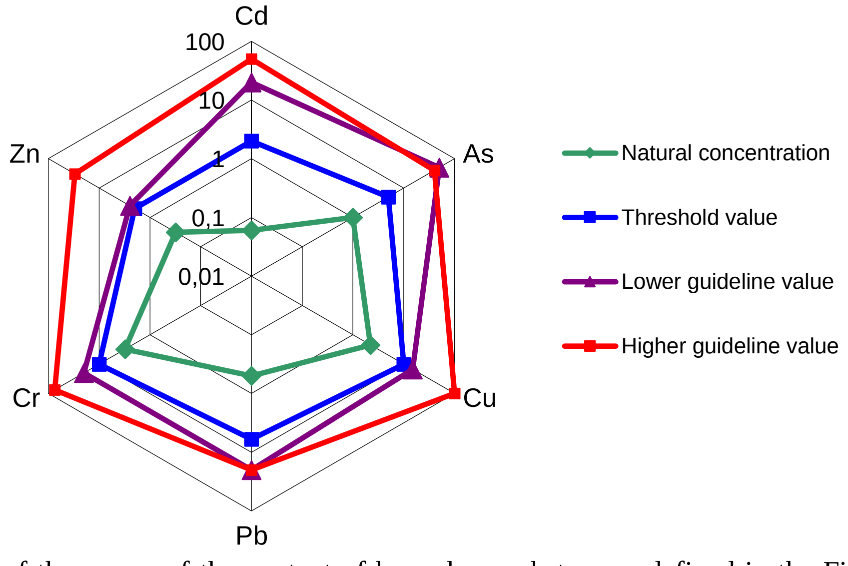


Fig. 4. The ratio of the norms of the content of hazardous substances, defined in the Finnish regulatory document, to their permissible content in solid biofuel

As can be seen from Fig. 4, the content of hazardous substances in the soil, which requires remediation, may exceed their permissible content in solid biofuel several tens of times. This confirms the possibility of a significant influence of hazardous elements, which get from the soil onto the surface of plants, on their content in solid biofuel. Therefore, when planning phytoremediation of land, it is advisable to prevent contact of cut plants with the soil.

The calculation results shown in Fig. 4, can also be used to estimate the duration of phytoremediation (also considering the thickness of the contaminated soil layer and the yield of plants (in terms of dry matter)).The indicated results can also be used in a first approximation to estimate the content of hazardous substances in solid biofuel, considering the values of transfer coefficients given in the study and the influence of soil pH on such transfer.

If at the stage of planning works on phytoremediation of contaminated land, a significant probability of exceeding the content of hazardous substances in energy plants is determined, it is advisable to foresee the possibility of reducing their concentrations by adding raw materials from land that is less polluted by these elements. Therefore, it is important to determine the content of harmful elements in the soil for the modeling and planning of phytoremediation works. In this regard, we would like to draw attention to the fact that a little-researched aspect of phytoremediation is the restoration of lands damaged due to modern hostilities.
Modern warfare pollutes the soil more heavily because the remains of ammunition and military equipment contain many times more electrical and radio engineering products, printed circuit boards, electronic components, power supplies, and various protective coatings (in the manufacture of which heavy metals are used) than it was several decades ago. At the same time, the soil is mechanically damaged, exposed to high temperatures, and contaminated with fuel and lubricants. Moreover, the increase in the destructive power of ammunition leads to the dispersion of harmful substances, which composition and concentration are difficult to predict. In contrast to soil pollution by industrial emissions, which are distributed over the land area relatively evenly, soil pollution because of hostilities is considerably uneven.
Therefore, it may be appropriate to use technologies that can be adapted to the characteristics of certain land plots, as is done in precision agriculture. This will determine the need to clarify the data on the concentrations of harmful substances in the soil when planning phytoremediation works compared to the measurements made in previous years. As for mathematical models of phytoremediation, the models like the one presented in the study are promising. The combination of several such models will make it possible to consider the probabilistic distribution of pollutant concentrations.
When planning phytoremediation, it is advisable to provide periodic measurements of the content of heavy metals to prevent their content from being exceeded in solid biofuel production. It is advisable to predict the planting in such a way as to create prerequisites for the subsequent identification of the model parameters, which relate to the growth of plant mass and the absorption of hazardous elements by plants. The use of Salix and Populus plantations with a short growth period makes it possible to quickly (in a few years) adjust the phytoremediation work plan. It is particularly possible to change the density of planting given the expected duration of the cycle or to use different types of energy plants.

Conclusions and proposals.

1. The specificity of the pollution of the lands affected by military activities is due to the high content of pollutants in modern weapons and the uneven distribution of pollution on the territory.
2. The ratio of the concentration of pollutants in the soil and energy plants to their permissible concentration in biofuel is convenient for evaluating the duration of phytoremediation and the impact of plant soil pollution on the content of harmful elements in the biofuel produced from them.
3. When developing a soil phytoremediation plan, it is advisable to use stochastic phytoremediation models and experiment planning methods to refine model parameters. Particular attention should be paid to the content of cadmium, which is used in electronics, electrical devices, galvanic elements, protective coatings and can enter the soil due to the destruction of military equipment.
4. For phytoremediation of soils affected by military activities, it is recommended to use precision farming methods and plants with a short growing period, such as Populus and Salix.

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Information about author

Anastasiia Suska, Dr.Hab. in Economics, Professor, Dean of the Faculty of Forestry, Woodworking Technologies and Land Management, State Biotechnological University. Address: 44 Alchevskikh str., Kharkiv, 61002, Ukraine; phone: +380979843711; e-mail: n.suska@btu.kharkiv.ua. Fields of interest: forestry, forest sector of the economy, ecological-economic system.

Serhii Shevchenko, Dr.Hab. in Technics, Associate Professor, Associate Professor of the Departments of Woodworking Technologies and Systems Engineering of Forest Complex, State Biotechnological University. Address: 44 Alchevskikh str., Kharkiv, 61002, Ukraine; phone: +380572622125; e-mail: serg.shevchen@btu.kharkiv.ua. Fields of interest: forestry, woodworking.

Jolanta Valciukiene, doctor of technological sciences, Associate professor, head of the Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, K. Donelaicio g.58, Kaunas, Lithuania, phone +370 37 752372, e-mail: jolanta.valciukiene@vdu.lt. Fields of interest: spatial planning, abandoned land, sustainable land use of rural areas.

Daiva Jukneliene, doctor of technological sciences, lecturer of the Department of Land Use Planning and Geomatics, Faculty of Engineering, Vytautas Magnus University, K. Donelaicio g.58, Kaunas, Lithuania, phone +370 37 752372, e-mail: daiva.jukneliene@vdu.lt. Fields of interest: spatial planning, abandoned land, land law, and administration.

Anna Opashniuk, student, Faculty of Forestry, Woodworking Technologies and Land Management, State Biotechnological University. Address: 44 Alchevskikh str., Kharkiv, 61002, Ukraine; phone: +380572622125; e-mail: a.opashniuk@btu.kharkiv.ua. Fields of interest: forestry.

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FARM HOLDINGS OPTIMIZATION

Aleknavičius Audrius
Vytautas Magnus University

Abstract. The paper's main objective is to analyse the distribution of large farm plots and opportunities for their optimization. In the context of intensive changes in the management and use of agricultural land, it is particularly important to optimise the land holdings of large farms. Most large farms are characterised by a fragmented, uncompacted spatial distribution. 15 large farms were selected for analysis in Jonava municipality. There are 22 separate fields on average per holding, 2/3 of the farm centres (farmsteads) are located in large settlements, and 1/3 of the farm centres are located in one-farm settlements and in small villages. It was found that the average area of individually cultivated fields is 14.9 ha, and the average distance from the farmstead to the fields is 4.35 km. Land holdings are very fragmented – fragmentation coefficient K2 value range from 2.64 to 8.81 (average 3.62) for selected farms. It is proposed to draw up municipality land use planning schemes, which would project the prospective boundaries of land holdings, and to legalize by law the right of pre-emption for the farm owner to acquire the ownership of the plots of land to be sold within these boundaries in order to increase the compactness of farm land holdings. A state can facilitate sporadic land consolidation by farmers through the preparation of the proposed municipality land use planning schemes.
Keywords: land holding, land plots fragmentation, land use planning schemes, sporadic land consolidation.

Introduction

Land reform in Lithuania started in 1989 and one of its results is the creation of around 140 000 natural and legal farms. 1465.8 thousand plots of private agricultural land were registered in the Cadastre and Register of Real Property, with a total area of 3501 thousand ha (average plot size 2.39 ha) until 2022. Most of this area is used by agricultural subjects receiving direct payments from the State. These include farms of private persons meeting the definition of a farmer in the Law on the Farmer's Farm (Lietuvos..., 2002b) and farms of legal persons engaged in agricultural activities and other farms declaring agricultural land. There is a great distribution in terms of distribution of the number of farms and their declared area (fig. 1).

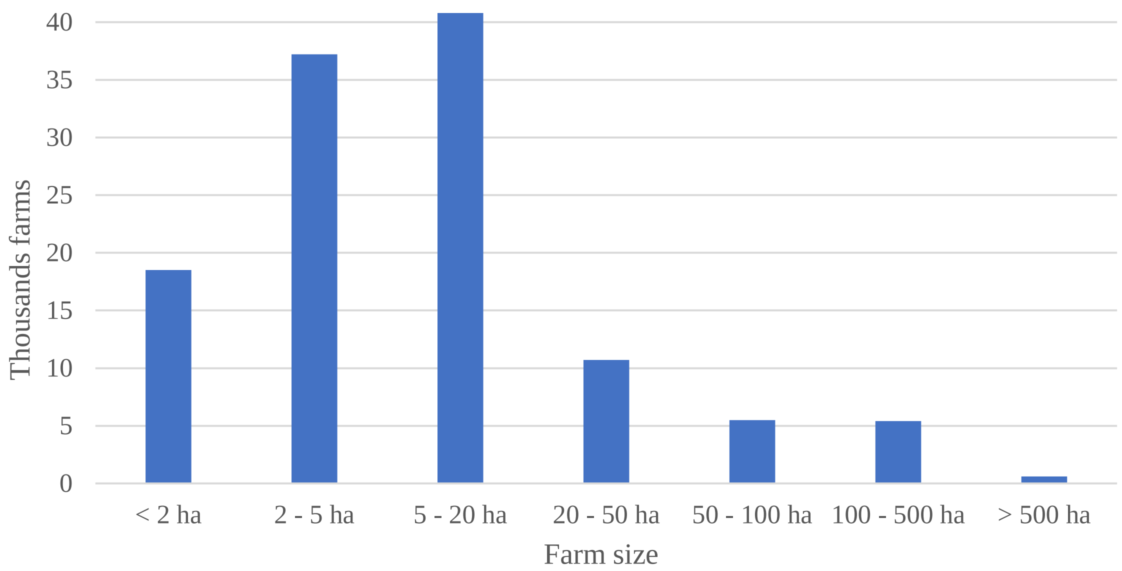

Fig. 1. Distribution of a number of farms according to their size. Source: (Informacija..., 2022).

118.7 thousand farms declared 2900 thous. ha, with an average farm area of 27.4 ha in 2022. Only a small part of farms is larger than 50 ha, however the small number of such farms doesn't mean that they cultivate less area of land, its opposite (fig. 2).

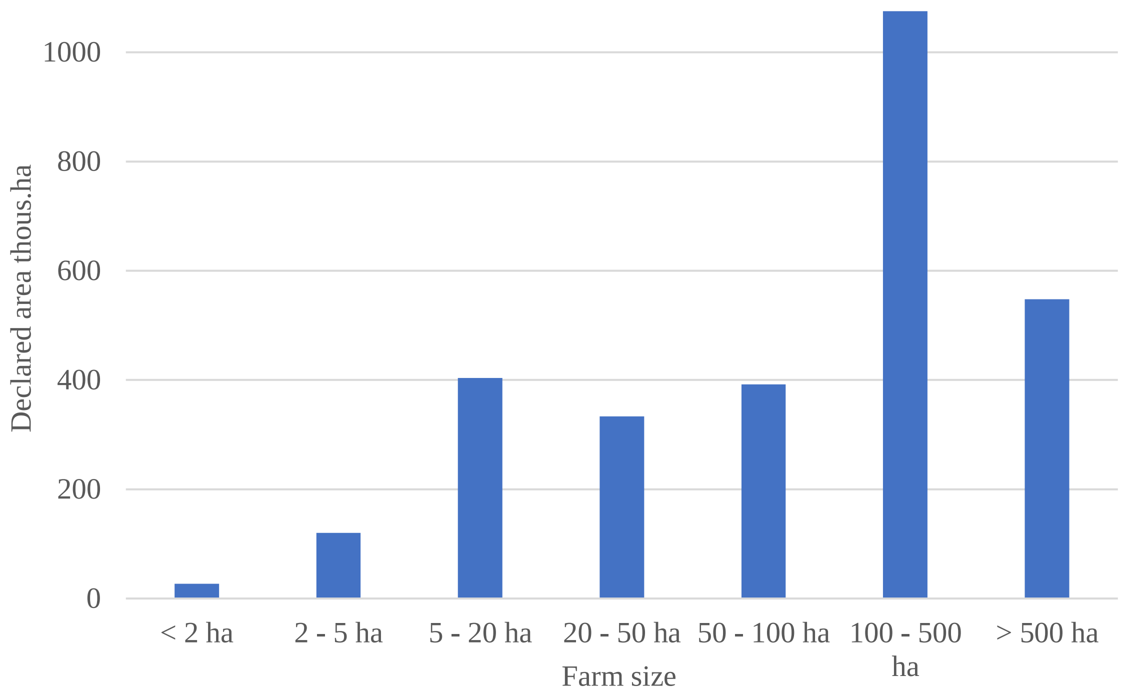

Fig. 2. Distribution of declared area of farms according to their size. Source: (Informacija..., 2022).

In order to identify the possibilities to regulate the process of farm development and to gradually build up rational farm land holdings, this paper analyses the land holdings of large farms that are within the recommended rational farm size.

According to the first version of the Temporary Law on Acquisition of Agricultural Land of the Republic of Lithuania (Lietuvos..., 2003a), the concept of a rational farm holding or tenure was considered to be an area of land owned by a single farmer in private ownership, the size of which, and the location of individual parts of the territory with respect to the roads and the centre of the farm, creates favourable conditions for the development of efficient farming activities, applying advanced production technologies and complying with the requirements of the environment. In other legislation (Lietuvos…, 2002c), the definition of a farmland holding included the agricultural land used and declared by the farm. Thus, a farm's land holding includes both the land owned by the farm or its manager and land owned by the State and other landowners and used by the farm on the basis of the lease.

The researchers at the Lithuanian Institute of Agrarian Economics (LAEI) found that "the rational size of a farm, calculated on the basis of the need for investment in the technical equipment and modernisation of farms, the need for labour and the need for funds for the members of the farm, is:

- 200 ha for crop production (cereals, oilseed rape) with only family members and 470 ha with farm members and employees, maximising the use of state-of-the-art machinery and advanced crop production technologies;
- dairy farming - 20 dairy cows with only family members (40 and 52 ha, according to land productivity) and 50 dairy cows with hired labour (103 and 132 ha, according to land productivity);
- mixed farming (predominantly herbivores) - 90 and 120 ha, according to land productivity (Kriščiukaitienė et al., 2007a, 2007b).

According to a survey of the economic activity of the respondent farms, in 2009 the most technically efficient farms are large farms with more than 100 ha (Vinciūnienė et al., 2009). When looking at farm size modelling using the return of scale analysis method, LAEI researchers (Baležentis et al., 2013) also state that "the optimal farm size for crop production is around 280 ha, for mixed farming - 200 ha and for livestock production - 125 ha".

In 2001, an analysis of the land holdings of 224 farms larger than 40 ha, carried out at the Lithuanian University of Agriculture, showed that the land holdings of large farms (with an average of 94 ha of agricultural land) are not compact: it was found that some of the farms' land parcels are not located in a single massive and that the average distance to the fields of the farmer's own land is 3.2 km, and the distance to the fields of the entire land area of the farms is 4.38 km (Aleknavičius et al., 2002). This shows that even farms of a reasonable economic size do not always meet the requirements of a rational distribution of land holdings. Therefore, it has been suggested that the compactness of farm land holdings should be increased through the preparation and implementation of land-use planning documents.

The state legal regulation instruments that influence the process of formation of farm land holdings are such spatial planning documents, the decisions of which promote economically sound land use and correspond to the directions of rational use of land as specified in the legal acts. The general plan of the territory of the Republic of Lithuania (Lietuvos..., 2002a) provides for the following directions for the use of the country's land fund: 1) to ensure long-term land use priorities and rational land use; 2) to essentially maintain the traditional land and forestry and to territorially differentiate it. In order to implement these provisions, master plans are drawn up for the country's administrative territories, and, on the basis of these plans, special and detailed plans are drawn up. The land-use planning documents drawn up within the general planning system, such as land-use planning schemes and rural development land-use projects, are classified as specific plans. The content of the preparation of land-use schemes is specified in Article 38 of the Law on Land of the Republic of Lithuania (Lietuvos..., 2004a). One of the important issues addressed in land-use planning schemes is the prospective boundaries of farm land holdings. These boundaries would only be defined for farms with a business perspective, together with the possibility of improving the use of agricultural land through the restructuring of land ownership and use. Land use schemes should only be made for large or medium-sized farms' land holdings. Current trends showed that there is a rapid decline in the number of small farms

Nowadays the land owned by farmers is very fragmented. Researchers who have studied similar problems point out that the fragmentation of agricultural land in Central Europe is very high, which hinders the emergence of private commercial farms (Dijk, 2003). In addition, the fragmentation of land parcels prevents the creation of larger land parcels (Demetriou et al., 2012; Maasikamäe et al., 2015). Since changes in the shape and area of land parcels determine the cost of production, and the number of parcels and their fragmentation affect the cost of transporting the produce, it has been proposed to optimize these parameters (Alvarez et al., 2007).

One of the most commonly used instruments to increase the rationality of land holdings and reduce the fragmentation of parcels is land consolidation. However, these projects are relatively expensive, publicly funded, and time-consuming. Land use schemes could reduce the need for public funding for land consolidation by facilitating sporadic land consolidation, i.e. where landowners use their own resources to expand the area of their holdings and to reduce the fragmentation of existing parcels.

The main aim of the research is to investigate the fragmentation of large farms' land holdings and to identify opportunities for their optimization.

Methodology of research and materials

To achieve the aim of the research methods of cartographic material analysis, analysis of laws, and other legal acts, mathematical statistical methods were applied.

The research was carried out using legal acts and scientific articles on agricultural land use and spatial planning issues. The general plan of the territory of the Republic of Lithuania, the state accounting data of the Land Fund of the Republic of Lithuania, the data of the Department of Statistics, the Land Information System material on the territory of the farms under consideration, the statistical data published by the State Enterprise Centre of Registers, the National Land Service under the Ministry of Agriculture (hereinafter - NLS) and the National Paying Agency, the statistics of the Centre of Agricultural Information and Rural Business and the cartographic data of the Application Acceptance System, and the results of the specialists' survey have been analysed as well.

Farm land holdings selected for the study are located in Jonava municipality. In terms of indicators affecting the size of farm land holdings, Jonava municipality is close to the national average: the average land productivity score, the share of private land, and the area of declared land per farm differ from the national average by no more than 6 %. Data from 15 farms in Jonava, using 5006.5 ha of agricultural land, were used for the research.

ArcGIS software was used to analyse the cartographic material and calculate the average distances to the fields. Data on agricultural land use from the State Enterprise Centre for Agricultural Information and Rural Business, the National Paying Agency and the State Land Fund were used for the research.

The following formulas were used to assess the compactness of the land holding (Aleknavičius, 2002):

$$K_k = \frac{L}{\sqrt{P}}; \qquad (1)$$

K_k – compactness coefficient of land holding;

L – average distance from land plots to farm centre ($\frac{\sum P \cdot L}{\sum P}$), ha;

P – average farm holding area, ($\sum P$), ha.

$K_k = K_1 . K_2$; (2)
K_1 – theoretical ideal coefficient of land holding structure (K_1 = 0,049);
K_2 – coefficient of land holding fragmentation.

$$K_2 = \frac{K_k}{0{,}049} \quad (3)$$

The location of the land parcels comprising the farm holdings in the study area, their declared agricultural area and the average distance from the farmsteads were calculated using ArcGis software.

Discussions and results

Studies on the compactness of farm land holdings. Depending on the location of the arable fields and the territorial conditions for the organisation of agricultural production, farm holdings can be characterised as fragmented or scattered, close to compact and compact. Scattered holdings consist of several or several dozen separate fields with no common boundary. In this situation, the farm has longer distances from the farmhouse to the fields, limited possibilities for efficient use of agricultural machinery, and higher transport and crop production costs. An analysis of 15 large farms (334 ha of used agricultural land per farm on average) in Jonava district showed that most of these farms have a fragmented land holding pattern: the number of individually located fields on the farms ranges from 7 to 65, or an average of 22 per farm, with an average field area of 14,9 ha. 10 farm centres (farmsteads) are located in towns and large settlements, 5 farm centres are located in small villages. The average distance from the farmstead to the fields is 4.35 km, and the value of the K_2 coefficients of land holding fragmentation ranges from 1.8 to 8.8 (average 3.62), of which four farms have a higher value than the recommended maximum (Aleknavičius..., 2002). A lower coefficient of land-holding fragmentation shows a lower level of fragmentation. The main reasons for the formation of non-compact farm land holdings are the peculiarities of land supply to farms during the land reform.

According to the statistical data published by the NLS and the State Enterprise Centre of Registers, the area of agricultural land plots registered for the first time in this category, by type of land ownership, is distributed as follows: 73.4% acquired through the restoration of land ownership rights (returned in kind on the former site or transferred to ownership free of charge with an equivalent area on another site), 16.6% acquired through privatisation of personal farm land used by the owner, 10.0% acquired through the purchase of plots of the free state land fund. On average, per natural person, the initial land area acquired during the land reform is only 6-7 ha. The owner of the farm had to decide for himself whether to further increase his land holding for the development of agricultural production and to purchase or lease land from persons not working on it. This process, with little regulation by the state authorities, has resulted in farm land holdings of various sizes. Moreover, as a farm becomes larger, the compactness of its land holdings decreases and the number of individually located fields increases.

Thus, the differentiation of farms in Lithuania according to the area of land used by agricultural entities was determined by the peculiarities of their formation during the period of land reform:

- the size of the land area, to which the farmers’ property rights were restored;
- the possibility of purchasing state land adjacent to the farm's land holding;
- the farm's increasing production capacity thanks to the farm's activities and state support, which required the farm to grow more agricultural produce;
- the farm's economic opportunities to acquire ownership of, or rent conveniently situated land plots from other owners.

In the context of intensive changes in the management and use of agricultural land, it is particularly important to optimise the land holdings of large farms by matching the land area and the production volume in trying to reduce transport costs.

By 1 July 2016, 3551 land users in Jonava District privatised or used 7517 ha of personal farm land under state land lease agreements (2.1 ha on average). By this date, 10 213 applicants had their property rights restored by returning in kind or by transferring 41489 ha of rural land (4.1 ha per person on average) to ownership in an equivalent area. In addition, 5469 ha of state agricultural land in the free fund was sold or leased to farmers. In 2016 1321 agricultural holders declared agricultural land in the municipality. During the land reform works, the law and its implementation procedures allowed to provide of land (with the help of land management measures) to natural persons setting up small farms with an average area of 10 ha. A typical example of a dispersed farm holding is shown in Figure 2.

Land restituted in the same place or by the equal value area for a farm owner;
Private land which was inherited;
Land which was purchased or obtained in other ways into ownership;
Rented private land;
Rented State land;
Location of a farmstead.

Fig. 3. Structure of incompact farm tenure by type of land acquisition.

The agricultural land used by the farm (101,6 ha) is scattered in over 17 separate fields with an average area of 6,0 ha. The distance by road from the farm centre to the fields varies from 0,2 to 3,0 km (average 1,2 km). The farm had acquired 63,2 ha, of which 4,6 ha were acquired by restitution of ownership, 20,7 ha were inherited from landowners who had regained their land, 4,1 ha were acquired by donation, and 33,8 ha were purchased privately. In addition, private land rented by the farm amounts to 38,4 ha or 37,8 % of the total agricultural land in use.

These figures are similar to those of other large farms. An analysis of land use ownership data for 11 farms in Jonava municipality shows that on average, at the time of the establishment of the farm (1992-2008), the farm had 12 ha of privately owned land per farm, while in 2016 it was already 123 ha. However, land rented from other owners and from the state accounts for 34.5% of the total land used by these farms. The annual rent paid by farms to landowners for renting private land is between 80 and 100 €/ha, which is about 9 times higher the land tax for the owners of agricultural land (9-11 €/ha).

Legal framework for farmland optimisation. In order to facilitate the conditions for farms to increase the size of their own land and to improve the compactness of their land holdings, the conditions for the acquisition of land in to private ownership are regulated by the Law on the Acquisition of Land for Agricultural Purposes. This law determines a priority or pre-emption right for acquisition of private land as follows:

1. The co-owners of the land parcel, according to Lithuanian Civil Code;
2. The user of the land plot being sold, who has a rent agreement registered in the Real Estate Register and has used this land for agricultural activities for at least one year;
3. A person who owns the agricultural land plot, which is bordering to the land plot being sold (Lietuvos..., 2014).

However, such a priority order is applied to land plots regardless of the distance to the farming centre. Remote plots may even worsen the conditions for organising production. It was found that 90 plots of land used by 15 analysed farms in Jonava municipality were located 5 – 10 km away from the farmsteads, covering an area of 1731 ha or 34,6 % of the total area of these farms.

To prevent such a situation land use schemes for prospective boundaries of farms can be drawn up. Such schemes are special planning documents defined by laws, although none of them has been prepared yet.

It is not appropriate that even in those areas for which land use planning schemes will be drawn up and the prospective boundaries of the farms' land holdings will be planned, the plots of private land within these boundaries will be sold on a preferential basis to other persons. Therefore, it is proposed to improve the legislation by establishing the right of pre-emption for the purchase of private land according to the prepared land use planning scheme within the prospective boundaries of the land holding.

The establishment of prospective boundaries of farm land holdings through the preparation of land use schemes and the implementation of the solutions of these schemes may facilitate the rational arrangement of farm land holdings. Moreover, it would increase the possibility for farms to acquire on a preferential basis other plots of land within a reasonable economic distance, thus gradually creating a more compact farm land holding.

In addition, the design of the prospective boundaries of farm land holdings in land use planning schemes should be combined with the preparation of land consolidation projects or should allow the identification of areas where it makes economic sense to prepare land consolidation projects.

When revising the rules for the preparation of land use schemes, it is recommended that:

- Prospective boundaries of farm land holdings should be established for all farms using and declaring more than 40-100 ha of agricultural land;
- Location of farmsteads and existing buildings, and the location of land used by farms (owned and rented) are identified during the design work;
- The prospective boundaries of farms land holdings are designed considering a need for land for the efficient use of the farm's productive capacity, the interests of neighbouring farms, and the possibility of minimising transport costs for agricultural work.

The following project solutions are proposed for the determination of the prospective boundaries of the farms' land holdings:

- To interchange the land plots used by these farms if they are located closer to the farmstead of another farmer;
- To include in the prospective boundaries of farms land holdings land plots used by other farms, but which are located at a greater distance from these farms;
- To include in the prospective boundaries of the farms land holdings vacant, undeclared plots of land that are interfered between the fields of farms.

Conclusions and proposals

1. The differentiation of farms in Lithuania according to the area of land used by agricultural entities was caused by the peculiarities of their formation during the land reform period: the size of the restored land area to which the owners' property rights were restored; the possibility of purchasing state land adjacent to the farm land holding; the farm increasing production capacity thanks to farm activities and state support, which required the farm to grow more agricultural produce; and the farm economic opportunities to acquire ownership or rent conveniently located land plots from other owners. In the context of intensive changes in the management and use of agricultural land, it is particularly important to optimise the land holdings of large farms, matching the size of the land with the production volume of the farms and reducing transport costs.

2. Most large farms are characterised by a fragmented, uncompacted spatial distribution. These holdings are made up of separate, widely separated fields, the use of which increases transport costs and the cost of production. In addition, a large proportion of farmsteads are located in a town or other larger settlement, rather than in a farmland holding. In the 15 farms of Jonava district analysed, the average area of one farm holding is 334 ha, there are on average 22 separate fields per holding, 2/3 of the farm centres (farmsteads) are located in large settlements, 1/3 of the farm centres are located in one-farm settlements and in small villages. The average distance from the farmstead to the fields is 4.35 km, and the value of compactness coefficient K_2 coefficients of landholding ranges from 1.8 to 8.8 (average 3.62), of which four farms have a higher value than the recommended maximum. In order to reduce the labour costs on farms and improve the conditions for organising production, the development and conversion of large farms need to be regulated by legal and spatial planning measures.

3. When drawing up land use planning schemes providing the prospective boundaries of farms' land holdings, it is appropriate to include methodological recommendations and requirements in the rules for the preparation of such land use planning documents. It is proposed to take account of these provisions:

- Prospective boundaries of farm land holdings should be established for all farms using and declaring more than 40-100 ha of agricultural land;
- Prospective boundaries of farm land holdings should not include land parcels that are more distant (e.g. more than 5 – 10 km away from the farm centre);
- In addition to the fields closer to the farm and used by the farm, it is proposed to include land parcels used by other farms, but distant from their farmhouses;
- To include in the prospective boundaries of the farms land holdings the vacant, undeclared plots of land that are interfered between the fields of farms;
- The prospective boundaries of the farms land holdings are designed considering the need of land for efficient use of the farm's productive capacity, the interests of neighbouring farms, condition of access roads, distances, and the possibility of minimising transport costs for agricultural work.

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Information about author:
Audrius Aleknavičius, associate professor, doctor of technology sciences, researcher. Vytautas Magnus University Agriculture Academy, Faculty of Engineering, Department of Land Use Planning and Geomatics. Address: Universiteto str. 10. LT – 53361 Akademija. Kaunas. Lithuania. e-mail: Audrius.aleknavicius@vdu.lt. Fields of interest: real property market research and valuation, expansion of farms, land consolidation.