LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN (Poland)

VYTAUTAS MAGNUS UNIVERSITY (Lithuania)

BALTIC SURVEYING

INTERNATIONAL SCIENTIFIC JOURNAL

2021

Volume 14

ISSN 2255 – 999X (online)

ISSN 2255 – 999X (online)

DOI: 10.22616/j.balticsurveying.2021.14

LATVIA UNIVERSITY OF LIFE SCIENCES AND TECHNOLOGIES

UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN (Poland)

VYTAUTAS MAGNUS UNIVERSITY (Lithuania)

BALTIC SURVEYING

INTERNATIONAL SCIENTIFIC JOURNAL

2021 / 1

Volume 14

Published since 2014

THE EDITORIAL COMMITTEE

REVIEWERS

Peer review is the driving force of journal development, and reviewers ensure that Journal maintains its standards for high quality of published papers. The editors would like to express their sincere gratitude to the following reviewers for their devoted time and contribution:

1. **Aleknavicius Audrius**, Doctor of technology sciences, Vytautas Magnus University (Lithuania)
2. **Celms Armands**, Dr.sc.ing., Latvia University of Life Sciences and Technologies, Latvia
3. **Golej Julius**, PhD., Slovak University of Technology in Bratislava
4. **Gurskiene Virginija**, Doctor of technological sciences, Vytautas Magnus University (Lithuania)
5. **Horjan Oleg**, PhD, State Agrarian University of Moldova, Moldova
6. **Jakubus Monika**, Dr.hab., Poznan University of Life Sciences, Poland
7. **Jankava Anda**, Dr.oec., Latvia University of Life Sciences and Technologies, Latvia
8. **Kowalczyk Cezary**, PhD, University of Warmia and Mazury in Olsztyn, Poland
9. **Kryshenyk Nadiia**, PhD, Law and Engineering Company «Roxal», Ukraine
10. **Kurowska Krystyna**, Dr hab. ing., University of Warmia and Mazury in Olsztyn, Poland
11. **Marian Madalina – Cristina**, PhD, University of Pitesti, Romania
12. **Mirzayev Natig**, PhD on Economy, Lankaran State University, Azerbaijan
13. **Myslyva Tamara**, Doctor of Sciences, Belarussian State Agricultural Academy, Belarus
14. **Stoiko Nataliia**, PhD in Economic Science, Lviv National Agrarian University, Ukraine
15. **Valciukiene Jolanta,** Doctor of technological sciences, Vytautas Magnus University (Lithuania)

FOREWORD

BALTIC SURVEYING is an international, cross-disciplinary, scientific, peer-reviewed and open access journal, issued as online (ISSN 2255 – 999X) edition. The periodicity of the journal is 1 or 2 volume per year.

Journal is jointly issued by consortium of:

- Department of Land Management and Geodesy of Latvia University of Life Sciences and Technologies, Latvia
- Department of Spatial Analysis and Real Estate Market of University of Warmia and Mazury in Olsztyn, Poland
- Department of Geodesy of University of Warmia and Mazury in Olsztyn, Poland
- Institute of Land Management and Geomatics of Vytautas Magnus University, Lithuania

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

Scientific journal BALTIC SURVEYING contains peer-review articles. International reviewing of articles is provided by Editorial Committee. For academic quality each article is anonymously reviewed by two independent anonymous academic reviewers having Doctors of science degree. Names of reviewers are published in the reviewer's list. Articles have passed cross-ref test as well. Each author himself is responsible for high quality and correct information of his/ her article.

Scientific journal BALTIC SURVEYING is indexed in databases Agris, CAB Abstracts, EBSCO Applied Science & Technology Source Ultimate, EBSCO Discovery Service, Complementary Index and Primo Central (ExLibris).

Information about the journal is placed on the website: www.balticsurveying.eu

Editorial Committee
(baltic.surveying1@gmail.com)

CONTENT

DOI: 10.22616/j.balticsurveying.2021.14.001

CURRENT STATE AND PROSPECTS FOR USE OF LAND RESOURCES IN THE REPUBLIC OF BELARUS

Kolmykov Andrey, Avdeev Alexey
Belarusian State Agricultural Academy, Republic of Belarus

Abstract
All land of the Republic of Belarus can be classified by categories (7 categories), types of lands (14 types), land users, forms of ownership and types of rights to land plots.
The total area of land in the Republic of Belarus is 20760 thousand hectares, including agricultural land occupies 9103.0 thousand hectares (43.8%) of the total area of the republic; settlements, horticultural associations, dacha cooperatives - 849.0 thousand hectares (4.1%); industry, transport, communications, energy, defense and other purposes - 622.2 thousand hectares (3.0%); environmental, health, recreational, historical and cultural purposes - 868.7 thousand hectares (4.2%); forest fund - 8656.4 thousand hectares (41.7%); water fund - 37.3 thousand hectares (0.2%); reserve land - 623.4 thousand hectares (3.0%).
The basis of the land resources used in the agro-industrial complex of the republic is arable land, meadows and land under permanent crops, which in general occupy 8387.1 thousand hectares, or 40.4% of the total area of land.
The state owns 20683.6 thousand hectares (99.63%) of land, private property - 76.4 thousand hectares (0.37%) of the total area of all lands of the republic.
In terms of environmental stability, the territory of the republic belongs to medium-stable territories, the coefficient of environmental stability is 0.63, and in terms of the degree of anthropogenic load - to territories with a relatively low anthropogenic load, the coefficient of anthropogenic load is 2.79.
Key words: land management, land resources, ecological state, land optimization.

Introduction

Currently, in the Republic of Belarus, as well as throughout the world, there is an acute problem of environmental degradation and degradation of natural systems. Against this background, there is a significant increase in the growth of agricultural production, including environmentally friendly, which causes the need for intensive use of land resources, revision of agricultural production technologies, as well as the farming system. At the same time, the widespread application of the principles of intensive farming, aimed at increasing the area of productive arable and meadow lands, often negatively affects the state of ecosystems, gradually destroying them, this fact is aggravated by the increased anthropogenic impact.
The above reasons lead to the ecologically irrational use of land resources, which, in turn, leads to the loss of sufficiently large productive areas due to a decrease in their natural fertility. The most significant threat is posed by the excessively high use of synthetic fertilizers and pesticides, depletion and salinization of soils, drainage of swamps, and land degradation.
A number of works by European scientists are devoted to the development of land relations, the ecological state, the use of land resources, the anthropogenic load on rural areas, the development of degradation processes and the development of measures to reduce them. Thus, the definition of the natural value of agricultural land on the example of the region of Apulia, Italy is considered in the scientific work of F. Bozzo, V. Fucilli, A. Petrontino, S. Girone (Bozzo et.al., 2019).
Prospects for the development of agrarian reforms in the field of land relations in Ukraine are considered in the scientific work of M. Bogira (Bogira et.al., 2019).
H. Hansson studied the attitude of farmers to environmental changes related to agricultural production using the example of the restoration of the wetlands of Lake Hurnborgashen in Sweden (Hansson, Kokko, 2018).
The issues of re-profiling of agricultural lands to combat climate change were considered by H. Vinge (Vinge, 2000).
Bonn University professor Joachim von Braun notes that land degradation is a serious economic problem in the Baltic region, and further inaction will lead to serious losses (Von Braun, Mirzabaev, 2018).
The scientific work of Bai Z. G., Dent D. L., Olsson L., Schaepman M. E. (Bai et.al., 2008) reflects the results of the analysis of 23-year studies of degrading areas around the world, identifies the most affected regions and evaluates the impact of individual factors on the current situation.

In A. Karklins, a researcher at the Latvia University of Agriculture, examines in his work the state of the soil in Latvia and highlights the factors that affect soil productivity and its vulnerability to pollution in the long term (Karklins, 2000).
To ensure sustainable development of agricultural production, rational use of land resources, it is necessary to analyze the dynamics of changes in their area, zoning of the territory according to agro-ecological factors and the introduction of measures to reduce environmental stress.
The basis of project proposals for the organization of rational use of land resources are regional schemes for the use and protection of land resources; schemes of land management of administrative-territorial and territorial units, territories of special state regulation; projects of inter-farm and intra-farm land management; working projects for land reclamation, land contours, soil protection from erosion and other harmful effects, preservation and enhancement of soil fertility and other useful properties of land (Кодекс Республики Беларусь…, 2008).

Methodology of research and materials
In the scientific research, dialectical, abstract-logical and monographic methods were used, as well as the method of induction, deduction, analogy, analysis, synthesis, correlation-regression analysis and others. The basis of the scientific search was the existing scientific developments in the field of land use and land management of domestic and foreign scientists and the experience of using land in the agro-industrial complex of the republic.
For scientific research, land registration data, information on the quantitative and qualitative state of lands, regulatory and legislative acts in the field of land use and protection, as well as scientific and reference literature, etc. were used.
The calculation of the coefficient of ecological stability of the territory was made according to the formula (Колмыков, 2013):

$$K_{e.st.} = \frac{\sum_{i=1}^{n} k_i P_i}{\sum_{i=1}^{n} P_i} k_i, \qquad (1)$$

k_i – coefficient of ecological stability of landsof the *i*-th type;
P_i – land areaof the *i*-th type, hectare;
k_p – coefficient of morphological stability of the relief.
In accordance with the proposal of S.N. Volkov's classification (Волков и др., 1992), depending on the obtained values of the coefficient of ecological stability ($K_{e.st.}$), the studied territories can be attributed to:
- ecologically unstable territories, if $K_{e.st.}$ less than 0.33;
- unstable stable territories, if $K_{e.st.}$ is in the range from 0.34 to 0.50;
- moderately stable territories, if $K_{e.st.}$ is in the range from 0.51 to 0.66;
- ecologically stable territories, if $K_{e.st.}$ more than 0.67.

The coefficient of anthropogenic load on the territory is determined by the formula (Волков, 2001):

$$K_{AL} = \frac{\sum_{i=1}^{n} Б_i P_i}{\sum_{i=1}^{n} P_i}, \qquad (2)$$

$Б_i$ – score corresponding to an area with a certain anthropogenic load;
P_i – area of the i-th type of land with the corresponding anthropogenic load, hectare.
According to the classification proposed by S.N. Volkov (Волков, 2001), the degree of anthropogenic load and the corresponding scores are adapted to the species composition of the lands of the Republic of Belarus and are presented in table 1.

Table 1

The degree of anthropogenic pressure on the territory

Anthropogenic load	**Score**	**Lands corresponding to the degree of anthropogenic load and assessment score**
High	5	Land under roads and other transport communications, public land, building land, disturbed land
Significant	4	Arable land and land under permanent crops
Average	3	Meadow lands, fallow lands
Insignificant	2	Forest lands, lands under swamps and under water bodies, as well as lands under trees and shrubs
Low	1	Unused lands, other lands

Discussions and results

According to the main document regulating land relations in the republic, the Land Code of the Republic of Belarus, the concept of land resources is defined as land, land plots that are used or can be used in economic or other activities (Кодекс Республики Беларусь…, 2008). Thus, land resources are a part of the land fund that is used or can be used in the national economy.

The current state and structure of land resources in the republic are determined by natural and climatic conditions, the results of economic activities, as well as economic and social features of the development of territories and measures aimed at preserving land.

In accordance with the legislation on the protection and use of land, data on the composition, structure and distribution of land resources are contained in the Register of Land Resources of the Republic of Belarus (Реестр земельных ресурсов…, 2020). It follows from this document that as of January 1, 2020, the total land area of the republic amounted to 20760 thousand hectares. The entire land fund of the republic is divided into seven categories, its composition and structure are shown in figure 1.

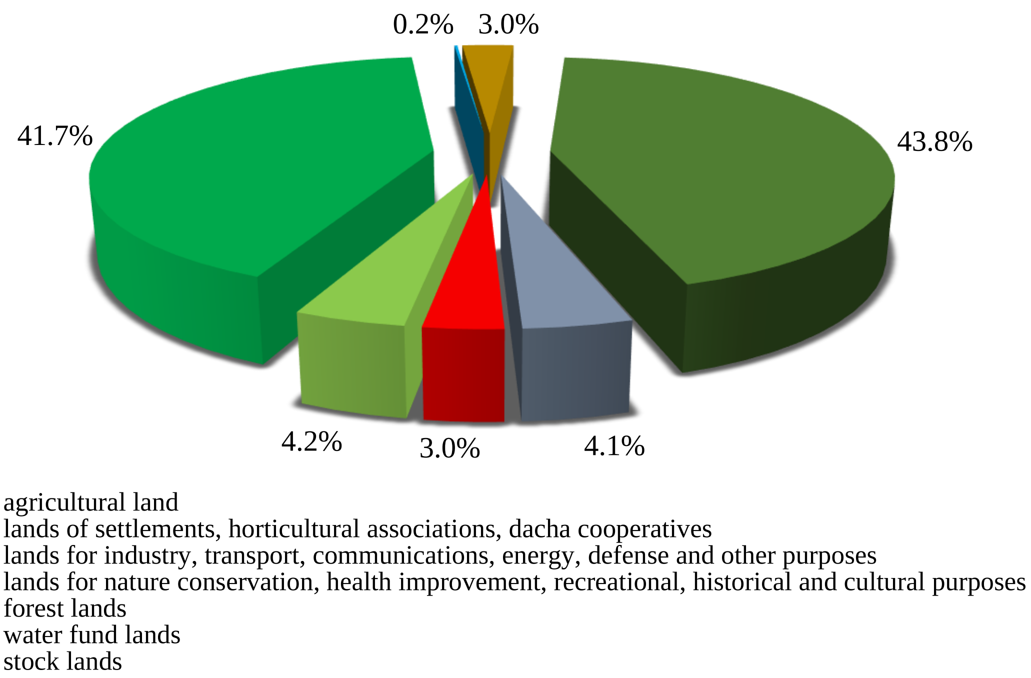


Fig. 1. Composition and structure of the land fund of the republic in the context of land categories as of 01.01.2020

The distribution by land categories is as follows: agricultural land occupies 9103.0 thousand hectares or 43.8% of the total area of the republic; lands of settlements, horticultural associations, dacha cooperatives - 849.0 thousand hectares, or 4.1%; land for industry, transport, communications, energy, defense and other purposes - 622.2 thousand hectares, or 3.0%; land for nature conservation, health-

improving, recreational, historical and cultural purposes - 868.7 thousand hectares, or 4.2%; forest land - 8656.4 thousand hectares, or 41.7%; water fund lands - 37.3 thousand hectares, or 0.2%; reserve lands - 623.4 thousand hectares, or 3.0%.
In addition to the division into land categories, the lands of the Republic of Belarus are divided into fourteen types (fig. 2).

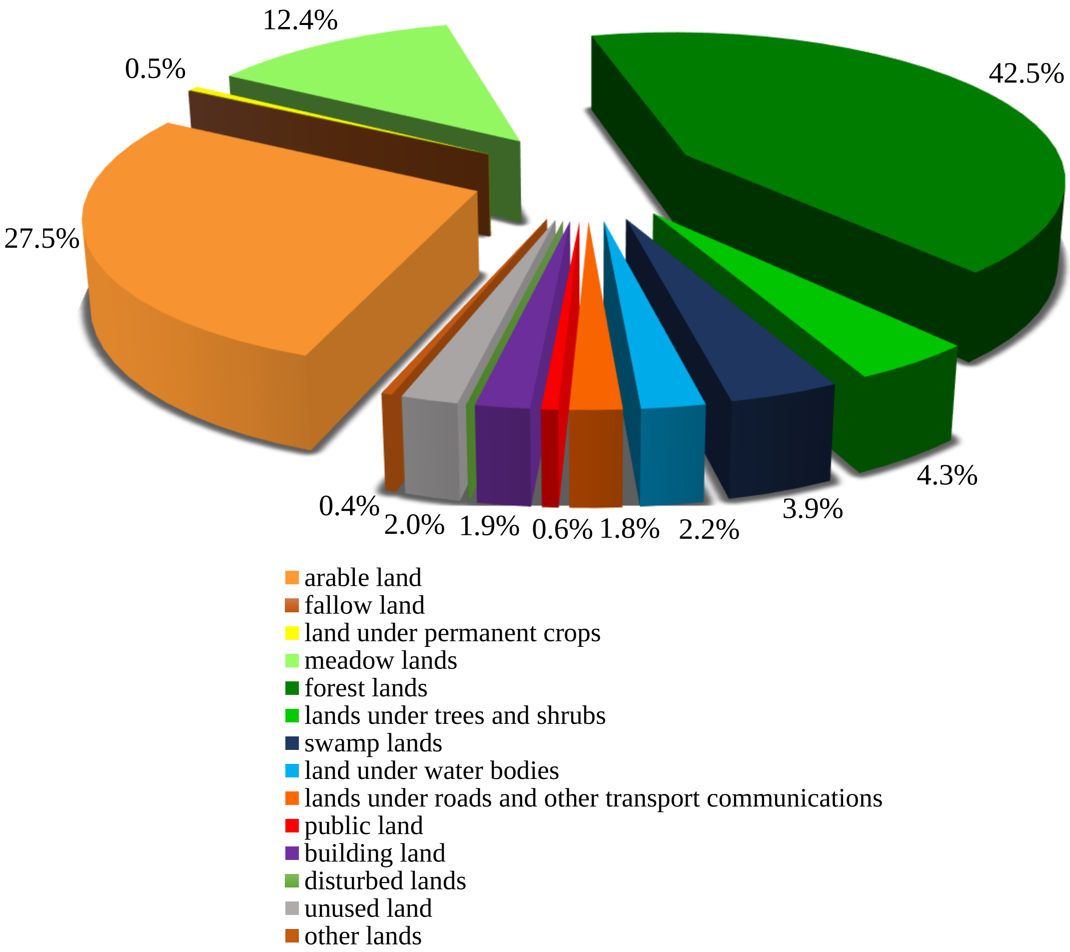


Fig. 2. Composition and structure of the land fund of the republic in the context of land types as of 01.01.2020

The distribution by type of land is as follows: arable land makes up 27.52% of the total area of the republic, or 5713.1 thousand hectares; fallow lands - 0.06%, or 3.5 thousand hectares; land under permanent crops - 0.51% or 106.5 thousand hectares; meadow lands - 12.37% or 2567.5 thousand hectares; forest lands - 42.45%, or 8813.6 thousand hectares; land under trees and shrubs - 4.32%, or 897.8 thousand hectares; land under swamps - 3.86%, or 801.0 thousand hectares; land under water bodies - 2.23%, or 463.5 thousand hectares;land under roads and other transport communications - 1.83%, or 379.7 thousand hectares; common land - 0.59%, or 121.9 thousand hectares; building land - 1.89%, or 392.9 thousand hectares; disturbed lands - 0.02%, or 3.6 thousand hectares; unused land - 2.00%, or 415.5 thousand hectares; other lands - 0.38%, or 79.9 thousand hectares. Thus, the basis of the land resources used in the agro-industrial complex of the republic is arable and meadow lands.
The distribution of land in the Republic of Belarus by forms of land ownership is as follows: the share of state ownership is 99.63%, or 20683.6 thousand hectares, the share of private property is only 0.37%, or 76.4 thousand hectares.
The distribution according to the types of land rights is as follows: 713.6 thousand hectares, or 3.44% of all lands of the republic, are in inherited possession for life; in permanent use - 18817.9 thousand hectares, or 90.64%; in temporary use - 257.1 thousand hectares, or 1.24%; rented - 283.2 thousand hectares, or 1.36% and privately owned - 76.4 thousand hectares, or 0.37%.

The land fund of the republic is distributed among land users as follows: 8854.4 thousand hectares of land are assigned to agricultural organizations, or 42.7%; for peasant (farm) households - 248.6 thousand hectares, or 1.2%; 849.0 thousand hectares, or 4.1%, were allocated for the needs of citizens; industrial organizations occupy 60.7 thousand hectares, or 0.3%; railway transport organizations use 48.7 thousand hectares or 0.2%; motor transport organizations - 159.8 thousand hectares, or 0.8%;154.2 thousand hectares, or 0.7%, are assigned to the organizations of the Armed Forces of the Republic of Belarus; communications, energy, construction, trade, education and healthcare organizations use 198.8 thousand hectares, or 1.0%; environmental, health, recreational, historical and cultural organizations occupy 868.7 thousand hectares, or 4.2%; 8656.4 thousand hectares, or 41.7%, are assigned to forestry;organizations operating and maintaining hydraulic and other water management structures use 37.3 thousand hectares, or 0.2%; land plots not provided to land users, and common land not classified as land of other categories of land users, amount to 623.4 thousand hectares, or 3.0%.
The assessment of the qualitative state of land resources of the Republic of Belarus was carried out using the data (points of the cadastral assessment and the point of soil fertility) of the first and second rounds of the cadastral assessment of agricultural lands by administrative regions and the republic (table 2).

Table 2

Indicators of cadastral valuation of agricultural lands of the Republic of Belarus and its regions

Name	**Total score of the cadastral assessment**		**Scoreofsoilfertility**	
	firsttour	**secondtour**	**firsttour**	**secondtour**
Brestregion	29.7	30.6	29.5	30.2
Vitebskregion	24.8	23.3	25.7	25.8
Gomelregion	27.8	26.9	27.6	27.3
Grodnoregion	31.7	32.3	31.7	32.9
MinskRegion	30.7	31.0	30.3	31.3
Mogilevregion	29.5	27.7	28.9	28.8
RepublicofBelarus	29.0	29.0	28.9	29.0

Analysis of the results of the cadastral assessment of land and soil fertility (table 2) showed that the maximum scores were recorded in the Grodno region and are 31.7 and 32.9, respectively, and the minimum are in the Vitebsk region - 25.7 and 25.8. Despite the constancy of the value of the score of the cadastral assessment of land in the Republic of Belarus according to the results of the first and second rounds - 29.0, there is a slight decrease in the Vitebsk region (-1.0), Gomel (-1.2) and Mogilev regions (-1.8), and in Brest, Grodno and Minsk regions have some growth, respectively - (+0.8) and (+0.4) points. There is also an increase in the score of land fertility in the Brest region - (+0.7), Grodno - (+1.2), Minsk region - (+1.0). In other regions, the change in the fertility score is insignificant. In the republic as a whole, the fertility score, according to the second round, was 29.0.
It should be noted that the increase in the values of the indicators under consideration is primarily due to the use of fertilizers and plant protection products, as well as the use of modern adaptive agricultural production technologies. The decrease in the score of the cadastral valuation of land is associated with the transfer of highly productive agricultural land for non-agricultural purposes, land degradation, and the emergence of spatial and territorial deficiencies.
For the ecological assessment of the territory of the Republic of Belarus in the context of administrative regions, the coefficients of the ecological stability of the territory and the anthropogenic load on the territory are determined.
After calculating the coefficient of ecological stability of the territory in accordance with the adopted classification (Волков и др., 1992) and depending on the obtained values of the coefficient of ecological stability ($K_{e.st.}$), it can be stated that, in general, the territory of the Republic of Belarus belongs to medium stable territories, since $K_{e.st.}$equals 0.63, but if we consider this indicator in the context of regions, then the following is established: the territories of Brest region ($K_{e.st.}$ = 0.63), Grodno region ($K_{e.st.}$ = 0.57), Minsk region ($K_{e.st.}$ = 0.58) belong to the average stable and Mogilev regions ($K_{e.st.}$ = 0.63); the group of ecologically stable territories includes Vitebsk ($K_{e.st.}$ = 0.69) and Gomel region ($K_{e.st.}$= 0.68).
As a result of the study, the following values of the coefficient of anthropogenic load on the territory were obtained: Brest region K_{AL} = 2.78, Vitebskregion –K_{AL} = 2.67, Gomel region –K_{AL} = 2.64, Grodno region – K_{AL} = 2.93, Minsk region –K_{AL} = 2.93 and Mogilev region –K_{AL} = 2.83, in the republic as a

wholeK_{AL} = 2.79. According to the classification proposed by Professor Volkov (Волков, 2001), according to the degree of anthropogenic load, the territory of the Republic of Belarus as a whole and its administrative regions in particular belongs to territories with a relatively low anthropogenic load.

To analyze the change in land areas, based on the materials of the state land cadastre over the past ten years, the three largest types of land in terms of area were selected, which are the main land resources of the republic - arable, meadow and forest, moreover, these lands have the greatest impact on the ecological stability of the territory. The dynamics of the areas of these types of land is presented in table 3.

Table 3

Dynamics of the distribution of arable, meadow and forest lands in the context of the administrative regions of the Republic of Belarus, thousand hectares

Years	Republic of Belarus	Brest region	Vitebsk region	Gomel region	Grodno region	Minsk Region	Mogilev region
Arable land							
2011	5510.5	818.0	910.7	812.4	846.0	1261.1	860.2
2012	5506.4	817.9	907.5	814.6	844.2	1259.4	860.8
2013	5521.6	816.9	919.7	818.9	844.4	1259.6	860.2
2014	5559.7	820.4	962.1	820.2	841.6	1251.7	861.8
2015	5662.1	828.4	961.1	863.8	840.9	1314.5	851.5
2016	5677.4	832.3	956.4	881.3	843.2	1311.1	851.2
2017	5683.8	834.4	914.4	914.2	844.2	1314.1	860.6
2018	5727.3	835.2	913.0	916.2	845.1	1349.1	866.9
2019	5712.3	835.0	906.7	911.5	843.8	1348.0	865.5
2020	5713.1	842.9	907.4	909.5	841.8	1346.6	863.0
Meadow lands							
2011	3240.6	590.5	639.7	552.4	395.2	570.5	491.9
2012	3223.7	588.2	637.0	549.2	388.6	568.4	491.9
2013	3154.0	584.9	597.8	526.2	386.2	566.3	492.2
2014	3032.6	579.0	523.1	517.6	385.9	564.0	462.6
2015	2844.0	566.4	512.0	465.4	380.4	499.1	420.3
2016	2783.6	554.1	501.6	433.6	374.8	500.0	419.1
2017	2737.6	534.8	536.9	394.5	371.6	498.4	401.0
2018	2653.1	533.9	526.0	389.0	357.6	460.6	385.6
2019	2629.6	534.0	513.9	383.2	358.7	461.0	378.4
2020	2567.5	504.5	502.6	372.5	357.5	461.4	368.6
Forest land							
2011	8566.7	1223.6	1666.8	2014.4	915.2	1604.6	1139.4
2012	8584.7	1230.7	1668.6	2015.6	918.9	1607.7	1140.5
2013	8588.5	1233.8	1668.5	2018.6	919.8	1603.3	1138.7
2014	8630.7	1233.6	1671.3	2023.5	922.7	1600.8	1173.0
2015	8652.6	1235.8	1679.8	2029.9	922.8	1600.0	1178.5
2016	8742.1	1244.4	1719.6	2054.1	922.4	1604.9	1190.9
2017	8769.4	1248.6	1723.8	2069.3	923.7	1605.6	1192.6
2018	8773.5	1248.9	1718.5	2071.2	928.4	1607.4	1193.4
2019	8791.0	1249.5	1722.6	2071.0	934.5	1607.5	1200.2
2020	8813.6	1260.7	1724.4	2072.4	939.6	1607.8	1202.8

According to the data in table 3, it is established that in the republic and in separate regions there is a tendency for a significant reduction in the area of meadow lands, in a ten-year period their area has decreased by 26.2%, or 673.1 thousand hectares. The area of arable and forest lands for the same period increased by 3.6 and 2.8%, or 202.6 and 246.9 thousand hectares, respectively.

The study of the dynamics of areas was carried out using correlation-regression analysis, as a result, functions were selected that most accurately describe the ongoing changes in the selected types of land (table 4).

Table 4

Forecast of arable, meadow and forest land areas for 2023.

Name	Forecast Function	Area, thousand hectares	
		2020	2023
Arable land			
Republic of Belarus	$y = -2.115x^2 + 51.63x + 5424.0$	5713.1	5737.8
Brest region	$y = 0.045x^2 + 2.420x + 813.0$	842.9	852.1
Vitebsk region	$y = -2.254x^2 + 23.48x + 883.5$	907.4	807.8
Gomel region	$y = -0.511x^2 + 19.8x + 777.0$	909.5	948.0
Grodno region	$y = 0.073x^2 – 0.976x + 846.0$	841.8	845.6
Minsk region	$y = 0.198x^2 + 10.06x + 1238.0$	1346.6	1402.2
Mogilev region	$y = 0.328x^2 – 3.081x + 864.4$	863.0	879.8
Meadow lands			
Republic of Belarus	$y = 3.511x^2 – 121.4x + 3419.0$	2567.5	2434.2
Brest region	$y = -0.484x^2 – 4.088x + 598.1$	504.5	463.2
Vitebsk region	$y = 3.020x^2 – 47.91x + 696.3$	502.6	583.9
Gomel region	$y = 0.631x^2 – 30.38x + 601.1$	372.5	312.8
Grodno region	$y = -0.099x^2 – 3.389x + 398.1$	357.5	337.3
Minsk region	$y = 0.150x^2 – 16.55x + 600.2$	461.4	410.4
Mogilev region	$y = 0.293x^2 – 19.12x + 525.0$	368.6	326.0
Forest land			
Republic of Belarus	$y = -0.408x^2 + 35.38x + 8512.0$	8813.6	8903.0
Brest region	$y = 0.061x^2 + 2.932x + 1222.0$	1260.7	1270.4
Vitebsk region	$y = -0.152x^2 + 9.822x + 1648.0$	1724.4	1750.0
Gomel region	$y = -0.038x^2 + 8.512x + 1998.0$	2072.4	2092.2
Grodno region	$y = 0.255x^2 – 0.539x + 917.9$	939.6	954.0
Minsk region	$y = 0.209x^2 – 1.896x + 1607.0$	1607.8	1617.7
Mogilev region	$y = -0.651x^2 + 15.24x + 1116.0$	1202.8	1204.1

A retrospective analysis of the dynamics of the use of arable, meadow and forest lands and a forecast for a three-year perspective showed that, while maintaining the current trends in their change, the area of arable and forest lands in the republic by 2023 will increase by 24.7 and 89.4 thousand hectares, or 0.43 and 1.01 % in comparison with 2020 and will amount to 5737.8 and 8903.0 thousand hectares, respectively. The area of the meadow land will be reduced by 133.3 thousand hectares or 5.19% and will amount to 2434.2 thousand hectares.

According to the research carried out, it was found that in order to increase the efficiency of the use of land resources in agricultural organizations, it is advisable to carry out the following measures:

– to introduce the implementation of agroecological zoning of the territory of land use of agricultural organizations with the establishment of a regime for the use of land in the allocated zones;

– carry out the transformation of land, taking into account its environmental acceptability and economic feasibility in order to increase the area of agricultural land;

– to optimize the size of land use of agricultural organizations;

– to improve the specialization of production of agricultural enterprises based on the availability of land, material and labor resources, as well as the social need for agricultural products and other factors;

– eliminate territorial disadvantages of land use;

– to establish a rational ratio of lands;

– introduce adaptive crop rotations;

– to ensure the rational placement of agricultural crops in ecological and technological working areas;

– to reduce soil compaction by machine-tractor units;

– to bring the crops of labor-intensive, load-intensive and machine-intensive agricultural crops closer to economic centers and improved roads;

– to place crops of agricultural crops cultivated by machine-intensive technologies in areas with maximum rut length, minimum slopes and soil resistivity.

In the process of land management of administrative-territorial and territorial units, introduce the following measures to maintain the environmental stability of their territory:
– transfer of unproductive land plots for non-agricultural purposes,
– reclamation of disturbed lands,
– a decrease in the intensity of land use (the introduction of soil-protective crop rotations, the creation of perennial meadow lands, etc.),
– allocation of land for ecological corridors;
– arrangement of zones with environmental protection regime;
– intensification of agricultural production within ecologically acceptable limits;
– ecologically acceptable elimination of small contour;
– improvement of the land reclamation state;
– maintaining the ecological well-being of the territory;
– to introduce the principles and methods of organic farming in agricultural organizations to restore the natural fertility of the land and reduce the anthropogenic impact on the land;
– to introduce the practice of state support and encouragement of agricultural producers for ensuring their effective use of land and improving their quality condition.

Conclusions and proposals

As a result of the performed scientific research, the following conclusions can be drawn:
1. All lands of the Republic of Belarus are subdivided into 7 categories and 14 types. The largest area is occupied by agricultural land - 9103.0 thousand hectares, or 43.8% of the total area of the republic, and the smallest - land of water resources - 37.3 thousand hectares, or 0.2%. In accordance with the species composition of the republic's lands, the largest area is occupied by forest lands - 42.45%, or 8813.6 thousand hectares, and the smallest - disturbed lands - 0.02%, or 3.6 thousand hectares.
2. The state property is 20683.6 thousand hectares, or 99.63% of the republic's land, in private ownership - 76.4 thousand hectares, or 0.37%.
3. Analysis of the results of the first and second rounds of cadastral valuation of land and soil fertility showed that despite the constancy of the value of the cadastral valuation of land in the Republic of Belarus - 29.0, there is a slight decrease in the Vitebsk region (-1.0), Gomel (-1.2) and Mogilev regions (-1.8), and in Brest, Grodno and Minsk regions there is some growth, respectively - (+0.8) and (+0.4) points. The land fertility score increased in the Brest region - (+0.7), Grodno - (+1.2), Minsk region - (+1.0). In other areas, the change in the fertility score is insignificant. In the republic as a whole, the fertility score, according to the second round, was 29.0.
4. The existing organization of the lands of the Republic of Belarus as a whole allows its territory to be ecologically related to medium stable territories, the coefficient of ecological stability is 0.63;
5. Analysis of the anthropogenic load on the territory of the republic makes it possible to classify it as a balanced territory in terms of land composition with a relatively low anthropogenic load. the anthropogenic load factor is 2.79;
6. Retrospective analysis of the dynamics of the areas of arable, meadow and forest lands of the republic and regions for the period from 2011 to 2020. revealed a tendency towards a reduction in the area of meadow lands and an increase in the area of arable and forest land relative to the initial year (2011).
7. The forecast of the areas of productive land until 2023 showed that the area of arable and forest land in the republic will increase by 24.7 and 89.4 thousand hectares, or 0.43 and 1.01% in relation to 2020 and will amount to 5737.8 and 8903.0 thousand hectares, respectively, and meadow land will be reduced by 133.3 thousand hectares, or 5.19% and will amount to 2434.2 thousand hectares.
8. To increase the efficiency of the use of land resources in agricultural organizations and maintain the ecological stability of their territory, it is advisable to carry out the measures given in the scientific work.

References

1. Bai Z. G., Dent D. L., Olsson L., Schaepman M. E. (2008) Proxy global assessment of land degradation, Soil use and management, Vol. 24, no. 3, p. 223–234.
2. Bogira M., Sokhnych A., Soliarchuk Y. (2019) Prospects Of Agrarian Formations Development At The Stage Of Land Relations Transformations In Ukraine, Scientific Papers: Management, Economic Engineering in Agriculture & Rural Development, Vol. 19, p. 37–43.
3. Bozzo F., Fucilli V., Petrontino A., Girone S. (2019). Identification of High Nature Value Farmland: a methodological proposal. Italian Review of Agricultural Economics, Vol. 74(3), p. 29–41.
4. Hansson H., Kokko S. (2018) Farmers' mental models of change and implications for farm renewal - A case of restoration of a wetland in Sweden, Journal of Rural Studies, Vol. 60, p. 141-151.

5. Karklins A. (2000) Soil degradation status and data availability in Latvia. In: Batjes N and Bridges E, Implementation of a Soil Degradation and Vulnerability database for Central and Eastern Europe, FAO and ISRIC, Rome, Italy.
6. Vinge H. (2018) Farmland conversion to fight climate change? Resource hierarchies, discursive power and ulterior motives in land use politics, Journal of Rural Studies, 2018, Vol. 64, p.20 – 27.
7. Von Braun J., Mirzabaev A. (2016), Land Use Change and Economics of Land Degradation in the Baltic Region, Baltijskij region, Vol. 8, no. 3, p. 45 – 60.
8. Волков С.Н. (2001) Землеустройство: в 9-ти т. Т. 2: Землеустроительное проектирование. Внутрихозяйственное землеустройство (Land management: in nine volumes Volume 2: Land management design. On-farm land management).«Колос», Москва, 648 с.(in Russian).
9. Волков С.Н., Хлыстун В.Н., Улюкаев В.Х. (1992) Основы землевладения и землепользования (Fundamentals of land tenure and land use). «Колос», Москва, 144 с.(in Russian).
10. Кодекс Республики Беларусь о земле (Land Code of the Republic of Belarus) от 23.07.2008 № 425-З: ред. от 18.07.2016 // Нац. реестр правовых актов Респ. Беларусь. 30 июля, 2008, № 2/1522 (in Russian).
11. Колмыков А.В. (2013) Землеустроительное обеспечение организации рационального использования земель сельскохозяйственного назначения (Land management support for the organization of rational use of agricultural land). УО БГСХА, Горки, 337 с. (in Russian).
12. Колмыков А.В., Авдеев А.Н. (2019) Зонирование территории Минской области для целей землеустройства (Zoning of the territory of the Minsk region for land management purposes). Вестник БГСХА. Научно-методический журнал, № 1,Горки: УО БГСХА, с.143 – 148 (in Russian).
13. Реестр земельных ресурсов Республики Беларусь (Register of land resources of the Republic of Belarus) (http://www.http://gki.gov.by/ru/activity_branches-land-reestr) (in Russian).

Information about authors:

Andrey, Kolmykov, Doctor of Economic Sciences, docent, First Vice-Rector, Belarusian State Agricultural Academy.213407, Belarus, Mogilev region., Horki, st.Michurina 5, +375 (29) 692-17-66, kolmykov@tut.by. Land management, land optimization, economics of land management.

Alexey, Avdeev, Assistant of the Department of Land Management, Belarusian State Agricultural Academy.213407, Belarus, Mogilev region., Horki, st.Mandrikova 4, +375 (25) 756-26-49, lex_avdeev@bk.ru. Land management, land optimization, economics of land management.

DOI: 10.22616/j.balticsurveying.2021.14.002

METHODOLOGY OF APPLICATION OF MODERN TECHNOLOGIES IN LAND INVENTORY OF TERRITORIAL COMMUNITIES

Koshkalda Iryna[1], Anopriienko Tetiana[1], Pilicheva Maryna[2], Maslii Lubov[2]
[1]Kharkiv National Agrarian University named after V.V. Dokuchayev,
[2]O. M. Beketov National University of Urban Economy in Kharkiv

Abstract
The article defines that the land inventory allows to form land plots of state and communal property, to fill the State Land Cadastre with information about objects and subjects of land relations and to eliminate existing errors. The aim of the article is to improve the procedure of conducting the land inventory in Ukraine, taking into account modern technologies within the current regulatory framework. The methodology of land inventory using modern technologies has been developed, which includes the following components: surveying of the inventory object, topographic and geodetic works, vectorization of its territory using remote sensing data, project works, creation of a consolidated inventory plan, development of technical documentation, its state expertise, adjustment and approval, entering data into the State Land Cadastre. It is established that an effective method of implementation of topographic and geodetic works during updating of the cartographic materials is a combined method, which includes the use of aerial images with simultaneous geodetic surveying of complex areas. The use of geoinformation technologies and remote sensing data is allowed to optimize the duration and frequency of land inventory. In particular, the classification of land should be performed in the attribute tables. Ways to solve problems of protection and rational use of the lands of the inventory object have been developed. They include registration of land plots without cadastral numbers; control of compliance of land and environmental legislation, taking into account the results of land inventory for updating statistical cadastral information and making changes of the State Land Cadastre data.
Key words: land use, land inventory, territorial communities, GIS technology, remote sensing data

Introduction

The revelation and functioning of the land market, especially agricultural land, requires its regulation by the state – accounting for quantity and quality, protection of land and their rational use. Therefore, one of the important measures is to fill the geographic information system of the State Land Cadastre with reliable and complete information about the objects and subjects of land relations and to eliminate existing errors as a result of a continuous land inventory. At the same time, the location of land plots, their boundaries, sizes, legal status and restrictions are established, lands that are not used, used irrationally or not for their intended purpose are identified, and their qualitative characteristics are established.

According to the decentralization of power in Ukraine, the creation and future increase of territorial community areas through their unification, land inventory becomes one of the key factors of their further success and development, planning and receipt of funds to the local budget from land tax and land rent depends on condition and amount of land the community will receive. It is possible to form land plots of state and communal property on the basis of land inventory materials.

The vast majority of countries in the world have 4 stages of lands inventory: determining current land use conditions, preparing a base map, deciding on land use categories collecting current land use data, preparing the current land use map (Land Use…, 2005). Computerized Land Information Systems (LIS), based on GIS, are widely used at all stages to manage and analyze a large number of data on the use of land resources, perform statistical and spatial processing, create the necessary information products in the form of maps, as well as tabular and textual reports for the management decision-making (Sombroek W.G.; Antoine J., 2000; Udovenko et.al., 2020). Typical methods for the determination of the current state of land use are modern technologies, such as: terrestrial geodetic survey methods for urban development, aerial photography and space survey data for rural areas and country estates (Land Use…, 2005; Lowry, 2006; Ramteke et. al., 2018).

Problems of improving the State Land Cadastre and land inventory in Ukraine have been studied in the works of domestic scientists (Кондратенко, 2019; Дорош, 2015; Лакатош, 2013; (Мартин, 2012; Нестеренко, Бідун 2013; Bavrovska, Boryskevych, 2017), where researchers note that the information function of the inventory is one of the main, as it ensures the reliability of information on land. The inventory results later become the basis for making many management decisions, and most importantly – financial decisions.

Despite the above, today there is no unambiguous view on the essence of land inventory as a form of obtaining (updating, adjusting) information on the state of land tenure and land use, which is entered in the State Land Cadastre of Ukraine.

Methodology of research and materials

Therefore, the **aim of the article** is to improve the procedure of conducting the land inventory in Ukraine, taking into account modern technologies within the current regulatory framework.
The following tasks were set for achieving this goal:

1. to analyze the existing regulatory framework of land inventory in Ukraine;
2. to study the technological process of land inventory in Ukraine;
3. to form a methodology for conducting land inventory works using modern technologies on the example of the territorial community;
4. to develop recommendations for the rational use of the land inventory object.

The object of study is the land resources of the territorial community.
The article uses methods of analysis, synthesis and generalization of regulations, scientific literature, land management documentation for land inventory and statistics.

Discussions and results

In Ukraine works on land inventory are carried out according to the "Procedure for conducting land inventory and recognizing some resolutions of the Cabinet of Ministers of Ukraine as invalid " (Про затвердження Порядку …, 2019).
To conduct the land inventory of the territorial community, the customer (local government) enters into an agreement with the contractor to develop technical documentation, which reflects the cost and timing of work, which should not exceed six months since the signing a contract.
The contract is also accompanied by an estimated budget and terms of reference for land inventory work, which is issued by the customer, approved by the contractor and includes: basis for work, purpose of work, brief description of the object, initial data for work, requirements for technical documentation, expected results and the order of works realization, materials which are provided after the termination of works, the order of delivery of the developed technical documentation.
The general procedure for conducting a community land inventory is shown in Figure 1 and it consists of 4 main stages (Про затвердження Порядку …, 2019): survey stage, topographic and geodetic stage, design, seach and approval stage and approval of technical documentation on land management for land inventory. Geographic information technologies are used for fast and high-quality source data processing, as well as inventory of objects. The advantage of using GIS is that the creation of graphic materials significantly increases the accuracy of drawings, in addition, electronic cartographic materials can be used an unlimited number of times to reproduce both the general drawing and fragments, to overlap some drawings on others.
The first stage of the land inventory procedure is survey work, which includes collection and analysis of initial data for land inventory (materials from the State Fund of Land Management Documentation, planning and cartographic materials, etc.) and field survey of the inventory object by the executor. The results of the work performed are presented on a working inventory plan, which is based on the next cadastral plan or other planning and cartographic materials within cities and towns – at a scale of not less than 1: 5000, within rural settlements – at a scale of not less than 1: 2000, within the territories defined as formation of the territory and establishment of village borders, settlement councils by the projects – in scale not less than 1: 10000, within districts – in scale 1: 25 000, with indication of borders: object of inventory; administrative-territorial units that are part of the object of inventory; territories defined by projects of territory formation and establishment of city, settlement, village councils borders; lands of all forms of ownership; land plots included in the State Land Cadastre; restrictions (encumbrances) in the use of land.

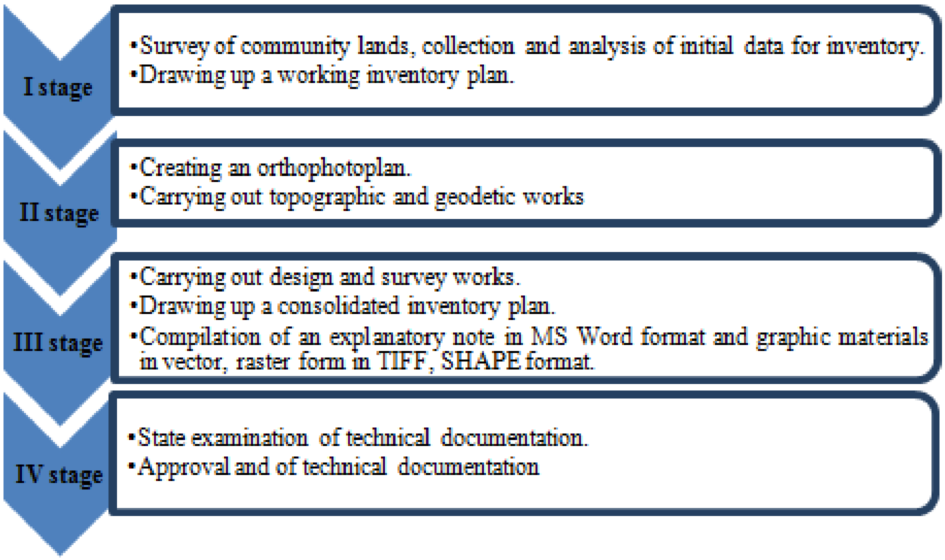


Fig. 1. Stages of land inventory

Based on modern experience of topographic and geodetic works, the most effective method of updating the cartographic basis is a combined method, which includes the use of aerial photography materials with simultaneous instrumental geodetic survey of the most complex areas that require a more detailed image.

The technological process of creating an orthophoto is shown in Figure 2, which schematically shows the transformation of individual images into a single orthophoto.

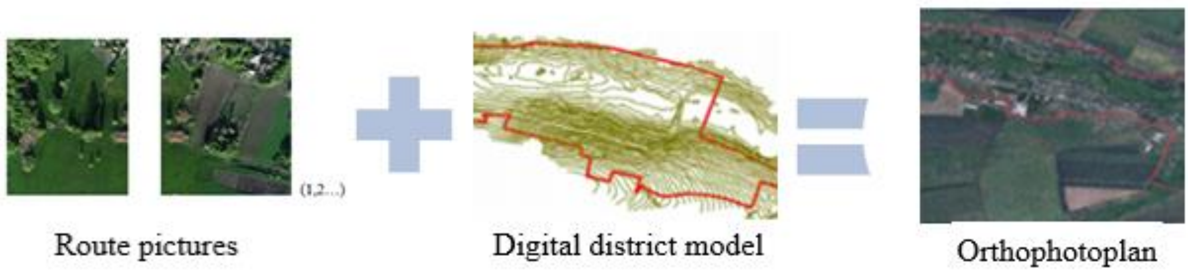


Fig. 2. Technological process of creating an orthophotoplan

A detailed list of works while creating an orthophotoplan is shown in Figure 3.

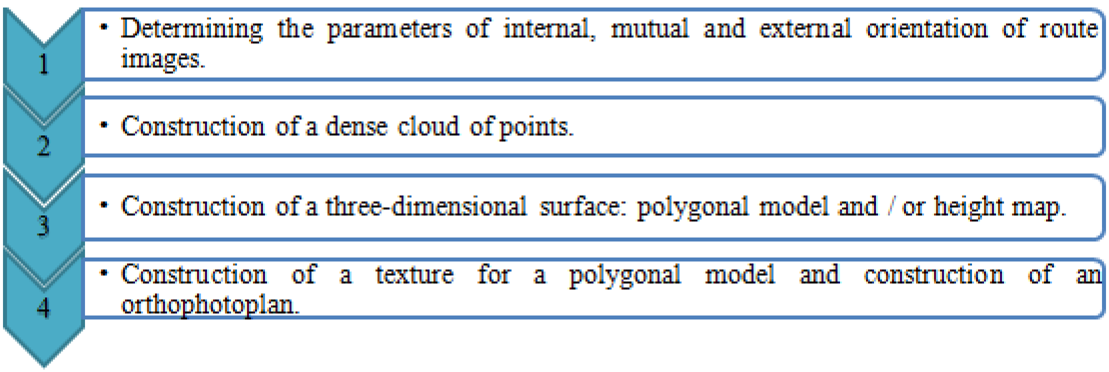


Fig. 3. Stages of creating an orthophotoplan

At the first stage of an orthophotoplan creation common points of pictures are found and elements of mutual orientation of pictures of a route are defined by these points. The result of the stage is a sparse cloud of common points in the 3D space of the model and data on the orientation of the camera, which serves only to visually assess the quality of image alignment. In the second stage, a dense cloud of points is constructed based on the camera positions and images at the time of taking photos. The third stage is a three-dimensional polygonal model that describes the shape of an object based on a dense cloud of points. Sometimes it is possible to proceed the construction of a height map, refusing the construction of a polygonal model. The choice of cartographic projection is obligatory. At the final stage, the orthophotoplan is projected on the surface specified by the user, it can be a height map or a polygonal model.

In order to link aerial photography materials to the area, as well as to determine or clarify the boundaries of land plots, restrictions (encumbrances) in their use and lands, field geodetic works are performed in order to obtain the coordinates of the survey base points. The starting points of the state geodetic network are the nearest permanent stations. The points of the shooting base are temporarily fixed on the ground with cross-shaped marks, which are located on the scheme of the plan basis (Fig. 4).

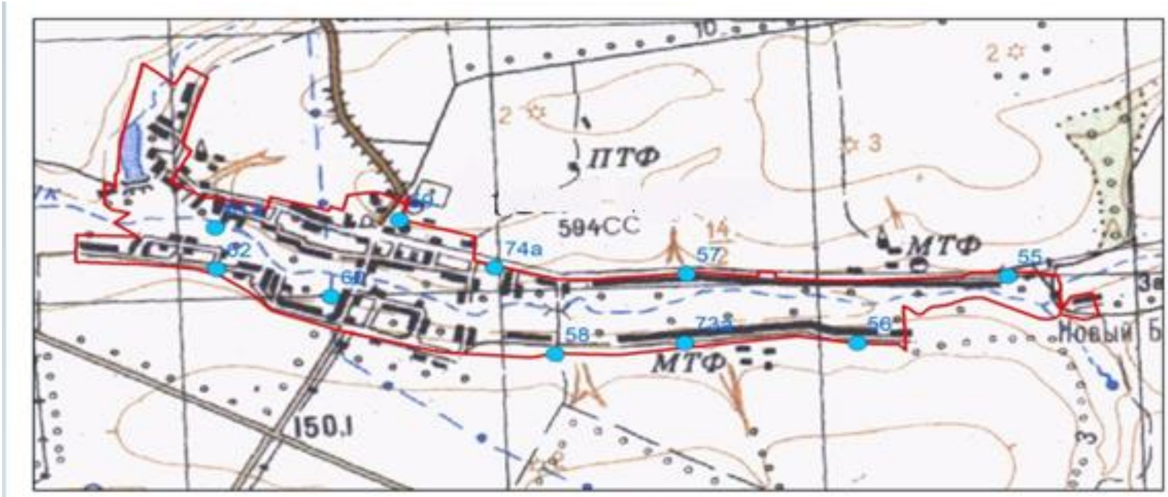


Fig. 4. Scheme of the plan basis with points of geodetic network

The coordinates of the shooting base points are determined by satellite methods using GPS receivers. Observations were performed only by static method, by separate sessions. The duration of the sessions while determining the points of the shooting base is minimum 20 minutes. The recommended number of observed satellites is minimum four, during the study their number averaged 8-9. The measurement results are shown in Table 1.

Table 1

Data of route mean square deviations (RMS) of the planned basis

Point	RMS by X, m	RMS by Y, m	RMS by H, m	RMS by XY, m
61a	0.012	0.012	0.015	0.013
62	0.011	0.012	0.014	0.012
59	0.010	0.009	0.019	0.014
74a	0.010	0.009	0.018	0.014
57	0.010	0.009	0.019	0.014
55	0.010	0.009	0.018	0.014
56	0.011	0.012	0.018	0.013
73a	0.010	0.009	0.014	0.014
58	0.010	0.009	0.020	0.014
60	0.010	0.012	0.019	0.014

Survey of complex areas is performed tacheometrically using tacheometers or satellite methods. Survey of the homestead's boundaries, industrial and socio-cultural facilities and engineering networks was performed by satellite using GPS receivers. Satellite observations were performed from the base station in Stop and Go mode and in RTK mode, with separate sessions at each static point for at least 5 minutes, the number of satellites observed is minimum 7. Kinematic measurements were performed at an average speed of 6 km / year with a data resolution of 2 s. During the topographic and geodetic works, land plots were also inspected for the presence and / or absence of power grids with a voltage of 0.4 kV and more, main pipelines and other objects with special creation and protection conditions were also inspected.

To ensure the reflection required accuracy for the account area accepted unit of the deviation of land plot boundaries turning points relative to the nearest points of the state geodetic network should not exceed (Про затвердження Порядку …, 2019):

- in cities Kyiv, Sevastopol and cities of regional subordination – 0.1 meters;
- in other cities and towns – 0.2 meters;
- in villages – 0.3 meters;
- outside the settlements – 0.5 meters.

During the land inventory, the area of the land plot is indicated up to 1 sq. meter, taking into account the deviation of the plan scale in the case when the coordinates of the boundary turning point are determined with an accuracy of 0.01 meters.

Then design and survey works are carried out in order to process the data of topographic and geodetic works, create a geodatabase and perform vectorization of objects in the inventory area. All lands are subject to classification by purpose, availability of title documents for land, form of ownership, others and by entering the necessary information in the attribution tables in the process of vectorization, which allows to optimize the work when performing land inventory. The result of land inventory is a consolidated inventory plan (Fig. 5).

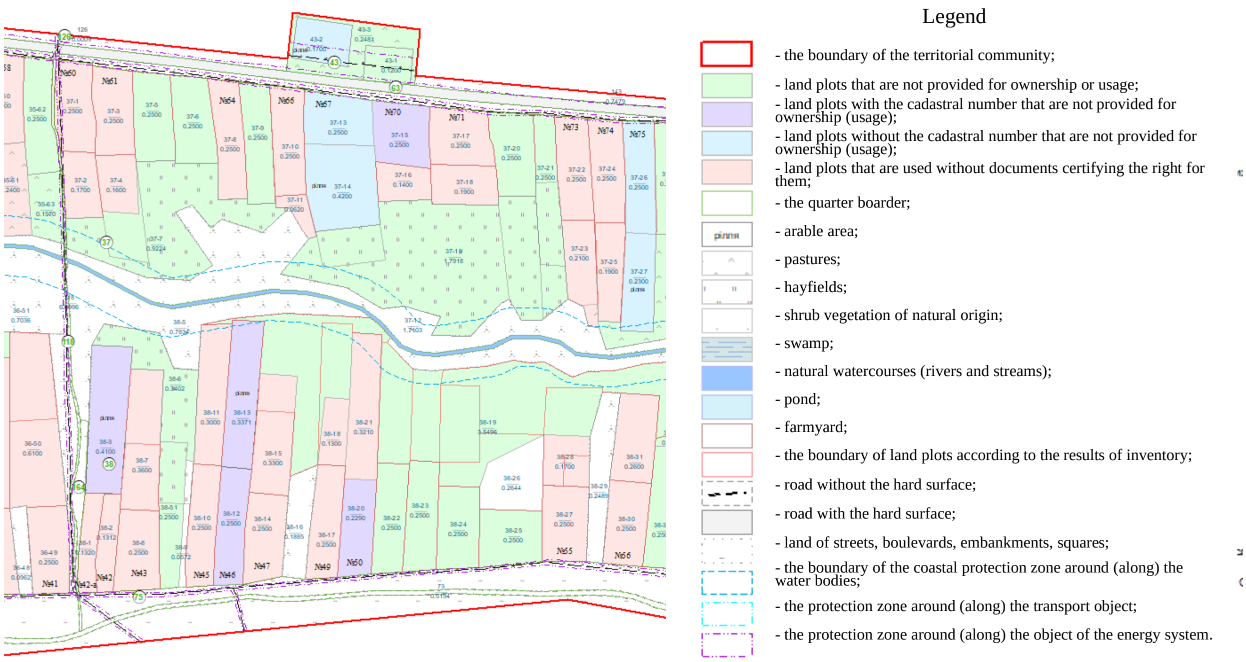


Fig. 5. Fragment of a consolidated inventory plan

The consolidated inventory plan draws the boundaries of (Про затвердження Порядку …, 2019):

- land plots provided for ownership (usage);
- land plots not provided for ownership (usage);
- land plots used without documents certifying the right to them, or not for the intended purpose;
- existing restrictions in the use of land;
- unclaimed land shares (“pais”/land units);
- land plots (lands) of deseased heritage;
- lands;
- water bodies and hydraulic structures;
- irrigated and drained lands.

Appropriate summary tables are created. An example of a consolidated comparative table of data obtained as a result of land inventory and according is given in Table 2.

Table 2

Consolidated comparative table of data obtained as a result of land inventory and accounting

No.	Land title	Area according to land accounting reports, ha	Area according to the data obtained as a result of land inventory, ha	Variance, ha
1	Arable	89.5468	55.6602	-33.8866
2	Perennial plantings	31.9000	-	-31.9000
3	Hayfields	72.4000	109.2611	36.8611
4	Pastures	38.3000	38.9664	0.6664
5	Land under agricultural and other farm buildings and yards	12.5430	14.7912	2.2482
6	Other forest plantings	1.8765	0.4530	-1.4235
7	Shrub vegetation of natural origin	30.0986	27.8946	-2.2040
8	Land for housing	57.1342	84.9875	27.8533
9	Lands under socio-cultural facilities	1.7309	3.5183	1.7874
10	Land under buildings and structures of transport	0.0123	0.0100	-0.0023

The fourth stage is the creation of an electronic document containing information on the results of land management and land valuation in electronic form in XML format (in the case of state or communal land formation), approval of the developed technical documentation and its state examination. Together with the positive conclusion of the state examination, the technical documentation is submitted for approval, followed by tansmission in paper and electronic forms to the territorial body of the State Geocadastre for entering data into the State Land Cadastre.

On the basis of the received data of land inventory the decisions of land protection and rational land use of inventory object are developed, the recommendations concerning the following can be the examples:

1. Registration of land plots without cadastral numbers in the State Land Cadastre by owners / users of land plots, in order to prevent the imposition of land plots on adjacent land plots when registering the ownership of new land plots.
2. Carrying out explanatory works with land users who use land plots without documents certifying the right to them, regarding their registration of the right to land plots according to the current legislation of Ukraine.
3. Monitoring compliance of land and environmental legislation, land use and protection by local governments and state administrations.
4. Using the results of land inventory when updating statistical cadastral information and making changes to the State Land Cadastre by the departments of the State Geocadastre.
5. Taking into account the results of land inventory when making decisions related to land issues and changes in the legal status of land by local governments.

Conclusions and proposals

Summarizing all the issues, we can say that:

1. In order to update the data on the land community fund, it is advisable to conduct a land inventory every 3-5 years.
2. In order to improve the procedure for conducting land inventory, local governments and executive authorities need to take urgent measures for the organized implementation of works and ensuring their proper funding.
3. In order to simplify the procedure for conducting land inventories, it is necessary to update the cartographic basis, as well as to develop general plans and projects for the establishment and restoration of settlements and territorial communities' boundaries.
4. Issue is to update the data on the accounting forms for the number of lands based on the results of the inventory and update the Land Books, most of which do not meet current requirements. New forms of statistical reporting should include information that is missing or partially not collected in the State Land Cadastre system. Codes of economic activities and statistical codes of economic entities organizational forms are completely absent, which leads to obtaining them from other sources and conducting significant research. Today it is necessary to make changes to the information base of the electronic document in XML format in terms of inputting this information.

5. In order to increase the accuracy of the land inventory, there is a need to inform the public about it. After all, one of the problems of inventory is the lack and insufficiency of information on title documents for land plots.

The given methodology of modern technologies application at inventory of territorial communities' lands will allow to reduce financial, time and resource expenses for carrying out and realization of the further data actualization on resource potential of communities.

References

1. Bavrovska N., Boryskevych O. (2017) Inventory of land as the forming tool for the state land cadastre of ukraine in modern conditions. Viewed 21 January, 2021, (https://llufb.llu.lv/Raksti/Journal_Baltic_Surveying/2017/Journal_Baltic_SurveyingVol6_2017-51-58.pdf).
2. Land Use. Resource guide (2005) revised by Center for Land Use Education, University of Wisconsin-Stevens Point/Extension. 136 p.
3. Lowry J. (2006). Low-cost GIS software and data for wetland inventory, assessment and monitoring. Gland, Switzerland. 32 p.
4. Ramteke I.K., Sen T. K., Singh S. K., Chaterjee S., Obi Reddy G.P., Rajankar P. B., Das S.N. (2018). Geospatial techniques in land resource inventory and management: a review. International Journal of Remote Sensing & Geoscience (IJRSG), Volume 7, Issue 1, pp. 8-19.
5. Sombroek W.G., Antoine J. (2000). The Use of Geographic Information Systems (GIS) in Land Resources Appraisal. Viewed 21 January, 2021, (https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/colloques2/010008433.pdf).
6. Udovenko I., Kyselov I., Shemyakin M., Domashenko H., Kononenko S. (2020) Land inventory on the basis of methods of GIS technologies use. Viewed 21 January, 2021, (http://lib.udau.edu.ua/bitstream/123456789/7545/1/Udovenko%2C%20I.%2C%20Reznik%2C%20N.%2C%20Kyselov%2C%20I.%2C%20Shemyakin%2C%20M.%2C%20Domashenko%2C%20H.%2C%20Kononenko%2C%20S.%20Land%20inventory%20based%20methods%20of%20gis%20technologies%20use.pdf).
7. Дорош О. С. (2015) Інвентаризація земель: методичні підходи до її проведення [Land inventory: methodological approaches to its implementation]. АгроСвіт, №. 11, с. 24-30. (in Ukrainian)
8. Кондратенко Д. Ю. (2019) Інвентаризація земель як правова форма обліку земель [Land inventory as a legal form of land registry]. Науковий вісник Міжнародного гуманітарного університету. Сер.: Юриспруденція, № 42, Том. 1, с. 124-128. (in Ukrainian)
9. Лакатош М. І. (2013) Необхідність проведення інвентаризації земель в Україні. Організаційно-правові передумови [The need for land inventory in Ukraine. Organizational and legal prerequisites]. Науковий вісник Ужгородського університету. Серія «Географія. Землеустрій. Природокористування», № 2, pp. 156-161. (in Ukrainian)
10. Мартин А. Г. (2012). Інвентаризація земель: як її здійснювати в сучасних умовах [Land inventory: how to carry it out in modern conditions]. Viewed 20 January, 2021, (http://www.zsu.org.ua/index.php?option=com_content &view=article&id=2254:2011-05-27-14-48-38&catid=62:2011-01-12- 14-57-08&Itemid=87). (in Ukrainian)
11. Нестеренко Г. А., Бідун І. В. (2013). Інвентаризація земель як основний компонент у земельному кадастрі та системі управління земельними ресурсами (на прикладі Ківерцівського району Волинської області) [Land inventory as the main component in the land cadastre and land resources management system (on the example of Kivertsy district of Volyn region)]. Вісник Львівського національного аграрного університету. Серія «Економіка АПК», № 20(2), с. 153-158. (in Ukrainian)
12. Про затвердження Порядку проведення інвентаризації земель та визнання такими, що втратили чинність, деяких постанов Кабінету Міністрів України (Procedure for conducting land inventory and recognizing some resolutions of the Cabinet of Ministers of Ukraine as invalid) Постанова Кабінету Міністрів України від 05 червня 2019 р. № 476. Viewed 21 January, 2021, (https://zakon.rada.gov.ua/laws/show/476-2019-%D0%BF). (in Ukrainian)

Information about authors:
Iryna Koshkalda, Doctor of Economic Sciences, Professor, Chair of the Department of Land Resources Management and Cadastre, Kharkiv National Agrarian University named after V.V. Dokuchayev. Dokuchaevske-2, Kharkiv district, Kharkiv region, 62483, Ukraine, +38 050 323 55 94, irinavit1506@gmail.com. Land managenet, rational land use, land evaluation, land cadastre.
Tetiana Anopriienko, Candidate of Economic Sciences, Associate Professor of the Department of Planning of the Territory of Settlements and Construction, Kharkiv National Agrarian University named after V.V. Dokuchayev. Dokuchaevske-2, Kharkiv district, Kharkiv region, 62483, Ukraine, +38 095 688 83 77, atatyanav2017@gmail.com. Land managenet, rational land use, land evaluation, land cadastre, planning of territory.
Maryna Pilicheva, Candidate of Technical Sciences, Associate Professor, Associate Professor of the Department of Land Administration and Geoinformation Systems, O. M. Beketov National University of Urban Economy in Kharkiv, 17, Marshala Bazhanova Street, Kharkiv, 61112, Ukraine, +38 099 212 58 04, maryna.pilicheva@gmail.com. Land managenet, rational land use, land cadastre, geodesy, remote sensing.
Lubov Maslii, Senior Lecturer of the Department of Land Administration and Geoinformation Systems, O. M. Beketov National University of Urban Economy in Kharkiv, 17, Marshala Bazhanova Street, Kharkiv, 61112, Ukraine, +38 099 178 48 80, gnomomir@gmail.com. Land managenet, rational land use, land cadastre, geodesy.

DOI: 10.22616/j.balticsurveying.2021.14.003

SPATIAL PATTERN OF RESIDENTIAL DENSIFICATION IN HOUSING SUBMARKET OF A TRADITIONAL URBAN AREA

Mohammed Jibrin Katun [1], Sulyman Aremu Olanrewaju [2], Aliyu Abdullahi Alhaji [1]
[1]Federal Polytechnic, Bida, Nigeria
[2]Federal University of Technology, Minna, Nigeria

Abstract
The study aimed at examining the spatial pattern of residential densification in housing submarkets of Bida, an ancient traditional town in Nigeria. The study adopted the 2015 standard residential density of Niger State Urban Development Board to determine the level of residential density and occupancy rates of the various submarkets of the town. The study also adopted primary method of data collection through the use of satellite images, handheld GPS and georeferencing of demarcated areas and the buildings, using point features and vector approach in ArcGIS environment to achieve the area coverage, number of buildings and buildings per hectare (ha) in the housing submarkets. The finding of the study reveals that in 2008 Town housing submarket has the highest area coverage, followed by the Project Quarters and then GRA, but in terms of residential density, four housing submarkets of Town, Rahmatu Dangana, Gbazhi and Wadata have high densities above the other seven submarkets. The study further reveals that in the year 2013, additional eight housing submarkets have high residential densities, GRA medium density while Eyagi and Prject Quarters had low densities respectively. It was therefore recommended that there is the need for rational densification (planned densification) for urban development in order to check the increasing unplanned residential density that reduces the green and open spaces in urban environment.
Keywords: housing submarket; residential densification; spatial pattern; traditional urban area

Introduction

Nigeria's urban population is estimated at 44% in the year 2005 with an annual growth rate of 3.7% (United Nations, 2009) and increases to 48% in the year 2014 with 4.7% annual growth rate (United Nations, 2014). With this unprecedented rates of urban population expansion since 1996, it is perhaps not surprising that the housing supply of many cities are falling (Asian Development Bank, 2012; Asian Development Bank, 2015). Estimate by UN-Habitat shows that there are eight hundred and eighty-one million people currently dwelling in slums in the cities of the developing world compared to seven hundred and ninety-two in the year 2000. By 2025, adequate and affordable housing will likely be required by another 1.6 billion. This is, however, a wake-up call to authorities, advising them to take action resolutely to allow all urban residents to have access to housing (UN-Habitat, 2015). As rapid urban agglomeration is experienced globally, building additional living apartments has to be complemented by urban gentrification and densification actions. (Lin et al., 2015).

The on-going debate over the environmental sustainability of different urban forms is both assuming a high profile and contentious. In the context of urban planning (of the Global North) the discussion however seems to be primarily focused on the issue of densification (Schmidt-Thomé et al., 2013). Several policies promote urban densification (i.e., compact city forms creation or the densification of existing cities) in order to achieve reduction in urban sprawl. Urban densification denotes upsurge in the urbanisation level of a limited area, which could have negative impact on the urban green spaces biodiversity through habitats destruction, pollutions or increase of soil temperature, fragmentation and alteration of sociospatial structure (Vergnes et al., 2014). Although, urban densification is also viewed as problem solving approach (Leffers & Ballamingie, 2013, 2013).

However, urban densification conceived as intensification of built-up area as a result of concentrated urbanisation. This has great impact on urban forms and has caused changes in the housing sector most especially the housing market. Density has a wide range of application in urban form, population studies, transport studies, residential development, commercial development, in architecture and also by a varied range of professions (Medayese et al., 2015). According to Obateru (2005) density in urban forms can be measured in various ways; residential density, population density, housing density, occupancy rate, accommodation density, bedspace density and floor space rate.

Residential density is the ratio of a population to residential land area. This measure can be further classified in terms of net and gross residential densities based on the definition of the reference area. However, there is no consensus on the definitions of net and gross areas; as they vary across cities and countries (Medayese et al., 2015). Obateru (2005) conceived residential density to be the entire built-up area of human settlement. Broitman and Koomen (2015) sees urban densification as the housing units added within the existing urban area. Therefore, this study conceived urban densification in form of residential density growth (i.e., growth in the built-up area).

Measuring urban density has been a problem of many researchers (Ståhle, 2008). Broitman and Koomen (2015) measured residential densification using a high level detail spatial data that covers the whole of Netherland. Wang et. al. (2019) generate a land use transition of 2001 to 2011 matrix using land use maps with the aid of ArcGIS and examines the spatial and temporal urban density changes. In contrast, Jiao (2015) acquired high quality Landsat TM/ETM+ images, where the images classified using the Maximum Likelihood Classification method in ENVI 4.5. Urban densification was also measured using microclimate simulations with different models. The results are compared, and uncertainty ranges are documented by testing the impact of urban fabric on current climate (Loibl, 2019). Shahtahmassebi (2016) also developed a framework for measuring urban densification using time series of impervious surface fractions (ISFs) derived from remotely sensed imagery.

Housing submarkets are typically defined as geographic areas where the price per unit of housing quantity (defined using some index of housing characteristics) is constant (Goodman & Thibodeau, 1998). Although as an urban economic, land use and residential location model – the residential location theory (Alonso, Muth, Mills) is also applicable to housing market segmentation. Even without certain factors, segmentation of an urban area can still be carried out, if there is disparity in households' preferences and/or income with respect to accessibility and space (Kauko et al., 2002).

Although, there is agreement by several researchers on using locational and structural features to define a submarket, identifying a submarket and approach to be adopted have little consensus (Xiao, 2012). Usually, spatial and non-spatial specifications for housing submarket are the main two methods (Islam & Asami, 2009; Xiao, 2017). People's housing choice of homogenous preferences based on geographic predefined areas are enphasised by spatial specifications which is the main index (e.g. political districts, north/south, inner/outer city, and postcode districts) (Xiao, 2012).

Hitherto, several studies were conducted on housing segmentation based on spatial specification For example, McCluskey & Borst (2011) uses utilises Geographically Weighted Regression (GWR), a geostatistical modeling method to identify and demarcate the housing submarkets. Goodman & Thibodeau (1998) describes housing submarkets as a geographical area where housing price per service unit is constant and characteristics of individual housing are available for purchase. Wu & Sharma (2012) developed a methodology for submarket classification based on spatially constrained data-driven to achieve spatially integrated housing market segments. Park (2013) proposes spatial housing submarkets division basis in enhancing the housing market understanding. Manganelli et al. (2014) adopted Geographically Weighted Regression (GWR) in housing market analysis, in homogeneous areas through identification and defining a single location marginal contribution to the property's value at the housing market. Accuracy of estimation is emphasised by non-spatial submarket specifications, promoting a data driven method, without considering the pre-defined geographic area (Goodman & Thibodeau, 1995; Xiao, 2012).

These techniques are used in building the submarket emphasis on the house prices supply-side and uses housing stock characteristics (e.g., square feet of living area, dwelling type, dwelling age) to build the submarkets and/or neighbourhood characteristics (e.g., neighbourhood schools quality, local police quality). Other techniques in delineating submarket emphasis on demand-side of house prices determinants and form housing submarkets based on household incomes or other socioeconomic/demographic characteristics (Goodman & Thibodeau, 2007; Xiao et al., 2016). Both spatial and non-spatial approaches to housing market segmentation have received wide range criticism. It make scientific research complex and not simply replicated (Xiao, 2012), while non-spatial approach is said to be ambiguities in presentation for interventions of policy (Xiao, 2017).This indicates that both spatial and non-spatial approaches of housing submarket delineation cannot effectively represent true nature of the submarket.

Bida a typical traditional setting is experiencing urban densification which has attracted people from different parts of the country and consequently led to an increase in housing demand. The intensity of housing demand in the city has also resulted in increased residential densities of various housing submarkets.

Several literatures have emerged on housing submarket (for example, Royuela Mora & Vargas, 2007; Park, 2013; Manganelli, Pontrandolfi, Azzato, & Murgante, 2014), very little is written on delineation of housing market (for example, Wu & Sharma, 2012; Manganelli *et al.*, 2014). Wu & Sharma (2012) classified housing submarket by developing a spatially constrained data-driven methodology to segment the housing market. Specifically, the model based on cluster analysis and Principal Component Analysis

(PCA) was developed for housing submarket delineation. The model constitutes a number of locational attributes which were used for PCA, and also the incorporation of spatial locations of the houses into the cluster analysis. Manganelli *et al*., (2014) adopted Geographically Weighted Regression in analysing housing market, in order to identify homogeneous areas and to define housing submarkets. The studies focus on the spatial specification of housing submarket delineation which has been criticised (Xiao, 2012). However, none of these studies focus on the residential density changes in housing submarkets.

Therefore, this study focused on the spatial specification of housing submarket delineation due to the nature of data and type of investigation which is best explained using this method of housing submarket classification. It is on this premise this paper intends to examine the pattern of residential densification of housing submarket in Bida, Nigeria between years 2008 – 2018.

Methodology

This study is carried out in Bida town, an ancient traditional Nupe settlement in the north central Nigeria. The settlement is located on latitude 9.083N and longitude 6.017E (Fig. 1). The town is headquarters of Nupe speaking nation, which is ruled by both the Chairman of the Local Government and the Emir as the traditional ruler. The town has a total built up area of about 67.45km^2 and 255,008 inhabitants, according to the last national population figures census (Mohammed & Sulyman, 2019).

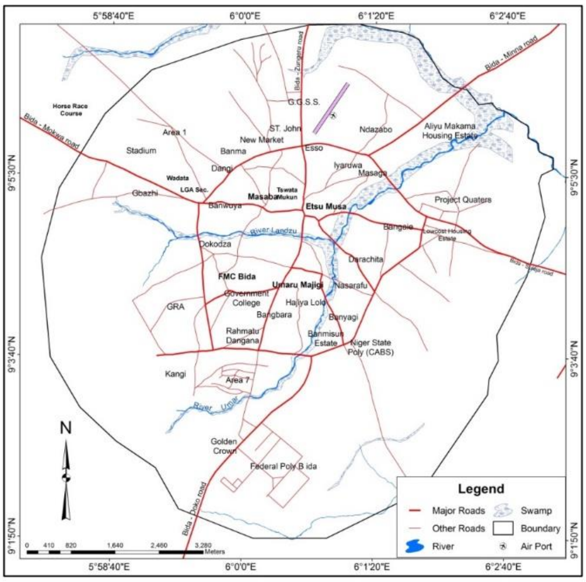


Fig. 1. Map of Bida, the Study

The housing submarket was demarcated based on the market structure by professional estate surveyors and valuers in the study area. Satellite imageries were captured for the housing submarkets using the area demarcations. For each demarcated area, three satellite imageries were captured for three different periods, i.e., 2008, 2013 and 2018 using 6 metres resolution on the Google Earth application. Images captured using area demarcation gives better resolution. The choice of Google Earth is due to its user friendly and historical images available.

Satellite images captured based on the demarcated areas were georeferenced where vector approach was adopted in digitising all the buildings using point features in ArcGIS environment for better data handling. The entire buildings for each year under study were represented by points.

This paper adopted residential density measurements by Niger State Urban Development Board (2015). Using this, residential density vis-à-vis the occupancy rates of building in a given location to give level of density, which was calculated as:

Building occupancy rate = $\frac{Number\ of\ buildings\ in\ a\ submarket}{Total\ land\ area\ of\ the\ submarket}$

For example, low density is between 0 – 1.49 occupancy rate, medium density is between 1.5 – 1.99 occupancy rate while high density is 2.0 and above occupancy rate (Table 1).

Table 1

Residential Density Level Measurement

Occupancy Rates	Residential Density Level
0 – 1.49	Low
1.5 – 1.99	Medium
2.0 and above	High

Source: Niger State Urban Development Board (2015)

Results

The pattern of urban densification dynamics in terms of level of residential density by housing submarkets and number of buildings and area coverage by housing submarkets is discussed in this section. This was achieved by measuring the total area of the housing submarkets, number of buildings in the housing submarkets and buildings per hectare (ha) in the housing submarket. It was found out that Town housing submarket have highest area coverage with 1,214.97ha. This is followed by Project Quarters with 984.31ha; Poly Area and GRA have area coverage of 823.13ha and 800.08ha respectively (Table 1, 2 and 3).

Table 2

Residential Density Level and Building Units Per Hectares by Housing Submarkets 2008

Submarket	Area Coverage (Ha)	No. of Buildings	Occupancy Rate	Density Level
Kangi	457.52	661	1.44	Low Density
Rahmatu Dangana	14.5	83	5.72	High Density
Town	1214.97	25945	21.35	High Density
Poly Area	823.13	787	0.96	Low Density
Eyagi	725.34	165	0.23	Low Density
Gbazhi	215.81	489	2.27	High Density
Wadata	398.51	1020	2.56	High Density
Avenue	417.08	524	1.26	Low Density
Ndazabo	692.99	605	0.87	Low Density
Project Qtrs	984.31	358	0.36	Low Density
GRA	800.08	773	0.97	Low Density

Source: Authors' field survey, 2019

Residential density is measured by the residential development within the housing submarkets. The study revealed in Fig. 2 that in the year 2008 four housing submarkets i.e., Town, Rahmatu Dangana, Gbazhi and Wadata each are of high residential density respectively, where the remaining seven submarkets are of low residential densities in that year. The implication of this result is that residential density pattern was classified in to two – i.e. low residential densities and high residential densities for the year 2008.

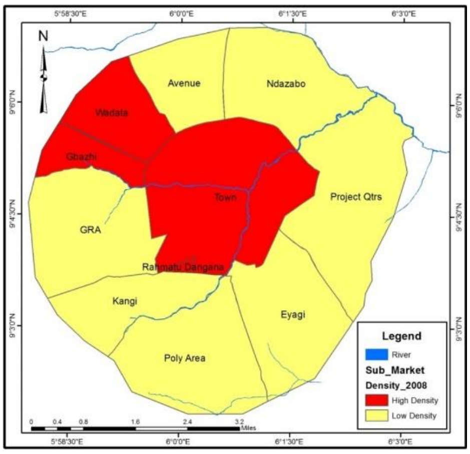


Fig. 2. Level of Residential Density by Housing Submarkets in the Year 2008
Source: Authors' field survey, 2019

This implies that people live in the Town housing submarket than any other submarkets in the study area. The Town housing submarket is also the traditional city centre where major commercial and cultural activities take place. The result also implies that Rahmatu Dangana with smallest area coverage is highly developed.

Table 3

Residential Density Level and Building Units Per Hectares by Housing Submarkets 2013

Submarket	Area Coverage (Ha)	No. of Buildings	Occupancy Rate	Density Level
Kangi	457.52	1103	2.41	High Density
Rahmatu Dangana	14.5	132	9.10	High Density
Town	1214.97	34242	28.18	High Density
Poly Area	823.13	1648	2.00	High Density
Eyagi	725.34	304	0.42	Low Density
Gbazhi	215.81	2077	9.62	High Density
Wadata	398.51	1707	4.28	High Density
Avenue	417.08	1283	3.08	High Density
Ndazabo	692.99	1758	2.54	High Density
Project Qtrs	984.31	793	0.81	Low Density
GRA	800.08	1442	1.80	Medium Density

Source: Authors' field survey, 2019

The result in Table 3 shows that in the year 2013 Town housing submarket had highest number of building units with 34,242. This is followed by Gbazhi with 2,077, Ndazabo 1,758, Wadata 1,707 building units respectively. During this period, the study reveals that Rahmatu Dangana had smallest number of building units. The result also shows that Town submarket recorded highest number of building to area ratio with 28.18, followed by Gbazhi with 9.62, Rahmatu Dangana 9.10 and Wadata 4.28 respectively. The lowest building to area ratio is recorded for Eyagi with 0.42.
The study further reveals in Fig. 3 that in the year 2013 eight housing submarkets have their residential densities to be high while GRA had medium residential density and Eyagi and Project Quarters had low residential densities respectively. The pattern of the residential density implies that there is tremendous shift in the residential density changes in the study area in that year.

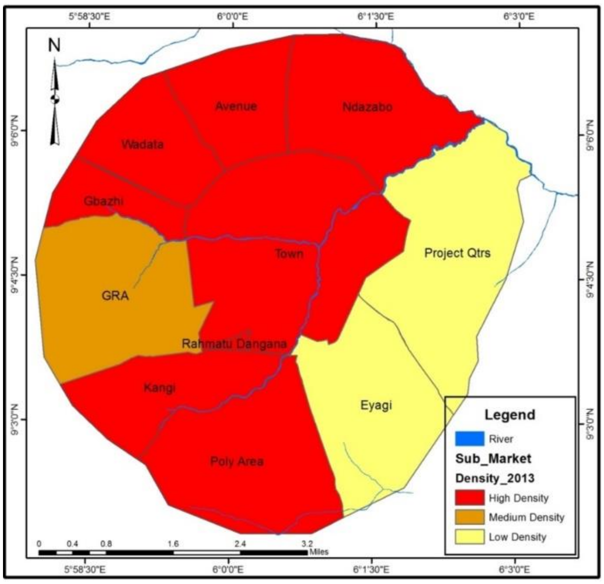


Fig. 3. Level of Residential Density by Housing Submarkets in the Year 2013

Source: Authors' field survey, 2019

The study revealed in Table 4 that in the year 2018 Town submarket had highest number of buildings with 29,985 followed by Poly Area with 2,450, Ndazabo 2,346, Gbazhi 2,331, Wadata 2,300 and Kangi 2,134 building units respectively. The lowest number of building units recorded was in Rahmatu Dangana with 124. The Table also revealed that Town submarket had highest building to area ratio with 24.68. This is followed by Gbazhi with 10.80 and Rahmatu Dangana 8.55. The lowest building to area ratio was recorded for Eyagi with 0.54.

Table 4

Residential Density Level and Building Units Per Hectares by Housing Submarkets 2018

Submarket	Area Coverage (Ha)	No. of Buildings	Occupancy Rate	Density Level
Kangi	457.52	2134	4.66	High Density
Rahmatu Dangana	14.5	124	8.55	High Density
Town	1214.97	29985	24.68	High Density
Poly Area	823.13	2450	2.98	High Density
Eyagi	725.34	393	0.54	Low Density
Gbazhi	215.81	2331	10.80	High Density
Wadata	398.51	2300	5.77	High Density
Avenue	417.08	1976	4.74	High Density
Ndazabo	692.99	2346	3.39	High Density
Project Qtrs	984.31	1466	1.49	Low Density
GRA	800.08	1889	2.36	High Density

Source: Authors' field survey, 2019

In the year 2018, urbanisation effects have a great impact on the urban form. The study in Fig. 4 shows that all the housing submarkets in the study area are of high residential densities except for Eyagi and Project Quarters who were of low residential densities respectively. This implies that there is transition from low residential density areas to high residential density areas in the study area. The entire housing market is becoming more developed as built-up areas increases in all dimensions.

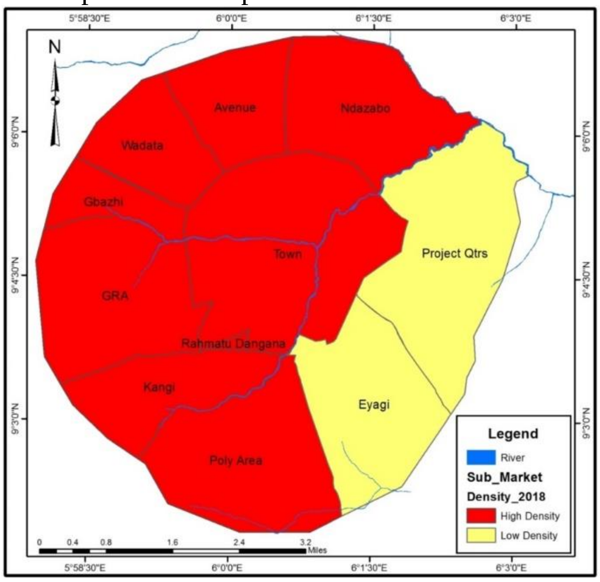


Fig. 4. Level of Residential Density by Housing Submarkets in the Year 2018
Source: Authors' field survey, 2019

The implication of this result is that transition in the urban morphology experienced tremendous changes where number of buildings in the Town submarket reduced from 34,242 in the year 2013 to 29,985 in the year 2018. This could be attributed to Bida old market razed by fire in early 2018. The result also implies that there was high residential development in Poly Area, Ndazabo and Gbazhi submarkets during this period which may have occasioned the sudden reduction.

Discussion

It was found out that in the year 2008, Town housing submarket have highest area coverage with 1,214.97ha. This is followed by Project Quarters with 984.31ha; Poly Area and GRA have area coverage of 823.13ha and 800.08ha respectively. It also revealed that people lived in the Town housing submarket than any other submarkets in the study area in all years under review, because the Town housing submarket is the traditional city centre where major commercial and cultural activities take place. The result revealed that Rahmatu Dangana with smallest area coverage is highly developed in the year 2013. The implication of this result is that transition in the urban morphology experienced tremendous changes where number of submarkets increases from 4 (Fig. 2) to 8 (Fig 3) and subsequently to 9 (Fig. 4) with additional high residential densities due to rapid urbanisation and development of built-up areas in all dimensions, but buildings in the Town submarket reduced from 34,242 in the year 2013 to 29,985 in the year 2018. This could be attributed to Bida old market razed by fire in early 2018. The result also implies that there was high residential development in Poly Area, Ndazabo and Gbazhi submarkets during this period which may have occasioned the sudden reduction. This finding is contrary to findings of Broitman and Koomen (2019) which opines that number of housing units located within the first several hundreds of metres around the city centre is usually low as an example of typical feature of historic cities.

The study revealed that in the year 2008 four housing submarkets i.e., Town, Rahmatu Dangana, Gbazhi and Wadata are of high residential density respectively, where the remaining seven submarkets are of low residential densities in that year. Findings of this study also showed that in the year 2013 eight housing submarkets have their residential densities to be high while GRA had medium residential density and Eyagi and Project Quarters had low residential densities respectively. The study also revealed that all the housing submarkets in the study area are of high residential densities except for Eyagi and Project Quarters who were of low residential densities respectively. The study also revealed that spatial approach to housing submarket allow easy analysis of data related to housing market and submarkets such as residential densification, and related housing studies. This is because homogeneous geographic locations can easily be identified and analysed.

Conclusion

From the study, it can be concluded that the inner part of the city has higher number of buildings throughout the study period and it is the region where commercial and cultural activities are carried out. The city centre maintains consistent high number of buildings units/ha and high residential density through the years under reviewed. This study therefore concludes that there has been consistent residential development from Town submarket in the year 2008 towards the north and south in the year 2013 with additional high density housing submarkets due to rapid urbanisation and increasing built-up areas with only low density housing submarkets in Eyagi and Project Quarters in 2018, indicating an evidence for increasing uncontrolled residential densification in the study area. Hence, the unplanned densification in urban environment could have negative implications through reduce green and open spaces, on optimal land resources utilisation and urban housing market. The study therefore recommends rational densification that could deliberately curb the increasing residential densities and its attendant negative implications. The study also recommends the application of GIS and spatial approach to housing market studies, particularly, the housing submarket and related studies.

References

1. Asian Development Bank. (2012). The State of Pacific Towns and Cities: Urbanization in ADB's Pacific Development Member Countries. Asian Development Bank.
2. Asian Development Bank. (2015). 'Revisiting the GMS Economic Corridor Strategies and Action Plans', Discussion Paper Prepared for the 7th Economic Corridors Forum Kunming. Asian Development Bank. http://www.adb.org/sites/default/files/related/33507/revisiting-the-gms-strategies-andaction-plans.pdf
3. Broitman, D., & Koomen, E. (2015). Residential density change: Densification and urban expansion. Computers, Environment and Urban Systems, Volume 54, pp. 32–46. https://doi.org/10.1016/j.compenvurbsys.2015.05.006
4. Broitman, D., & Koomen, E. (2019). The attraction of urban cores: Densification in Dutch city centres. Urban Studies, 004209801986401. https://doi.org/10.1177/0042098019864019

5. Goodman, A. C., & Thibodeau, T. G. (1995). Age-Related Heteroskedasticity in Hedonic House Price Equations. Journal of Housing Research, Volume 6, Issue 1, pp. 25–42
6. Goodman, A. C., & Thibodeau, T. G. (1998). Housing market segmentation. Journal of Housing Economics, Volume 7, Issue 2, pp. 121–143
7. Goodman, A. C., & Thibodeau, T. G. (2007). The Spatial Proximity of Metropolitan Area Housing Submarkets. Real Estate Economics, Volume 35, Issue 2, pp. 209–232. https://doi.org/10.1111/j.1540-6229.2007.00188.x
8. Islam, K. S., & Asami, Y. (2009). HOUSING MARKET SEGMENTATION: A REVIEW. Review of Urban & Regional Development Studies, Volume 21, Issue 2–3, pp. 93–109. https://doi.org/10.1111/j.1467-940X.2009.00161.x
9. Jiao, L. (2015). Urban land density function: A new method to characterize urban expansion. Landscape and Urban Planning, Volume 139, pp. 26–39. http://dx.doi.org/10.1016/j.landurbplan.2015.02.017
10. Kauko, T., Hooimeijer, P., & Hakfoort, J. (2002). Capturing Housing Market Segmentation: An Alternative Approach based on Neural Network Modelling. Housing Studies, Volume 17, Issue 6, pp. 875–894. https://doi.org/10.1080/02673030215999
11. Leffers, D., & Ballamingie, P. (2013). Governmentality, environmental subjectivity, and urban intensification. Local Environment, Volume 18, Issue 2, pp. 134–151. https://doi.org/10.1080/13549839.2012.719016
12. Lin, B., Meyers, J., & Barnett, G. (2015). Understanding the potential loss and inequities of green space distribution with urban densification. Urban Forestry & Urban Greening, Volume 14, Issue 4, pp. 952–958. https://doi.org/10.1016/j.ufug.2015.09.003
13. Manganelli, B., Pontrandolfi, P., Azzato, A., & Murgante, B. (2014). Using geographically weighted regression for housing market segmentation. International Journal of Business Intelligence and Data Mining 13, Volume 9, Issue 2, pp. 161–177
14. McCluskey, W. J., & Borst, R. A. (2011). Detecting and validating residential housing submarkets: A geostatistical approach for use in mass appraisal. International Journal of Housing Markets and Analysis, Volume 4, Issue 3, pp. 290–318. https://doi.org/10.1108/17538271111153040
15. Medayese, M., Martins, V. E., & Abdrazack, N. T. (2015). Density. In L. Egunjobi (Ed.), Contemporary Concepts in Physical Planning (First Edition, Vol. 1, pp. 263–290). University of Ibadan
16. Mohammed, J. K., & Sulyman, A. O. (2019). Spatio-temporal Analysis of Bida Housing Market using Geographic Information System. In L. T. Ajibade, N. B. Tanimowo, G. Amuda-Yusuf, & N. A. Bello (Eds.), The Proceedings of International Conference of Environmental Sciences, pp. 306–316
17. Park, J. (2013). The Division of Spatial Housing Submarkets: A Theory and the Case of Seoul. Environment and Planning A, Volume 45, Issue 3, pp. 668–690. https://doi.org/10.1068/a45337
18. Royuela Mora, V., & Vargas, M. (2007). Defining housing market areas using commuting and migration algorithms. Catalonia (Spain) as an applied case study. *IREA*–Working Papers, 2007, IR07/07
19. Schmidt-Thomé, K., Haybatollahi, M., Kyttä, M., & Korpi, J. (2013). The prospects for urban densification: A place-based study. Environmental Research Letters, Volume 8, Issue 2, pp. 025020. https://doi.org/10.1088/1748-9326/8/2/025020
20. Ståhle, A. (2008). Compact sprawl: Exploring public open space and contradictions in urban dens*ity*. School of Architecture, KTH
21. UN-Habitat. (2015). Housing at the Centre of the New Urban Agenda. UN-Habitat
22. United Nations. (2009). Challenges to Sustainable Development. United Nations, Department of Economic and Social Affairs, Population Division. http://www.un.org/en/development/desa/financialcrisis/challenges.shtml
23. United Nations. (2014). World Urbanization Prospects: *The 2014 Revision*. United Nations, Department of Economic and Social Affairs, Population Division
24. Vergnes, A., Pellissier, V., Lemperiere, G., Rollard, C., & Clergeau, P. (2014). Urban densification causes the decline of ground-dwelling arthropods. Biodiversity and Conservation, Volume 23, Issue 8, pp. 1859–1877. https://doi.org/10.1007/s10531-014-0689-3
25. Wang, L., Omrani, H., Zhao, Z., Francomano, D., Li, K., & Pijanowski, B. (2019). Analysis on urban densification dynamics and future modes in southeastern Wisconsin, USA. PLOS ONE, Volume 14, Issue 3, pp. 1–22. https://doi.org/10.1371/journal.pone.0211964
26. Wu, C., & Sharma, R. (2012). Housing submarket classification: The role of spatial contiguity. Applied Geography, Volume 32, Issue 2, pp. 746–756. https://doi.org/10.1016/j.apgeog.2011.08.011
27. Xiao, Y. (2012). Urban morphology and housing market [PhD Thesis]. Cardiff University
28. Xiao, Y. (2017). Urban Morphology and Housing Market. Springer Singapore. https://doi.org/10.1007/978-981-10-2762-8
29. Xiao, Y., Webster, C., & Orford, S. (2016). Can street segments indexed for accessibility form the basis for housing submarket delineation? Housing Studies, Volume 31, Issue 7, pp. 829–851. https://doi.org/10.1080/02673037.2016.1150433

Information about authors:
Jibrin Katun Mohammed, M.Tech (in view), lecturer, Department of Estate Management and Valuation, Federal Polytechnic, P.M.B 55, Bida, Nigeria, phone: +2348068868547, e-mail: muhammad.jibrinkatun@fedpolybida.edu.ng Fields of interest: urban form, housing market, GIS.
Aremu Olanrewaju Sulyman, Ph.D., associate professor, Department of Urban and Regional Planning, Federal University of Technology, P.M.B 65, Minna, Nigeria, phone: +2348033900864, e-mail: sulymanlance@gmail.com Fields of interest: housing, urban renewal, infrastructure planning.
Abdullahi Alhaji Aliyu, Ph.D. (in view), principal lecturer, Department of Urban and Regional Planning, Federal Polytechnic, P.M.B 55, Bida, Nigeria, phone: +2348063585110, e-mail: aliyuabdul777@mail.com Fields of interest: urban management, environmental impact assessment, infrastructure planning.

DOI: 10.22616/j.balticsurveying.2021.14.004

METHODOLOGY FOR DETERMINING SITE-SPECIFIC MANAGEMENT ZONES UPON IMPLEMENTATION OF PRECISION FARMING IN BELARUS

Myslyva Tamara, Kutsayeva Alesia, Kazheka Alesia
Belarussian State Agricultural Academy

Abstract
The aim of the study was to develop a methodology for determining homogeneous territorial zones for precision farming. In this study we took into account the national land use system which provides for the absence of private ownership of agricultural land. The algorithm for determining management-zones provides for: establishing zones of spatial heterogeneity; determining the presence of clusters and emissions; modeling the spatial distribution of soil quality indicators. It is recommended to use data from agrochemical soil studies which are conducted centrally every 4 years for each agricultural enterprise as input parameters. These data include: the humus content in the soil, the content of available phosphorus and potassium and soil pH. The data should be carefully examined using spatial statistics tools to provide a more accurate delineation of the management-zones boundaries. The developed technique makes it possible to determine fertile and marginal areas within each individual field and differentiate the use of fertilizers, taking into account the presence of intra-field heterogeneity. This will save from 2.5 to 21.8 kg P ha^{-1} and from 0.9 to 26.7 kg K ha^{-1} due to the redistribution of the fertilizer dose calculated for the planned yield, taking into account the identified site-specific management zones. The differentiated use of mineral fertilizers will increase the profitability of growing winter cereals by 2.2%, sugar beets by 1.3%, rapeseed by 1.1%, and malting barley by 0.8%.
Key words: land management, management zones, geospatial analysis, precision farming, profitability.

Introduction

The presence of intra-field heterogeneity - the fundamental basis of precision farming is the result of a complex interaction of biological (pests, lumbricides), soil (salinity, organic matter, macro- and microelements, particle size distribution), anthropogenic (acidification, loss of organic matter, soil compaction, contamination with pesticide residues), topographic (slope, flow direction, flow accumulation) and climatic (relative humidity, temperature, precipitation) factors (Corwin at al., 2010; Heege, 2013; Myslyva, 2020). The identification of management zones (MZ) as one of the key components of precision farming - an agricultural management strategy aimed at maximizing the productivity and resistance of agricultural crops to unfavourable environmental factors through the optimal use of material and production resources, is carried out precisely by taking into account the intra-field spatial heterogeneity (Méndez-Vázqueza at al., 2019).

Despite the presence of a significant number of studies devoted to the identification of intra-field heterogeneity, a unified method for its determination has not yet been developed. Researchers propose different approaches to identify areas of spatial heterogeneity for precision farming purposes. They are usually based either on the use of yield maps (Yuxin Miao et al., 2018), or on the use of soil and topographic properties (Vitharana et al., 2008; Davatgar et al., 2012) and data on soil conductivity, remote sensing data, vegetation indices, or a combination of several types of data (Georgi et al., 2018; Shannon et al., 2018; Edge, 2019). Such a variety of approaches is due to the fact that when introducing precision farming, it is necessary to take into account a number of different factors that have significant differences in the context of individual climatic zones, countries, continents. In addition to choosing a method for determining management- zones, the question of their optimal number also remains unresolved. In particular, when cultivating corn for grain, American scientists recommend allocating two or three management zones within the field, using information on the content of the clay fraction in the soil, the slope of the territory, the content of soil organic matter, the value of the topographic moisture index and NDVI (Reyes at al., 2019). Other researchers recommend distinguishing from three to five management zones according to such indicators as the topography of the territory and the electrical conductivity of the soil when growing grain crops (wheat, soybeans, and grain sorghum) in conditions of insufficient moisture (Fraisse at al., 2001). An integrated approach to the determination of MZ for nitrogen application in corn and soybean growing using relative elevation, organic matter, slope, electrical conductivity, yield spatial trend map, and yield temporal stability map has been identified as the most appropriate in the studies of American scientists. At the same time, it is indicated that the optimal number of allocated MZ should be no more than three, which will provide the potential for

economic return at the level of 19–55 USD/ha, depending on the zone (Yuxin Miao at al., 2018). German scientists proposed to use remote sensing data with a spatial resolution of 6.5 m to determine the zones of plant productivity according to the value of the vegetation index NDVI, which are advisable to use as potential management zones (Georgi at al., 2018). When introducing precision farming technology for growing grain crops, Pakistani scientists propose to identify four management zones, taking into account such indicators as the percentage of sand and clay fraction in the soil, the topography of the territory, the electrical conductivity of the soil and the nitrogen content (Farid at al., 2016). Researchers from Nigeria propose to distinguish four management zones according to a set of indicators, including: the content of total nitrogen and phosphorus, bulk soil density, carbon content, volumetric moisture, pH of the soil and its texture (content of sand, silt and clay) for the differentiated use of mineral fertilizers in growing vegetable crops (Oshunsanya at al., 2017).
The Republic of Belarus, which has just begun to introduce some elements of precision farming, in particular Variable Rate Technologies (VRT) also faced the problem of choosing both a method for determining zones of intra-field spatial heterogeneity and the optimal number of zones. Therefore, the purpose of this study was twofold: 1) to analyze the basic strategies for determining cite-specific zones and on the basis of their critical analysis, to develop methodological approaches and determine the parameters recommended for defining homogeneous management zones when introducing precision farming technology in the conditions of the Republic of Belarus; 2) to substantiate the methodological approaches for the use of geospatial statistics tools and develop a methodology for the formation of homogeneous territorial management zones in the process of on-farm land management for precision farming proposes.

Methodology of research and materials

Methods that were used in this research include analysis and synthesis method, a systematic approach method, abstraction, geostatistical and comparative research. The studies were carried out in 2017-2020 in such territories: 1) Gorky district of Mogilev region (Republic of Belarus) within the land use of RUE "Educational and experimental farm BSAA" on an area of 8342.1 thousand hectares of arable land (Figure 1); 2) Orsha district of Vitebsk region (Republic of Belarus) within the land use of RPUE "Ustye" NAS of the Republic of Belarus on an area of 7549.49 thousand hectares of arable land (Figure 2).

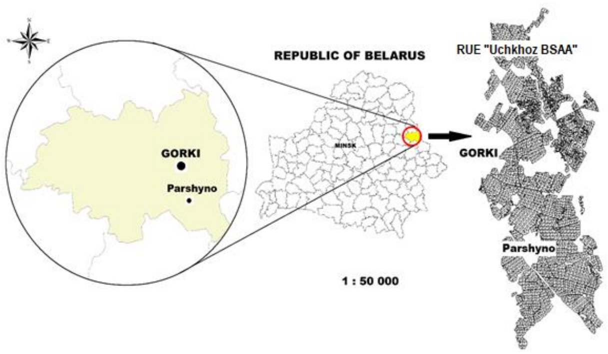


Fig. 1. The location of the studied territory of RUE "Educational and experimental farm BSAA"

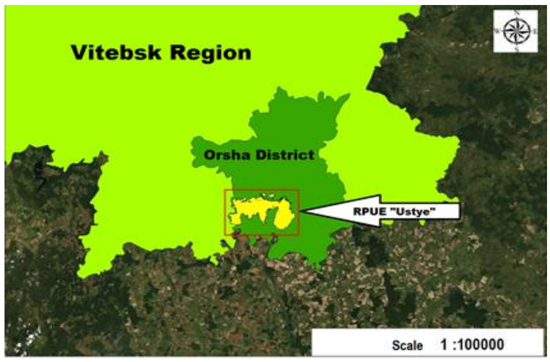


Fig. 2. The location of the studied territory of RPUE "Ustye" NAS of the Republic of Belarus

The climatic conditions of the study area are typical for the northeastern zone of the Republic of Belarus. The sum of active temperatures ranges from 2200 to 2400 degrees, and the average annual precipitation is 579 mm. The soil cover of the study area is represented by Sod-podzolic, Umbric Retisols (WRB, 2016); Eutric Podzoluvisol (FAO, 1988).
Agricultural enterprises on whose land use the research was carried out, specialize in dairy and meat production with developed grain production. The technologies they use for growing agricultural crops are generally accepted and are regulated by sectoral regulations that are binding on all subjects of agricultural activity on the territory of Belarus (Organizational and technological standards…. 2012a; 2012b).
The shape files with the placement of land within the study territories were created based on the results of digitization of planning and cartographic materials, which were obtained from the agrochemical

survey of the territory of RUE "Educational and experimental farm BSAA", executed in 2018 by the Mogilev regional design and exploration station of agrochemicalization and the territory of RPUE "Ustye" NAS of the Republic of Belarus, executed in 2019 by the Vitebsk regional design and exploration station of agrochemicalization.

Identification of management zones and calculation of their areas within the study land use were carried out using the ArcGIS version 10.5.

The global Moran (I) index was calculated by the formula (1) (Mitchell, 2005):

$$\mathrm{I} = \frac{n\sum_{i=1}^{n}\sum_{j=i}^{n} w_{ij}(y_i-\bar{y})(y_j-\bar{y})}{[\sum_{i=1}^{n}\sum_{j=i}^{n} w_{ij}][\sum_{i=1}^{n}(y_i-\bar{y})^2]} \tag{1}$$

Where n denotes the number of units in the sample,

w_{ji} denotes the weight of the spatial relationship between the i-th and j-th sampling units,

y_i denotes the attribute value for the i-th sample unit,

$\bar{y}$ denotes the sample mean value of the attribute.

The Getis-OrdGi * index value was counted using the formula (2) (Mitchell, 2005):

$$\text{Getis-OrdGi*} = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{[n\sum_{j=1}^{n} w_{i,j}^2 - (\sum_{j=1}^{n} w_{i,j})^2]}{n-1}}} \tag{2}$$

Where x_j denotes the attributive value of the object of observation,

$w_{i,j}$ denotes spatial weight between objects i and j,

n denotes the total number of objects.

Geospatial data analysis was used to pinpoint areas of spatial heterogeneity with low, fair, good and excellent land quality.

The economic efficiency of differentiated fertilization was carried out by determining the economic benefit of reducing the cost of purchasing and applying mineral fertilizers when growing individual crops. According to sectoral regulations documents (Organizational and technological standards…. 2012a; 2012b), the rates of fertilization for the planned yield of agricultural crops were calculated both for the entire area of the field and separately for each MZ defined within it. The costs for the purchase and application of mineral fertilizers, with and without taking into account intra-field heterogeneity, were calculated in a similar way. At the final stage, the profitability of growing crops using traditional and differentiated rates of mineral fertilizers was assessed.

Statistical processing of experimental data and the creation of mathematical models were carried out using Statistica version 13.0.

Discussion and results

The main task of modern land management in Belarus in the context of the introduction of precision farming is to develop a methodology for creating up-to-date digital maps and delineating land use territories by a set of land quality indicators. The market for similar products in the structure of elements of the precision farming system in the EU countries has grown by more than 17.5% over the past 5 years and is about 32% (Daheim et al., 2016), showing a steady upward trend (Aulbur et al., 2019).

The introduction of any element of the precision farming system should begin with the identification of management zones within the land use of agricultural organizations, which are more or less homogeneous not in one but in a number of indicators. In this regard the management zone in our opinion is a subsystem of precision farming and is a set of input parameters that are the basis for its determination and form a reaction as an economic effect that manifests itself in various aspects. On-farm land management is a universal tool for defining management zones and ensuring interaction between their input and output parameters. At the same time, the implementation of land management functions to define management zones should be carried out through the use of the functionality of geographic information systems. Moreover, the identification of site-specific management zones with the best and worst set of soil quality indicators (or other indicators, for example, the topography of the territory, agrophysical properties, productivity, values of vegetation indices) should be carried out as a mandatory measure within the framework of an on-farm land management (Figure 3).

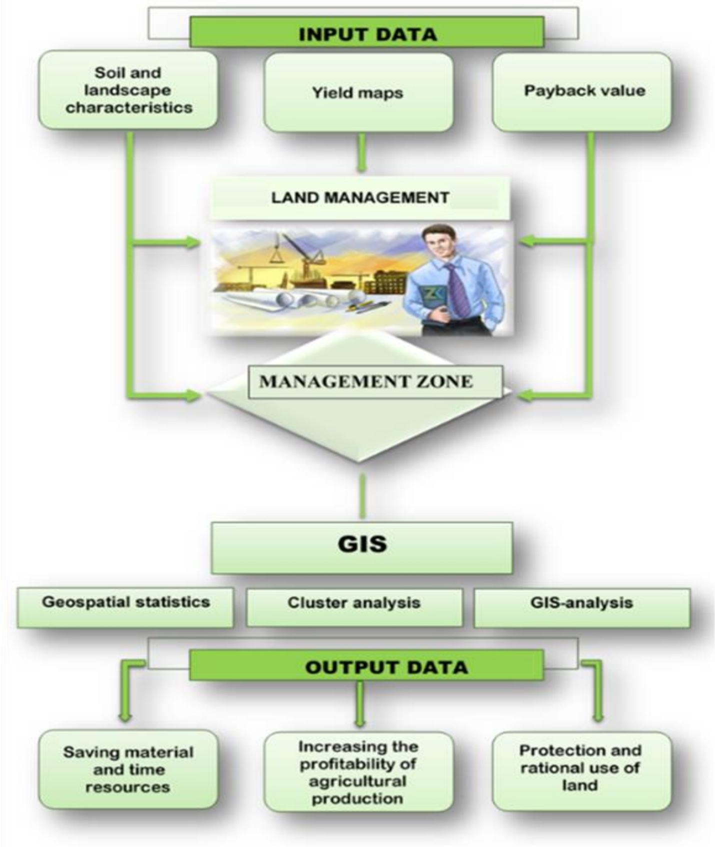


Fig. 3. The structure of the management zone as a subsystem of precision farming

In the future, the site-specific management zone should become an alternative to the use of elementary plots, which are the smallest spatial unit used in the implementation of on-farm land management and agrochemical survey of the land use area.

As mentioned earlier, today there are four main approaches to defining management zones: Approach 1: fields are divided into management zones in accordance with the values of one or more characteristics of the soil and landscape; Approach 2: determination of management zones is carried out using yield maps; Approach 3: management zones are determined by the value of the return on costs, primarily for the application of mineral fertilizers and plant protection products; Approach 4: integrated use of information about soil parameters or landscape characteristics and about the yield of agricultural crops or the return on costs of obtaining it.

The results of a critical analysis of these approaches as applied to the economic conditions of the Republic of Belarus indicate the following. Since elements of precision farming technology have just been introduced in Belarus, it is impossible to apply approach 3 based on economic characteristics. However, the definition of zones based on the values of soil parameters used in the US and EU countries (approach 1) and yield indicators (approach 2) also has a number of limitations. Based on this, when developing a methodology for determining management zones taking in regard the present conditions within the Republic of Belarus, the results obtained during an agrochemical survey of agricultural lands should be used as the initial ones. Data on soil chemical parameters are the results most often used by the agronomic services of agricultural enterprises. These parameters include, first of all, the content of humus, mobile phosphorus and potassium in the soil, as well as the pH of the soil solution. The list of recommended soil parameters can be expanded depending on the availability of geospatial data on soil properties and the requirements for defining management zones. In particular, it should contain information about the content of microelements in the soil, as well as the level of its contamination with pesticide residues, heavy metals and radionuclides.

The methodology has been developed for the identification of homogeneous territorial management zones for land management purposes when introducing precision farming (Figure 4). This technique has been tested within the land use of RUE "Educational and experimental farm BSAA" with an area of more than 8 thousand hectares.

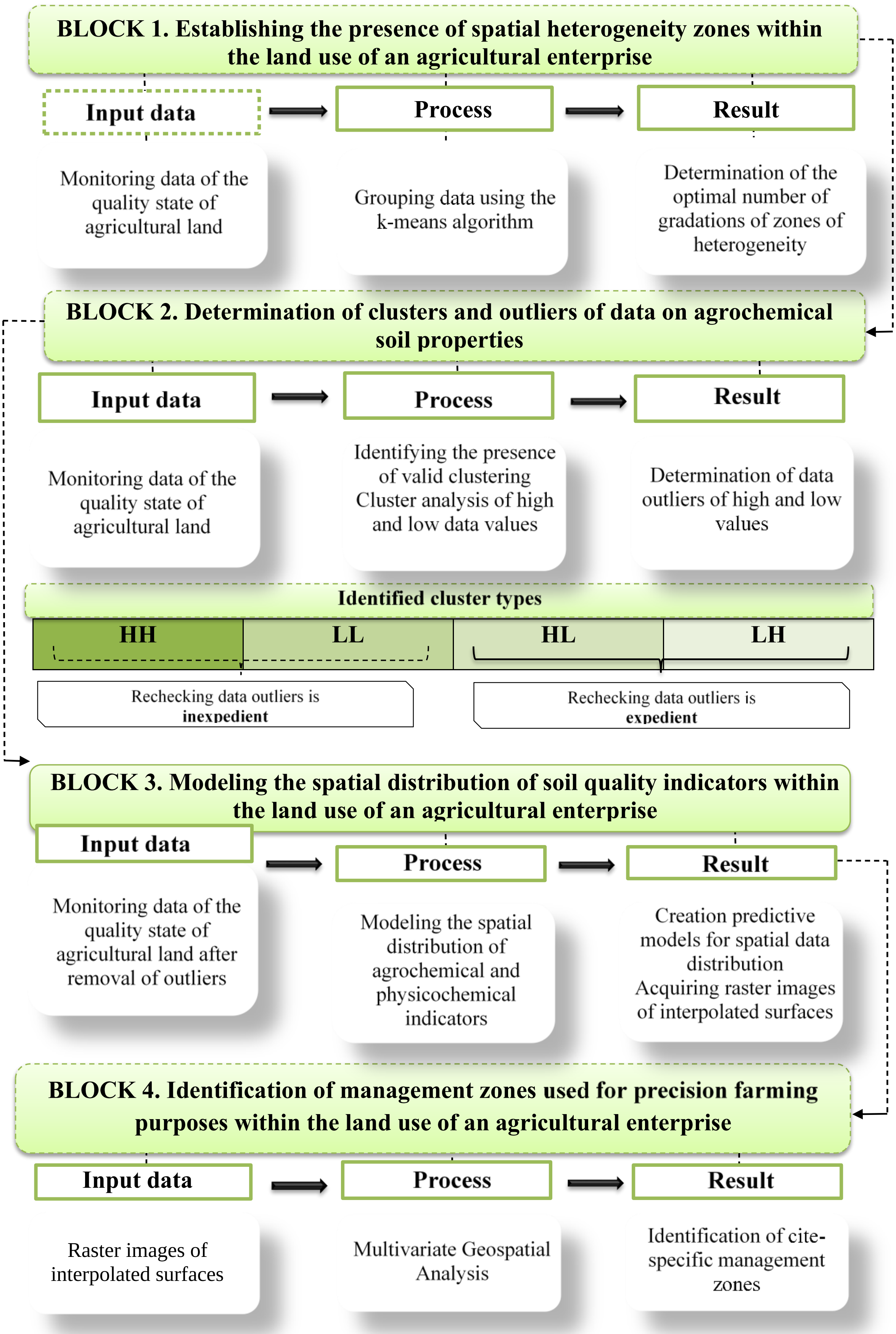


Fig. 4. Methodology for identifying cite-specific management zones with appropriate land quality (HL – cluster with high outliers; LH – cluster with low outliers)

The use of such a technique makes it possible to identify fertile and marginal areas within each individual field and to differentiate the use of fertilizers in accordance with the supply of nutrients to the soil. This technique also makes it possible to more efficiently plan the structure of sown areas. In the example of the RUE "Educational and experimental farm BSAA" it was found that on the area of 1411.76 ha it is possible to save from 2.5 to 21.8 kg P ha^{-1} and from 0.9 to 26.7 kg K ha^{-1} due to the redistribution of the dose of fertilizers for the planned crop yield, taking into account the identified management zones. The maximum saving of phosphorus fertilizers is achieved when applying them for winter wheat, corn for silage and peas grown for grain while potash fertilizers provide maximum saving when applying them for winter wheat, sugar beets and spring triticale.

The differentiated use of mineral fertilizers by reducing the cost of their purchase and use makes it possible to increase the profitability of growing winter grains by 2.2%, sugar beets by 1.3%, rapeseed for oilseeds by 1.1%, and malting barley by 0.8% (Table 1). The maximum saving of fertilizers is achieved when they are used under wheat cereals, spring cereals and rape. Hence the differential fertilizer application should be introduced primary for growing these crops.

Table 1

Economic efficiency of off-line technology of differentiated application of fertilizers

Agricultural crop	**Reducing the cost of purchasing fertilizers, BYN/hectare***		**Reducing the cost of applying mineral fertilizers, %***	**Profitability, %**
	P_2O_5	**K_2O**		
Winter wheat	30.94	0.18	20.8	2.2
Malting barley	14.19	0.99	11.1	0.8
Rapeseed	3.63	1.32	6.5	1.1
Sugar beets	4.79	5.28	7.0	1.3

Note: * compared to a traditional fertilization system, recommended by sectoral regulations documents (Organizational and technological standards…. 2012a; 2012b)

The implementation of the methodology for management zones identification of block 3 and block 4 tasks in Fig. 4, are described in detail in (Kutsayeva & Myslyva. 2020). In addition, the specificity of land use in Belarus, which provides for the concentration of agricultural land in state ownership (Myslyva, 2020), allows land surveyors to use a significant array of data on soil properties, which are obtained during planned rounds of agrochemical research. These data can and should be scrutinized with spatial statistics tools to enable further accurate identification of the site-specific management zone boundaries.

In particular, the implementation of the first block of tasks of the developed methodology provides for the determination of the optimal number of land quality gradations or the establishment of the optimal number of zones of spatial heterogeneity. Unfortunately, there is no single standard to establish the optimal number of zones of heterogeneity it will always differ. In each specific case it should be established based on the available geospatial data and their statistical characteristics, also taking into account the features of the relief of the land use area.

For example, within the land use RUE "Educational and experimental farm BSAA", the presence of four zones of spatial heterogeneity was established on the basis of a complex of 4 agrochemical indicators. At the same time, for land use RPUE "Ustye" NAS of the Republic of Belarus, the presence of 3 zones of heterogeneity was established on the basis of a complex of 9 agrochemical indicators. The optimal number of such zones is most rationally determined empirically by evaluating the output report on the results of grouping analysis using the k-means algorithm. Grouping efficiency can also be assessed using the Calinski-Harabasz pseudo-F-statistics (Calinski & Harabasz, 1974). This indicator reflects the similarity of objects in a group and the difference between groups and indicates the correctness of choosing the optimal number of heterogeneity groups (Figure 5).

Cluster analysis, provided by the second block of tasks of the methodology, should be performed in parallel with the grouping analysis. The results obtained should complement each other and ensure the possibility of making the only correct decision on the final identification the boundaries of site-specific management zones. First of all, it seems possible to determine the fact of the presence of spatial data clustering. This can be accomplished by calculating the nearest neighbor index value, which takes into account the coordinates, rather than the values of the control points attributes.

If this clustering type is set, the next step is to perform stepwise autocorrelation, which allows you to select a conceptual model of spatial relationships and set a threshold distance beyond which the mutual influence of neighboring objects is not taken into account. The obtained information can be used to establish the fact of the presence of clustering of attribute values at the control points, which is established by calculating the global Moran's index. If the value of the global Moran's index is greater than 1, this indicates the presence of clustering, and the next step should be to establish which values are clustered - high or low. This fact can be established by calculating the value of global Getis-Ord General G.

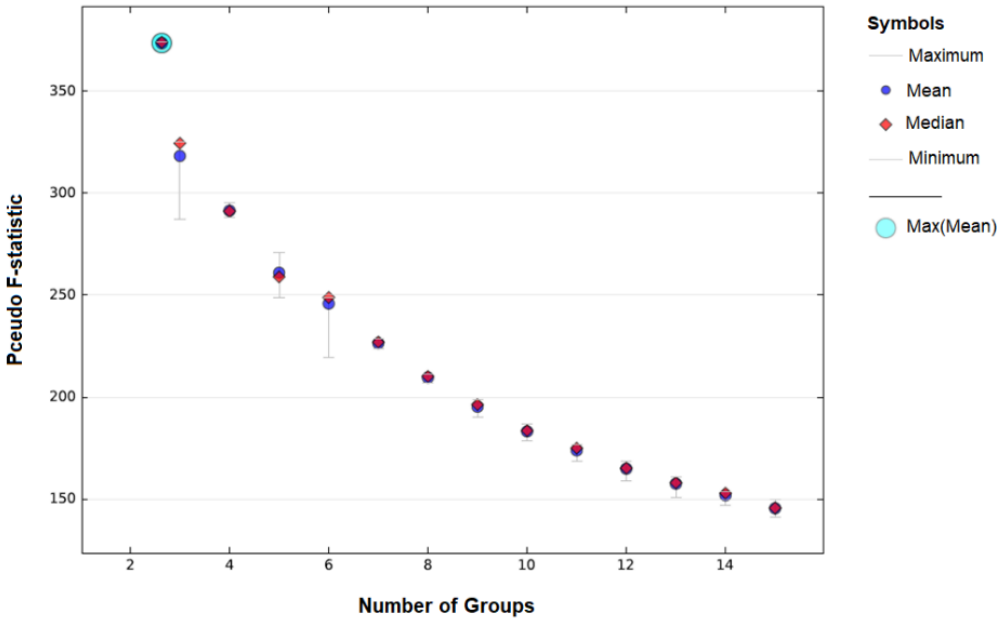


Fig. 5. Pseudo F-statistic plot (determining of spatial heterogeneity zones for the land use territory of RPUE “Ustye” NAS of the Republic of Belarus)

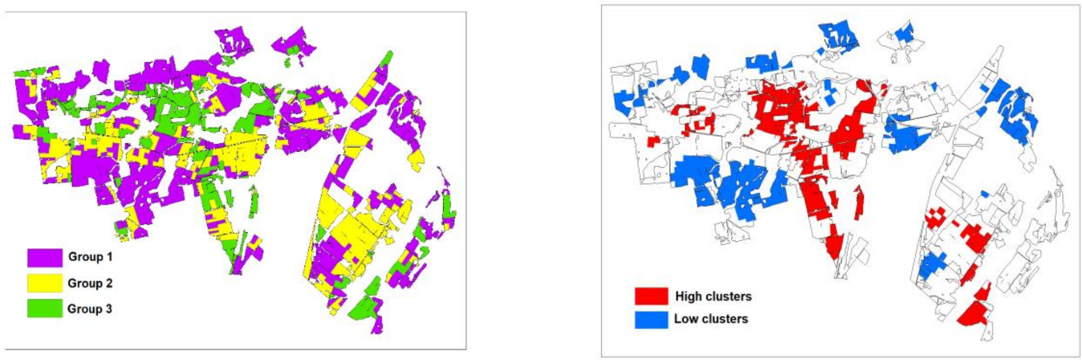
When clustering of both high and low values is present, their clustering is canceled out. Therefore, it is necessary to conduct a hot spot analysis. This allows not only to establish the presence of data clustering with high and low values, but also to assess the statistical significance of the identified clusters. This analysis is done by defining the Getis-Ord Gi *, a statistic that is calculated for each feature in the dataset. However, it should be noted that when calculating this indicator, not the attribute values of individual objects are taken into account, but the attribute values of their environment. These values are calculated for each object and compared with the values in the rest of the study area.

If significant clustering of high and low values is found, cluster and outlier analysis should be performed by determining Anselin Local Moran's I value. This analysis identifies concentration of high values, concentration of low values and spatial outliers of geospatial data. If, as a result of the cluster analysis, the presence of clusters of the high-low (HL) and low-high (LH) types is established, this indicates that spatial outliers of high (HL-clusters) and low (LH-clusters) values presents within the study area.

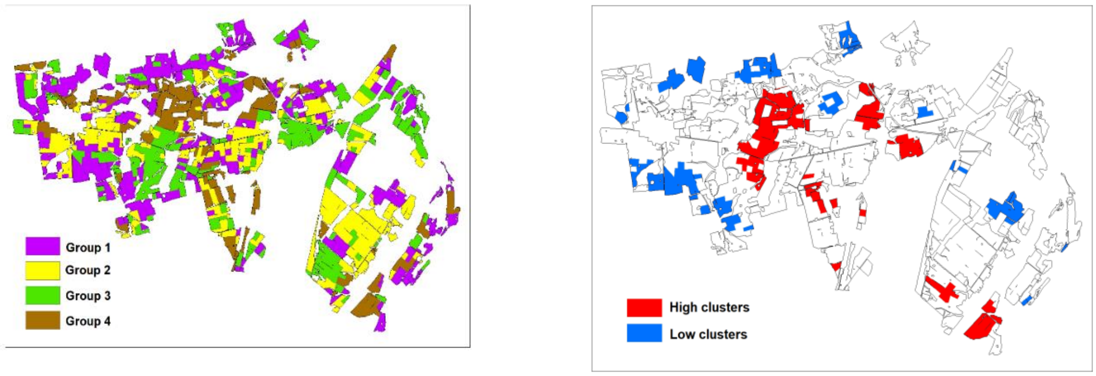
Performing cluster analysis is closely related to group analysis. Figure 6 shows the spatial localization of the identified groups - zones of spatial heterogeneity, as well as the result of cluster analysis, in the process of which statistically significant zones of concentration of high and low values of data on agrochemical and physicochemical properties of soil were identified.

The best ratio “cluster homogeneity - group homogeneity” was established when combined into three groups. With such a number of groups, the maximum coincidence was recorded for the localization of the lands of the 1st group with the localization of low clusters and for the localization of the lands of the 3rd group with the localization of high clusters. The area of land that belongs to group 1 was 3881.04 hectares, to group 2 - 2214.63 hectares, to group 3 - 1453.83 hectares, which in percentage terms was 51.4, 29.3 and 19.3% to the total land use area, respectively. When performing the identification of five groups, groups 3, 4, and 5 localize in the high clusters area while groups 1 and 2 - in the low clusters area. This indicates the inexpediency of separating such a number of groups. A similar trend is observed when performing division into four groups.

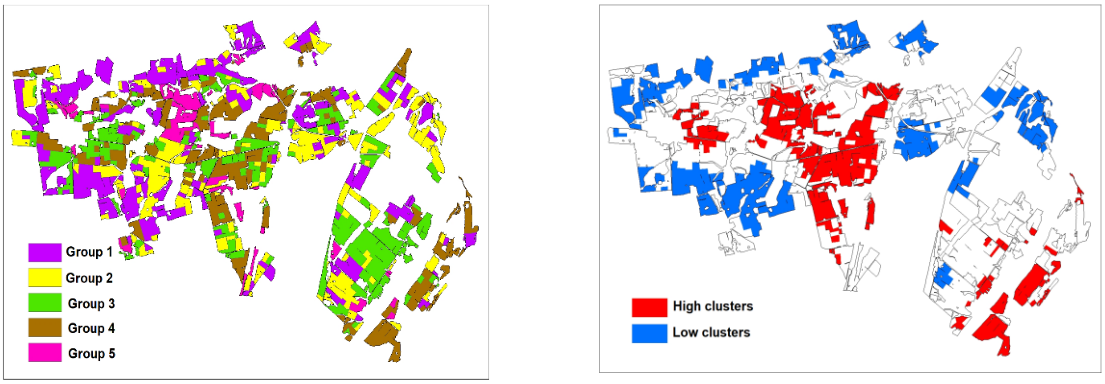
It should be specially noted that the implementation of the first two blocks of tasks is necessary and is an integral part of the identification process of management zones, since we are talking about developing a use strategy for significant land areas. This is due to the fact that according to statistics (Agriculture of the Republic…, 2019), an average land use of agricultural enterprise in Belarus contains more than 5.3 thousand hectares of agricultural land and over 3.5 thousand hectares of arable land.



a)



b)



c)

Fig. 6. Spatial localization of the identified groups - zones of spatial heterogeneity and the result of the cluster analysis within the arable land RPUE "Ustye" NAS of the Republic of Belarus (***for a***: *group 1 – land with low quality; group 2 – land with satisfactory quality; group 3 – land with good quality;* ***for b***: *groups 1–3 – see gradation for a; group 4 – land with excellent quality;* ***for c***: *1 – land with very low quality; group 2 – land with low quality; group 3 – land with satisfactory quality; group 4 – land with good quality; group 5 – land with excellent quality)*

Conclusions and proposals

The research results show that for the conditions of Belarus it is most expedient to determine the management zones on the basis of data on the agrochemical properties of the soil.

Geospatial statistics methods make it possible with a 99% probability to identify heterogeneities within an individual field, as well as the entire land use by one or more parameters. They also make it possible to establish clear boundaries between fertile and low-fertile lands. This can be used to determine management zones for precision farming purposes, within which certain land management activities are planned to be carried out.

The algorithm for determining the management-zones provides the sequential performance of the following operations:

- exploration geostatistical analysis;
- determination of the required number of gradations of land quality;
- assessment of data clustering and analysis, search for data outliers;
- construction of interpolated raster surfaces for a specific set of soil parameters;
- reclassification of rasters and multivariate analysis;
- converting the final raster into vector layers and determining the areas of the selected zones.

As input parameters, it is recommended to use the data of agrochemical soil survey performed centrally every 4 years for every agricultural enterprise.

The results of performing differentiation of management zones can be used for planning differentiated application of mineral fertilizers, which will save resources and improve the agrochemical, physical and biological properties of the soil.

References

1. Agriculture of the Republic of Belarus: statistical compilation (2019). National Statistical Committee of the Republic of Belarus, Minsk, 212 p. (in Russian).
2. Aulbur W., Henske R., Uffelmann W., Schelfi G. (2019). Farming 4.0: How precision agriculture might save the world. Munich: Roland Berger GMBH.
3. Calinski R., Harabasz J. (1974). A dendrite method for cluster analysis. Communications in Statistics, Volume 3, pp. 1–27.
4. Corwin D. L., Lesch S. M. (2010). Delineating site-specific management units with proximal sensors: in Geostatistica. Applications for Precision Agriculture. Springer Science+Business Media B. Y., pp. 139–165.
5. Daheim C., Poppe K., Schrijver R. (2016). Precision agriculture and the future of farming in Europe. Directorate-General for Parliamentary Research Services, Brussel. 274 p.
6. Davatgar N., Neishabouri M. R., Sepaskhah A. R. (2012). Delineation of site specific nutrient management zones for a paddy cultivated area based on soil fertility using fuzzy clustering. Geoderma, Volume 173–174, pp. 111–118.
7. Edge B. (2019). An economic-theory-based approach to management zone delineation. In: Poster Proceedings of the 12th European Conference on Precision Agriculture, Montpellier, France, pp. 56–57.
8. Farid H. U., Bakhsh A., Ahmad N., Ahmad A. (2016). Delineating site-specific management zones for precision agriculture. The Journal of Agricultural Science, Volume 154, Issue 2, pp. 273–286.
9. Fraisse C. W., Sudduth K. A., Kitchen N. R. (2001). Delineation of site–specific management zones by unsupervised classification of topographic attributes and soil electrical conductivity. American Society of Agricultural Engineers, Volume 44(1), pp. 155–166.
10. Georgi C., Spengler D., Itzerottet S., Kleinschmit B. (2018). Automatic delineation algorithm for site-specific management zones based on satellite remote sensing data. Precision Agriculture, Volume 19, pp. 684–707.
11. Heege H. J. (2013). Precision in Crop Farming. Springer, Netherlands, 356 p.
12. Kutsayeva A., Myslyva T. (2020). Creation of management zones for the purposes of land development at the implementation of precision farming in Belarus. International scientific journal: Baltic surveying, Volume 12, pp. 19 – 27.
13. Méndez-Vázqueza J., Lira-Noriegab A., Lasa-Covarrubiasc R., Cerdeira-Estradad S. (2019). Delineation of site-specific management zones for pest control purposes: Exploring precision agriculture and species distribution modeling approaches. Computers and Electronics in Agriculture, Volume 167, pp. 165–172.
14. Mitchell A. (2005) The ESRI Guide to GIS Analysis. Esri Press, Vol. 2. 252 p.
15. Myslyva T. (2020). Problems, prospects and experience in the implementation of precision farming in the Republic of Belarus in the context of national land use. Proceedings of the XI International Scientific Agricultural Symposium, East Sarajevo, pp. 972–978.
16. Oshunsanya S. O., Oluwasemire K. O., Taiwo O. J. (2017). Use of GIS to delineate site-specific management zone for precision agriculture. Communications in Soil Science and Plant Analysis, Volume 48, Issue 5, pp. 565–575.

17. Reyes J., Wendroth O., Matocha C., Zhu J. (2019). Delineating site-specific management zones and evaluating soil water temporal dynamics in a farmer's field in Kentucky. Vadose Zone Journal, Volume 18(1), pp. 1–19.
18. Shannon D. K., Clay D. E., Kitchen N. R. (2018). Precision Agriculture, American Society of Agronomy, USA, Madison, 259 p.
19. Vitharana U. W. A., Van Meirvenne M., Simpson D., Cockx L., De Baerdemaeker J. (2008). Key soil and topographic properties to delineate potential management classes for precision agriculture in the European loess area. Geoderma, Volume 143(1–2), pp. 206–215.
20. Yuxin M., Mulla D. J., Robert P. C. (2018). An integrated approach to site-specific management zone delineation. Frontiers of Agricultural Science and Engineering, Volume 5(4), pp. 432–441.
21. Организационно-технологические нормативы возделывания зерновых, зернобобовых, крупяных культур: сборник отраслевых регламентов (2012) (Organizational and technological standards for the cultivation of cereals, legumes, cereal crops: a collection of sectoral regulations) Минск, Беларуская навука. 288 с. (in Russian).
22. Организационно-технологические нормативы возделывания кормовых и технических культур: сборник отраслевых регламентов (2012) (Organizational and technological standards for the cultivation of forage and industrial crops: a collection of sectoral regulations) Минск, Беларуская навука. 471 с. (in Russian).

Information about authors:

Tamara Myslyva is a Doctor of Agricultural Sciences, Professor, Head of the Department of Geodesy and Photogrammetry of Belarusian State Agricultural Academy. Her current area of study surrounds the topics of GIS-analysis, GIS-modelling and geospatial statistics. Contact details: Faculty of Land Management, Belarusian State Agricultural Academy, Michurina 5, Gorki, Mogilev region 213407, Republic of Belarus, e-mail: byrty41@yahoo.com, tel: +375 2992 16839.
Olesya Kutsayeva is a Senior lecturer of the Department of Geodesy and Photogrammetry of Belarusian State Agricultural Academy. Her current area of study surrounds the topics of GIS-analysis, photogrammetry and remote sensing. Contact details: Faculty of Land Management, Belarusian State Agricultural Academy, Michurina 5, Gorki, Mogilev region 213407, Republic of Belarus, e-mail: alexa-1982@bk.ru, tel: +375 2933 21631.
Alesia Kazheka is a Post-graduate student of the Department of Geodesy and Photogrammetry of Belarusian State Agricultural Academy. Her current area of study surrounds the topics of GIS-analysis, photogrammetry and remote sensing. Contact details: Faculty of Land Management, Belarusian State Agricultural Academy, Michurina 5, Gorki, Mogilev region 213407, Republic of Belarus, e-mail: zybok.lesik@mail.ru, tel: +375 2984 37791.

DOI: 10.22616/j.balticsurveying.2021.14.005

APPLICATION OF MATHEMATICAL-CARTOGRAPHIC MODELING IN OPTIMIZING THE STRUCTURE OF THE REGIONAL LANDFILL OF SOLID NON-HAZARDOUS WASTE OF THE LUTSK MANAGEMENT CLUSTER

Korol Pavlo[1], Petrovych Oleksandr[2], Pavlyshyn Volodymyr[3]
[1]Lesya Ukrainka Volyn National University, [2]National University of Life and Environmental Sciences of Ukraine", [3]Volyn branch of the SE Rivne Research and Design Institute of Land Management

Abstract
Ukraine is one of the countries where the problem of waste management is particularly acute and deteriorating every year. The Regional Waste Management Plan in Volyn region by 2030 envisages a reduction in the total amount of landfilled waste from 97.68% to 30%, and the number of sites for their disposal – up to 4-8 regional landfills per region. Ecological-economic mechanism of solid non-hazardous waste (SNHW) management is based on a harmonious combination of environmental constraints with the economic attractiveness of regional landfills and involves working with geographically defined objects based on the use of methods of processing geospatial information, one of which is mathematical-cartographic modeling. Thus, the main purpose of this work is to substantiate the possibilities of applying the method of mathematical-cartographic modeling in the design of the system of regional landfills of SNHW in the Volyn region. In order to address the issue of placement of SNHW management facilities, the territory of the region is divided into four management clusters. The division of the territory took into account the composition, properties, methods of solid waste collection, logistics, load on waste processing complexes, volumes of waste generated, spatial planning, etc. Three probable options for the location of regional landfills have been developed for the Lutsk SNHW cluster. The results of the study can be used in the development and adjustment of regional plans, waste management programs, as well as in the work of the executive bodies of the united territorial communities.
Key words: solid non-hazardous waste, regional landfills, united territorial community, mathematical-cartographic modeling, multi-criteria decision analysis.

Introduction

One of the important steps of waste management reform in Ukraine is the National Waste Management Strategy until 2030, which provides for a gradual transition from landfill to sorting and reuse, recycling or disposal of waste with landfill disposal at "regional" landfills that meet requirements of the European Union. In this direction, it is proposed to develop regional waste management programs, first of all a plan to determine the rational area of coverage and location of "regional" landfills. Solving this problem requires decision-making support based on the processing and analysis of heterogeneous spatial information about municipal solid waste facilities and modeling the impact of environmental, economic, social factors and geomorphometric parameters of the territory The authors aim to consider the possibility of solving these problems with the help of mathematical-cartographic modeling. First, it is necessary to analyze the existing methods and assess the situation with landfills in the region, which will serve as a basis for the model of placement of regional landfills of SNHW.

Methodology of research and materials

This article used methods of analysis, generalization, theoretical method and cartographic. Using the cartographic method, author's maps were created, which show the current state of the object of study. The source of information for the creation of author's tables were the previously mentioned maps. The basis for the maps were statistical data, programs and waste management plans in Volyn region, data of the modern administrative-territorial structure of Ukraine, but because their format was not suitable for this study, they needed to reformat and identify new information by analyzing existing data. The map GIS software MapInfo Professional was used to create the maps.

In most cases, if there are several criteria for optimality and the necessary degree of completeness of the description of the real situation, the solution cannot be obtained by analytical methods in an acceptable time. The complexity of the algorithms increases significantly with increasing factors that influence the decision. Considering the fact that the problem of disposing of solid household waste objects is multifactorial, with the information provided in the form of judgments and wishes of experts and often subjective and fuzzy in nature, is proposed that combines the methods of multi-criteria analysis of solutions, the theory of fuzzy sets with GIS-technologies. The synergy of these approaches provides a more flexible tool that takes into account various decision-making strategies, i.e. adds missing functionality to the geographic information system that cannot be implemented by selecting locations for objects based only on spatial overlay operations. Thus, the urgent task is the development and improvement of models, methods and software tools that can be integrated into the geographic information system and provide increased decision-making on the disposal of solid waste in conditions of multi-criteria and uncertainty (Kuznichenko et.al., 2018).

GIS-oriented fuzzy two-stage multi-criteria decision analysis (MCDA) model for the deployment of SNHW facilities combines geospatial information about the SNHW landfills with estimates and opinion of experts, and also considers the attitude of decision maker (DM) to risk when making decisions. Description of the MCDA model in geographic space is formalized, where alternatives, criteria and other elements of solving the issue have spatial dimensions. A two-stage MCDA model is proposed to increase the analysis efficiency, which allows, at the first stage of macroanalysis, to form a set of acceptable alternatives considering the restrictions imposed by sanitary-construction standards using GIS tools, and at the second stage of microanalysis, to rank the set of acceptable alternatives according to their degree of suitability for SNHW objects deployment based on the MCDA methods with obtaining results in the form of a base map (Buchynska, 2018).

A fuzzy model for processing heterogeneous geospatial information on the location of solid waste includes a procedure for discretization of vector layers of criteria in a raster model by calculating Euclidean proximity metrics and a procedure for fassification of criteria, i.e. converting their attribute values into fuzzy set expert assessment of the fuzzy membership function (Wang et.al., 2009). The model allows decomposition of heterogeneous geospatial information into layers of criteria, identify many alternatives, as well as formalize expertise in the subject area, which increases the adequacy and validity of the decision-making process for the disposal of solid waste (Trofymchuk et.al, 2014).

An important tool for processing heterogeneous geospatial information about the location of solid waste objects is GIS-modeling as an integrative theory, which on a new methodological basis combines known methods of design, compilation, use and analysis of GIS-models to study real world objects using systems of ordering and transformation of information about these objects. Unlike theoretical modeling methods, GIS-modeling is a high-tech process and serves as a tool that provides collection, storage, processing, access, display and dissemination of spatially coordinated data.

GIS-modeling uses a powerful arsenal of spatial analysis tools, in particular: network analysis as a group of spatial-analytical operations, the purpose of which is to study the topological and geometric properties of solid waste landfills that form network structures; analysis of objects within the buffer zones, which allows to solve the problems of assessment of the zone of influence of the existing or projected network of landfills for solid waste; operations of the calculated geometry by means of which calculation of areas and coordinates of centroids of polygons, lengths of broken and curved lines, etc. is carried out; overlay operations, the essence of which is the imposition of two layers of different names with the generalization of derived objects and the inheritance of their attributes, which arise when they are geometrically combined.

In addition to standard functions, GIS-modeling for spatial analysis uses special programs created on the basis of deterministic and stochastic models, as well as special programs of GIS applications to predict the situation. One of the most important components of GIS-modeling is a cartographic module that provides cartographic representation of source, derived or resulting data in the form of digital, computer and electronic maps, while acting as an element of the user interface and a means of documenting the final results.

GIS-modeling includes the use of such types of modeling as geographical, cartographic, mathematical-cartographic, aerospace, computer, electronic-graphic. The defining function of cartographic modeling as part of GIS-modeling is the ability to analyze the available necessary information. Mathematical-cartographic modeling is understood as organic complexing of mathematical and cartographic models in the system of "creation-use" of maps for the purpose of constructing or analyzing thematic content of maps with the possibility of processing large amounts of information by one algorithm and processing of one array of information by different algorithms. The application and combination of these types of modeling provides researchers with a variety of created models of spatial objects that are suitable for spatial analysis (Король та ін., 2012).

This combination of two universal research methods has become possible due to the ability of the cartographic method to be elementary combined with other methods in the creation of any thematic or special maps. The involvement of the mathematical method in the process of creating maps gave

mathematical models spatial certainty and imagery, and at the same time allowed to create original cartographic models based on mathematical processing of huge amounts of information.
The whole process of mathematical-cartographic modeling can be represented in the form of elementary links that form the levels of modeling. Each elementary link always consists of a mathematical model and a map created on the basis of this model, and their number depends on the complexity of the modeled system and the number of steps required to create a final map and ranges from one to infinity. The vast majority of systems are complex and super-complex, i.e. includes an extensive set of internal and external system-forming elements and their relationships, which necessitates a variety of combinations of elementary links in chains, i.e. the construction of complex mathematical and cartographic models (Король та ін., 2012, 2013, 2013).
At the final stage of mathematical-cartographic modeling with the help of created models the basic principles of organization and integration of systems, possibilities of forecasting and management of solid household waste are revealed.

Discussions and results
General characteristics of the object of study. As part of the implementation of the reform of local self-government and territorial organization of power in 2015-2019 in Volyn region was created, and the order of the Cabinet of Ministers of Ukraine dated June 12, 2020 № 708-r "On the definition of administrative centers and approval of territorial communities of Volyn region" approved a list of 54 territorial communities in the Volyn region (11 urban, 18 urban village and 25 rural), which are united within 4 districts (Lutsk - with an area of 5247.8 km² and a population of 451.5 thousand people, Kovel with an area of 7647.9 km² and a population of 261.5 thousand persons, Volodymyr-Volynskyi with an area of 2558.2 km^2 and a population of 181.9 thousand people, Kamin-Kashyrskyi with an area of 4693.4 km^2 and a population of 136.6 thousand people). The object of this study is the territory of the Lutsk solid waste management cluster, which is spatially identified with the territory of the newly created Lutsk district. The Lutsk district includes the territories of Lutsk City, Lutsk, Kivertsi, Rozhyshche, Horokhiv, Berestechko urban, Kolky, Tsuman, Olyka, Torchyn, Marianivka urban village, Boratyn, Horodyshche, Pidhaitsi, Dorosyni and Kopachivka rural united territorial community (UTC) (Figure 1).

Figure 1. Administrative-territorial structure of Lutsk district (UTC)

SNHW landfills. As of April 15, 2020, there are 478 SNHW landfills in the Volyn region, only 110 of which are certified. For the Lutsk cluster, the corresponding indicators are 151 and 26 landfills (their location and main characteristics are given in Figure 2 and 3, and in Table 1).

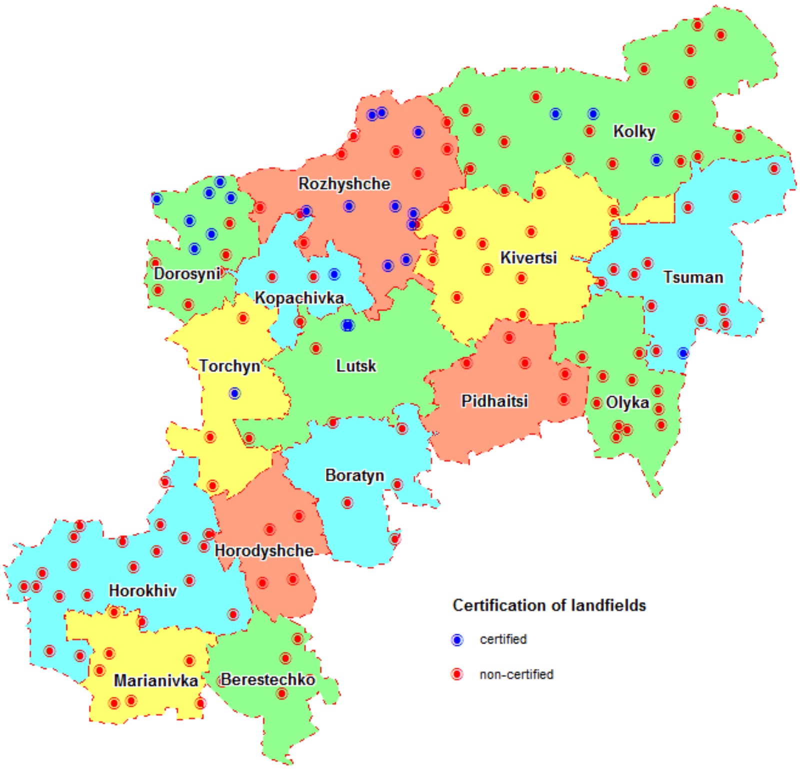


Figure 2. Location of existing SNHW landfills in Lutsk cluster

Table 1

Characteristics of existing SNHW landfills in the Lutsk cluster

№	UTC	Number of landfills	Number of certified landfills	Share of certified landfills,%	Actual area of landfills, ha
1	Lutsk	5	2	40	20.2797
2	Kivertsi	12	0	0	17.1178
3	Rozhyshche	18	11	61	14.9157
4	Horokhiv	20	0	0	15.9500
5	Berestechko	5	0	0	5.0000
6	Kolky	22	3	14	16.5425
7	Tsuman	14	1	7	15.3438
8	Olyka	11	0	0	12.4043
9	Torchyn	4	1	25	2.1010
10	Marianivka	7	0	0	8.3000
11	Boratyn	5	0	0	5.8400
12	Horodyshche	5	0	0	12.1331
13	Pidhaitsi	5	0	0	5.5300
14	Dorosyni	13	7	54	7.5800
15	Kopachivka	5	1	20	5.2310
	Total	**151**	**26**	**17**	**164.2689**

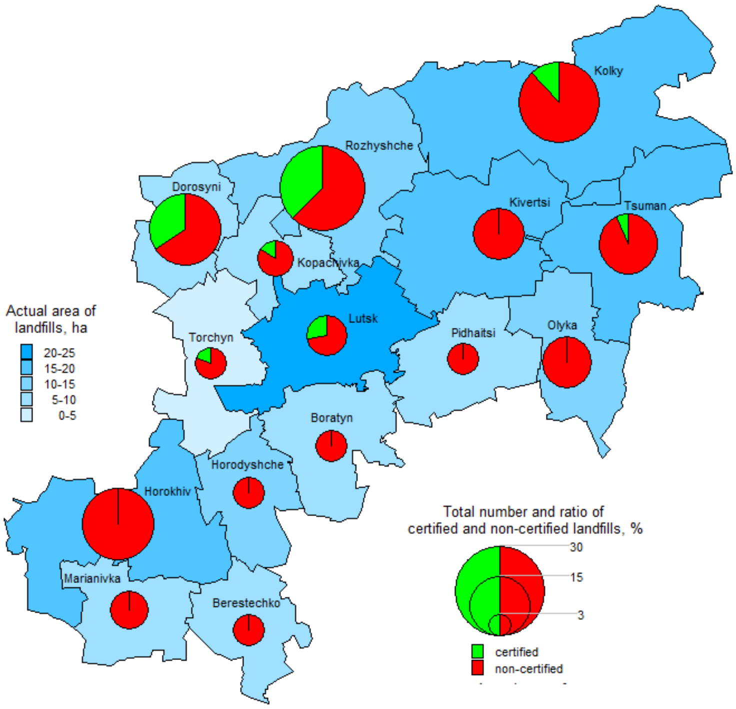


Figure 3. Characteristics of existing SNHW landfills in Lutsk cluster

Forecasting the amount of SNHW. The lack of complete and reliable information on waste management volumes and their composition at the time of development of the "Regional Waste Management Plan in Volyn Region until 2030" (Регіональний план, 2020) does not allow to perform reasonable forecasting of waste generation for the period up to 2030 taking into account different waste streams.

According to the norms of SBC B.2.2-12: 2019, the annual rate of solid waste generation (on average in the settlement, taking into account organizations and institutions, pendulum migration) is 300 kg/person or 1.8 m³/person. Given that the share of waste organizations and institutions is 12% of the total waste generation in the settlement, and the density of mixed solid waste - 166.7 kg/m^3, the estimated volume of solid waste generation in the region is 314900 t/year.

Criteria for determining the areas of optimal coverage. When determining the optimal coverage areas for SNHW management, the following types of alternative scenarios are usually considered: cluster boundaries or different ways of collecting and treating SNHW within certain clusters. The main technological objects of waste management, which are focused on servicing the whole or at least a significant area within the cluster (technological cores of clusters), are considered: regional landfills; mechanical-biological processing facilities or incinerator; other waste treatment facilities, such as waste sorting complexes.

The regional landfill is a part of the waste management complex, which is operated in accordance with construction, sanitary and ecological norms and serves several settlements and districts. The construction of modern regional landfills allows to reduce the area of land used for waste disposal in settlements, to organize the collection of biogas and filtrate from the landfill, to prevent negative impact on the environment and public health. In the future, a gradual reduction of the total number of landfills and construction of modern regional landfills with an approximate area of 8-13 hectares is envisaged (Програма поводження, 2018).

When determining the zones of optimal coverage for SNHW management are guided by the following main criteria: the recommended coverage of the population is 150-400 thousand people; there is a potential to create a regional landfill in each cluster; developed plans and prospects for the creation of facilities for in-depth processing of solid waste, in particular with energy production, and determined their technological parameters; minimized costs for transportation and disposal of waste, as well as the volume of waste disposal. In addition, there is a possibility to use additional criteria for determining clusters, including the current and future administrative structure of the region, established links between communities, districts, developed projects of cooperation of territorial communities, etc., local restrictions on the location of the landfill due to flooding, proximity to protected areas, etc.

Assumptions about the choice of methods of in-depth waste treatment. Analysis of the technological potential of measures aimed at reducing the amount of solid waste disposal shows that to ensure the implementation of the national target for reducing the amount of landfill (30% - by 2030) in the region it is necessary to introduce separate collection of secondary raw materials, composting of organic waste and extraction of individual fractions of waste suitable for the production of solid fuels. Among such technological solutions can be considered, including decision on obtaining solid fuel from solid waste. The following technological scenarios of in-depth solid waste recycling are considered for the Lutsk solid waste management cluster: creation of a waste processing plant, an incineration plant, mechanical and biological processing facilities and waste sorting complexes.

Assumptions about the location of regional landfills. In determining the location of regional landfills, the following factors were taken into account: the possibility of using the existing capacity of the landfill as a regional one while building a new landfill (or expanding the existing one by creating new maps); existing potential for the use of land resources near the existing facility to create new capacity; possible risks of social rejection of the construction of a new landfill in a new location (Регіональний план, 2020).

Taking into account the above assumptions, as well as taking into account the need to optimize the cost of transporting waste to waste treatment facilities, the options for dividing the area into solid waste management clusters are obtained. The clusters are formed taking into account the new division of the region into districts, taking into account the fact that the united territorial communities are mostly created within the existing districts. In cases where the boundaries of the established UTCs do not coincide with the existing boundaries of the districts, the presentation of the boundaries of the clusters will need to be adjusted accordingly (Петрович, Євсюков, 2020, 2021, Регіональний план, 2020).

In all the proposed options, the division of the Volyn region into four clusters: Lutsk (A); Volodymyr-Volynskyi (B); Kovel (C) and Kamin-Kashyrskyi (D). Within any cluster, there are alternative options for additional division into subregions - 2 subregions in each cluster, in particular for the Lutsk cluster - Lutsk (A1) and Horokhiv (A2) subregions (Table 2).

Table 2

Population and solid waste generation in the Lutsk cluster (Регіональний план, 2020)

№	Cluster/Subregion	Population, persons	Volumes of solid waste generation, m^3/year
1	Cluster A	451463	49719.4
2	Subregion A1	402872	44576.6
3	Subregion A2	48591	5142.9
	Total	451463	49719.4

According to the results of analysis and consultations as potential regional landfills for non-hazardous waste, for the Lutsk cluster can be considered: in the variant of a single cluster (Figure 4) – landfill (v. Bryshche), in the variant of two subregions (Figure 5) - landfill (v. Bryshche) and landfill (v. Tsegiv), in the variant with the main landfill for 4 central subregions - landfill (v. Bryshche), landfill (v. Tsegiv) and sand quarry (v. Radoshyn).

In all cases, the creation of regional landfills will require the expansion of existing or construction of a new landfill. It is assumed that the existing landfills will be operated until their capacity is exhausted with subsequent reclamation (Регіональний план, 2020).

Figure 4. The first variant location of regional SNHW landfills

Figure 5. The second variant location of regional SNHW landfills

Disposal of solid non-hazardous waste. The amount of waste disposal at regional landfills depends on the coverage of the territory (population and business entities), as well as the effectiveness of the implementation of measures to minimize the amount of waste disposal. When analyzing the expected volumes of municipal waste disposal, it is taken into account that industrial waste of hazard class III-IV can also be buried or used for landfill layers at landfills. The expected (planned) volumes of waste disposal at regional landfills are given in the Table 3.

Table 3

Expected volumes of waste disposal at regional landfills of the Lutsk cluster
(Регіональний план, 2020)

Landfill location	Coverage territory	Volumes of waste disposal, t/year	
		in general (including industrial)	population waste
v. Bryshche	Subregion A1	44576.6	32956.6
v. Tsegiv	Subregion A2	5142.9	3771.4
v. Radoshyn	Subregions A1, B1, C1, D2	73691.2	54414.1

The capacity of regional landfills must meet the need for waste disposal of the relevant clusters for a period of at least 20 years. Technological parameters of regional landfills are given in the Table 4.

Table 4

Technological parameters of regional landfills of Lutsk cluster (Регіональний план, 2020)

Landfill location	Coverage territory	Approximate landfill area, ha	Total power, t	Population, persons
v. Bryshche	Cluster A	6.1	994400	451463
v. Bryshche	Subregion A1	5.5	891500	402872
v. Tsegiv	Subregion A2	1.9	102900	48591
v. Radoshyn	Subregions A1, B1, C1, D2	15.3	1473800	690329

Conclusions and proposals

The problem with garbage in Ukraine requires a reduction in the amount of waste that is disposed of and, accordingly, a reduction in the number of landfills. In this regard, the division of regions into clusters and the creation of regional landfills is envisaged. The location of such landfills in the Lutsk cluster using mathematical-cartographic models makes it possible to take into account the modern administrative-territorial division, the established links between communities,
districts, developed projects of cooperation of territorial communities, etc., local restrictions on the location of landfills due to flooding, proximity to protected areas, etc., location of existing landfills, taking into account their certification and area.

A promising area of further research is the creation of a unified cartographic resource "GIS of solid waste management", which is designed to serve as a tool for decision-making in the field of solid waste management, a means of visualizing the current state and stages of local and regional solid waste management programs. The product is developed in accordance with the "National Waste Management Strategy in Ukraine until 2030", which was approved by the Order of the Cabinet of Ministers of Ukraine dated 08.11.2017 № 820-r. and Resolution of the Cabinet of Ministers of Ukraine of February 20, 2019 № 117-r "On approval of the National Waste Management Plan until 2030", is recommended for implementation at the regional (oblast) and local (territorial community, city) levels and will be used as a collection tool, accumulation, processing, analysis and dissemination of information on waste management. This GIS is designed to solve a number of problems related to the collection of information on the current state (inventory) of landfills, certification of landfills, visualization of sanitation schemes, development and optimization of logistics schemes and route collection removal of solid waste in the relevant territory, development of environmentally and economically optimal practices of solid waste management.

The main advantages of this cartographic resource are: the availability of tools for operational inventory of landfills by means of mobile technologies (including real-time) and technologies of unmanned aerial vehicles (UAVs), the creation of a database based on them (including 3-D models) places of solid waste storage; certification of landfills and dumps, creation of databases on solid waste storage sites and morphological features of landfills; visualization of existing and perspective vector schemes of sanitary cleaning of settlements in the mode of combination with town-planning documentation and land cadastre, system of popular cartographic services (Google Maps, Open Street Maps, etc.), which allows to take a comprehensive approach to solid waste management; formation and display of optimal logistic schemes of garbage collection routes; planning specific promising measures for technical and operational equipment of landfills, forecasting the future state of areas and other geometric parameters of landfills, developing a strategy for optimal concentration of storage sites and waste disposal; availability of a subsystem of electronic appeals of citizens and a platform for their operative analysis; providing the function of information support of local governments in decision-making in the field of environmental safety, risk management, automation of reporting on the results of environmental work.

The practical implementation of this cartographic resource will provide an opportunity to take into account the location of landfills; logistical support for the implementation of regional and local targeted waste management programs; minimization of costs for sanitary maintenance of territories; increasing the level of landscaping, improving the environment; strengthening the interaction between the government and the community, mobilizing members of the relevant territorial communities in solving problems of solid waste management; achieving a high level of awareness of citizens on solving the problems of collection, removal and disposal of solid waste.

The indicative structure of the database "GIS of solid waste management" will include basic and thematic information resources (Ільченко, Коцюба, 2011). The basic information resources will include: a single electronic cartographic basis that reflects the modern administrative-territorial structure of the territory, natural resource potential (orography, hydrography, soil and vegetation, mineral resources) and geographical conditions of the territory, road transport and engineering infrastructure, register geographical names, etc. Thematic information resources will include layers of the GIS, reflecting landfills, waste disposal sites, waste collection equipment (containers), transport bases, transshipment and sorting sites (waste transshipment or sorting stations), landfills or waste processing (plants), vector schemes of sanitary cleaning of settlements, etc.

References

1. Buchynska I.A. (2018) GIS-based decision support system for placing solid waste landfill // Monograph. Processing, Transmission and Security of Information. Wydawnictwo Naukowe Akademii Techniczno-Humanistycznej w Bielsku-Białej, Poland. Vol. 2. P. 33-40.
2. Kuznichenko S., Kovalenko L., Buchynska I., Gunchenko Y. (2018) Development of a multicriteria model for making decisions on the location of solid waste landfills // Eastern-European Journal Of Enterprise Technologies. Vol. 2. No 3(92). P. 21-30.
3. Trofymchuk O., Trysnyuk V., Novokhatska N., Radchuk I. (2014) Geoinformation Technologies in decision issues of municipal solid waste //Journal of Environmental Science and Engineering. No 3. P. 183-187.
4. Wang G., Qin L., Li G., Chen L. (2009) Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. Journal of Environmental Management. 90(8). P. 2414-2421.
5. Ільченко А.В., Коцюба І.Г. (2011) Використання програмного забезпечення з метою оптимізації системи поводження з твердими побутовими відходами міста Житомира (Use of the software to optimization system for the treatment of hard domestic waste in Zhytomyr) Екологічна безпека 1(11). С.13-16. (in Ukrainian)
6. Король П.П., Волошин В.У, Рудик О.В. (2012) Математико-картографічне забезпечення моніторингових досліджень ерозійно-небезпечних земель із застосуванням анаморфованих зображень (Mathematical-cartographic support for monitoring studies of erosion-prone land using pseudo cartograms). Геодезія, картографія і аерофотознімання. № 76. С. 110-116. (in Ukrainian)
7. Король П.П., Волошин В.У, Рудик О.В. (2013) Математико-картографічне забезпечення моніторингових досліджень ерозійно-небезпечних земель із застосуванням методу оцінювання пластики рельєфу (Mathematical-cartographic support for monitoring studies of erosion-prone lands using a method of relief plastics) Сучасні досягнення геодезичної науки та виробництва Вип. 1 (25). С.110-116. (in Ukrainian)
8. Король П.П., Волошин В.У., Фесюк О.В. (2013) Математико-картографічне моделювання водної ерозії ґрунтів на основі комбінованого універсального рівняння втрат ґрунту (Mathematical-cartographic modeling of soil erosion on the basis of combined universal soil loss equation). Вісник геодезії та картографії. №6. С. 35-42. (in Ukrainian)
9. Петрович О. М., Євсюков Т. О. (2020) Аналіз сучасних методичних підходів до визначення місць розташування полігонів твердих побутових відходів (Analysis of modern methodological approaches to determining the location of landfills for solid non-hazardous waste). Землеустрій, кадастр і моніторинг земель. № 2-3. С. 27-38. (in Ukrainian)
10. Петрович О. М., Євсюков Т. О. (2021) Еколого-економічний механізм вибору земельної ділянки для регіонального полігону побутових відходів Луцького кластеру Волинської області (Ecological-economic mechanism of land selection for the regional landfill for solid non-hazardous waste of Lutsk cluster of Volyn region). Львів: Західноукраїнський Консалтинг Центр. С. 310. (in Ukrainian)
11. Програма поводження з твердими побутовими відходами у Волинській області на 2018-2021 роки (2018) (Solid waste management program in Volyn region for 2018-2021) Луцьк: Волинська обласна рада. 25 с. (in Ukrainian)
12. Регіональний план управління відходами у Волинській області до 2030 року (2020) (Regional waste management plan in Volyn region until 2030) За заг. ред. І.В Сліпця. Київ: ATON GROUP. 230 с. (in Ukrainian)
13. Схема санітарного очищення м. Луцьк Волинської області (2018) (Scheme of sanitary cleaning of Lutsk City, Volyn region) За заг. ред. І.В Сліпця. Київ: ATON GROUP. 178 с. (in Ukrainian)
14. Шевчук І.Л., Даценко Т.С., Матвійчук Н.М. (2018) Особливості утворення та поводження з відходами у Волинській області (Features of waste generation and management in Volyn region) Луцьк: Молода наука Волині: пріоритети та перспективи досліджень. Економіка. С. 319-321. (in Ukrainian)

Information about authors:
Pavlo Korol. Candidate of Geographical Sciences, Associate Professor of the Department of Geodesy, Land Management and Cadastre of the Lesya Ukrainka Volyn National University. Address: Ukraine, 43021, Lutsk, Voly av. 13, phone +38(050)739-66-93, e-mail: pavking74@gmail.com
Oleksandr Petrovych. Postgraduate, National University of Life and Environmental Sciences of Ukraine. Land surveyor, Volyn branch of the SE Rivne Research and Design Institute of Land Management. Address: Ukraine, 43021, Lutsk, Vynnychenko str. 63, phone +38(096)194-95-91, e-mail: oleksandrpetrovych0@gmail.com
Volodymyr Pavlyshyn. Land surveyor, Volyn branch of the SE Rivne Research and Design Institute of Land Management. Address: Ukraine, 43021, Lutsk, Vynnychenko str. 63, phone +38(050)952-36-01, e-mail: pavlishinzem@ukr.net

DOI: 10.22616/j.balticsurveying.2021.14.006

POSSIBILITY OF GEOINFORMATION SUPPORT OF LAND MANAGEMENT WORKS

Pisetskaya Olga, Isayeva Yanina
Belarusian State Agricultural Academy

Abstract
Scientific and technological progress does not bypass any industry, including the agro-industrial complex. With the development of technologies for remote sensing of the Earth, obtaining relevant information about the availability of objects of their condition and use, the introduction of advanced technologies and modern equipment in agriculture, the automation of land management processes, including land management, becomes urgent. Analysis of existing geoinformation systems allows us to conclude that the task of geoinformation support of land management in full in the form of an independent geoinformation system is absent. At the same time, in the considered complexes, there is a solution to certain land management tasks, such as the creation of digital maps of fields, anti-erosion organization of the territory, the construction of digital relief models, correction of soil maps based on satellite images, etc.
The purpose of the article is to analyze information sources in the field of geoinformation support of the land management process in the Republic of Belarus, to identify tasks for the development of a comprehensive methodology for the implementation of digital land management in the Republic of Belarus.
Key words: **g**eoinformation support, land management, land information system, geoportal, organization of the territory.

Introduction

Informatization is an organizational socio-economic and scientific and technical process of meeting the needs of public authorities, legal entities and individuals in obtaining information about persons, objects, facts, events, phenomena and processes based on information systems and networks that generate and process information resources, and delivery of documented information to the user.
There are main types of information technologies: information technology of data processing, information technology of management, information technology of decision support, information technology of expert systems based on the use of artificial intelligence.
An information resource is an organized set of documented information, including databases, other sets of interrelated information in information systems (Об информации, информатизации …, 2008).
State information resources are resources that, as an element of property, are owned by the state. They ensure the fulfillment of the tasks of public administration; ensuring the rights and safety of citizens; support for the socio-economic development of the country, the development of culture, science, education, etc. (О составе государственных …, 2009).
The objects of management of regional authorities and various services are individual and collective economic entities represented by individuals (population) and organizations. Without displaying this information on an electronic map, we can only talk about the number of resources they own. Geographic information systems (GIS) are used to register the distribution of resources in the territory.
Geographic information resources are becoming more and more widespread in the development and increase in the productivity of the agro-industrial complex. Currently, there is automation, both of individual processes of the agro-industrial complex, and of the industry as a whole, including land management design.
The research of this article involves the study of information sources in the field of geoinformation support of digital land management in the Republic of Belarus, identification of tasks for the development of a comprehensive methodology for the transition to digital land management in the Republic of Belarus.

Methodology of research methods and materials

Information support and automation of land management are carried out by means of the land information system in the manner established by the State Committee on Property of the Republic of Belarus.
It should be noted that a tendency has been identified in the field of informatization of individual land management processes, but there is no separate geoinformation resource for the complete automation of the land management process.

It is necessary to analyze the sources in the field of geoinformation support of land management works in the Republic of Belarus.

Discussion and results

In the Republic of Belarus, the organization of land management is carried out by the State Committee on Property of the Republic of Belarus.

Land management activities aimed at implementing a unified state policy in the field of land use and protection and having national significance, including the creation and maintenance of a land information system, are carried out at the expense of the republican budget (Кодекс …, 2008).

In the Republic of Belarus, the implementation of land management work is provided in full in the traditional form, a trend has been revealed in the field of informatization of certain land management processes.

Among these measures for the effective management of agricultural enterprises and the functioning of precision farming, it should be noted that it is necessary to develop and apply a methodology for geoinformation support of the project for organizing the territory of the enterprise, projects to preserve and increase soil fertility and other useful properties of the land, as well as to fully implement the land management process.

In agriculture, land management should ensure the implementation of technologies for growing crops by creating optimal crop rotations and rational organization of their territory, the introduction of rational livestock raising systems, and improving the quality of land resources.

The main purpose of inter-farm land management in the formation of land plots of agricultural organizations is to bring the area of the farm, its specialization, location and border into line with the natural characteristics of the design object and the requirements for organizing the rational use of land and efficient production during the formation of land plots.

Land plots of agricultural organizations are characterized by the following parameters: location, area, composition and quality of land; configuration and compactness of the territory; location in relation to economic centers and other isolated parts; borders. Each of the characteristics is a factor influencing the efficiency of production and land use on the farm. Changing them can positively or negatively affect the controllability of production, the volume and cost of production, the amount of capital investment and annual costs, land productivity, soil erosion, and social conditions. The best combination and values of these interrelated parameters create rational land plots, which are best suited for efficient farming, land use and protection.

In the Republic of Belarus, the main geo-information resource for solving various problems, including in the field of land management, is the Geoportal of the land information system of the Republic of Belarus (Fig. 1.).

The geoportal of the land information system of the Republic of Belarus is a fully functional geographic information system designed to automate the storage, processing and provision of spatial information to all interested parties to support decision-making on the organization of effective work in the field of land management, geodesy, cartography, land, forest cadastre and real estate cadastre, urban planning and architecture, telecommunications, pipeline maintenance, oil and gas production and transportation, electrical networks, ecology and nature management, geology and geophysics, rail and road transport, banking, education, government, etc.

The Land Information System Geoportal allows you to obtain data on the boundaries of administrative-territorial units and land plots, on the land coverage of the territory, on the land reclamation state, on land use restrictions, on engineering communications and much more (Геопортал ЗИС …, 2020).

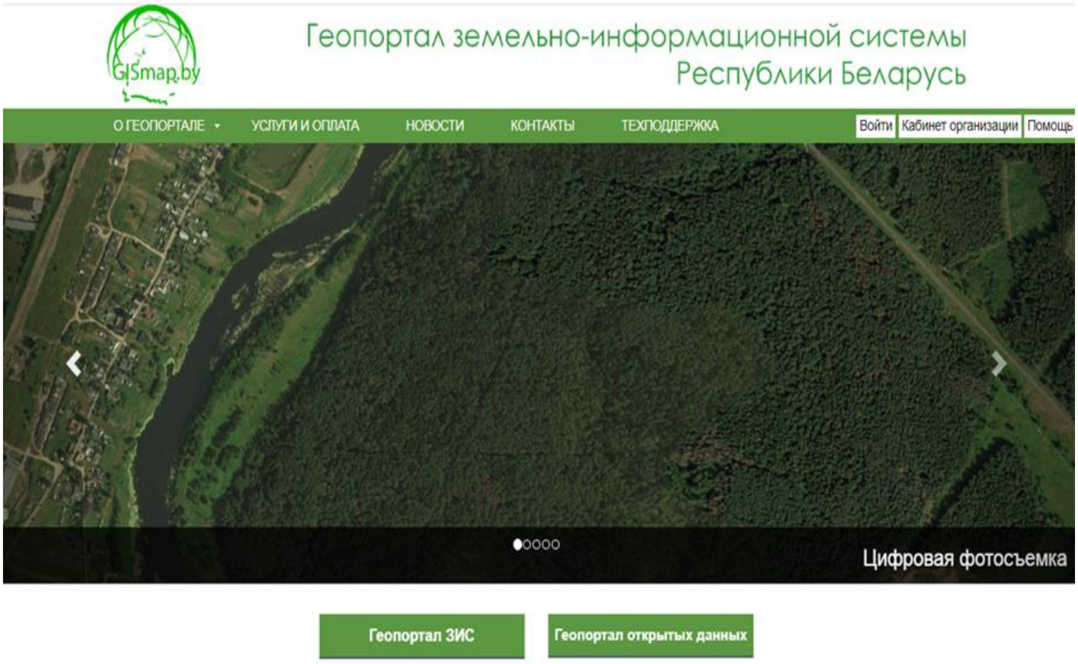


Fig. 1. View window of the Geoportal of the Land Information System of the Republic of Belarus

The basis for the creation of the Land Information System Geoportal is the land information system of the Republic of Belarus (Fig. 2).

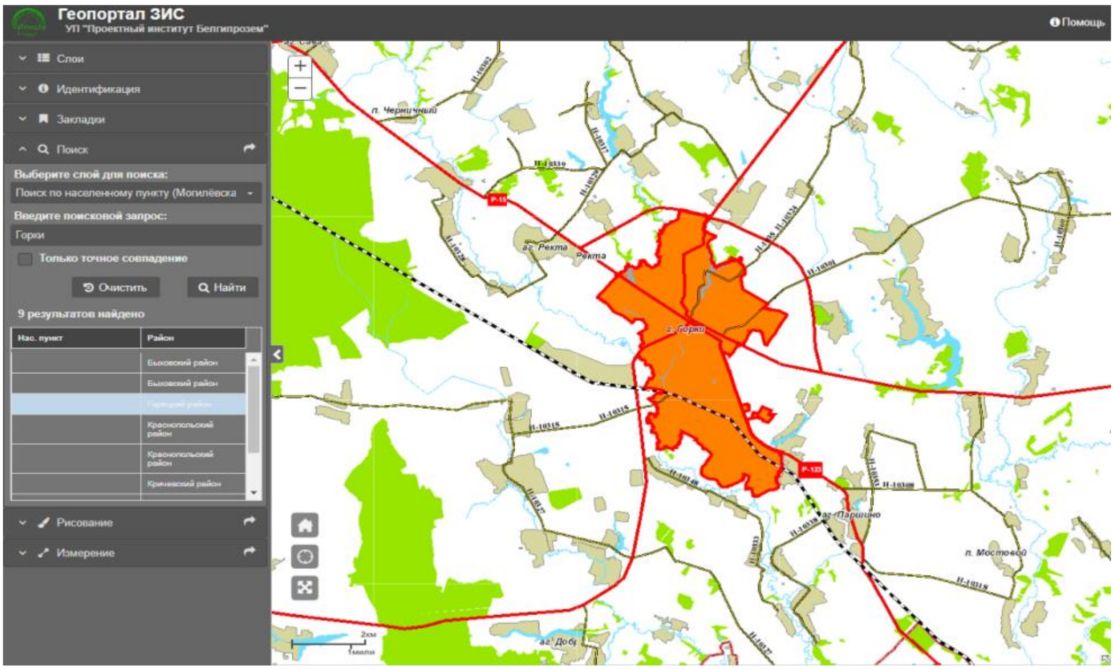


Fig. 2 View window of the public land information map of the Republic of Belarus

Land Information System (hereinafter – LIS) is a complex of software and hardware tools, databases of spatial and attributive data, information exchange channels and other resources, which provides automation of the accumulation, processing, storage and provision of information about the state, distribution and use of land resources in electronic form, including by means of geoinformation technologies.

The LIS of the Republic of Belarus is created within the boundaries of districts and settlements (cities and urban-type settlements). The information content of the LIS of the Republic of Belarus consists of: the LIS database of the Republic of Belarus as the sum of the databases of local LIS and sets of normative and reference information, fonts, legends and conventional symbols in digital form.

The LIS database of the Republic of Belarus contains information on the current state and use of land resources in the Republic of Belarus and consists of spatial and attributive data of land management, land cadastral and topographic content.
Work on the creation of the LIS of the Republic of Belarus is carried out by organizations of the State Committee for Property of the Republic of Belarus.
Spatial data of the Local LIS of the regions of the Republic of Belarus are created with the accuracy of a topographic map at a scale of 1:10 000.
LIS is created on the basis of aerial photography by means of office decoding and subsequent digitization. During the operation of the LIS, it is updated in relation to information that changes in the course of economic activity according to data provided by various services of local executive authorities. At the same time, the main update takes place on the basis of aerial photography with a frequency of 1 time in 5 - 7 years.
For the creation and operation of the LIS, special software is used.
The main tasks of the LIS are: creation and maintenance of a cartographic model of the state and use of land resources of the republic - the digital land cadastral map of the LIS; information support and automation of land management activities in the country.
The information of the digital land cadastral map of the LIS is used in the production of land management documentation.
The land information system on the LIS Geoportal is information and reference system, it is determined by the aerial photogeodetic method, has permissible errors, and is digitized from photographs obtained on a certain date of the territory's flight. Information about the date of the territory flight can be found directly on the LIS Geoportal in the "Land information system" layer (name of the region, year of the territory flight). The layer is currently renewed approximately once every 5 - 7 years. The boundaries of administrative-territorial units and land plots are updated on the LIS Geoportal in the process of updating the LIS once a quarter, and in the case of a large number of changes, even more often. The information on the LIS Geoportal can assist in making decisions on land management and other issues, but cannot reliably guarantee the state of the area at the moment.
According to the results of a review of literary sources that directly highlight the use of web technologies in the field of land management in the whole of the Republic of Belarus, it was not revealed, with the exception of some individual publications.
So, in the article (Ольшевский, 2011), the technology of providing and editing materials of land management schemes on the Internet is described. The architecture of this system is given, the scheme of communication of the server data with various organizations and external users, a prototype of the system is created, and the positive aspects of using this resource in the public domain are noted.
Today, the possibility of remote editing of spatial data has been implemented through individual functions of the ZIS Geoportal of the Republic of Belarus.
The issues of geoinformation support of land organization in case of on-farm land management are considered in the article (Фоменко, 2012).
The content and methodology for the development of a project for on-farm land management of an agricultural organization are considered. The technology of land management design using geographic information systems and technologies is proposed. The structural and functional diagram of GIS-support for land organization has been drawn up. An algorithm for organizing land by means of Arcview GIS is presented, which allows us to conclude that a project of on-farm land management in digital form can be available for managing agricultural production at the regional level by posting it on the Internet.
If we consider digital land management as an integral part of precision farming, then according to the analysis of publications from the near abroad, this is an insignificant number of them. The complex application of digital land management technologies is not given, there are only individual elements that are aimed at developing technologies or solving individual problems of precision farming.
In connection with the massive introduction of information technologies, the goal is to develop a comprehensive methodology for the transition to digital land management in the Republic of Belarus, as a part of precision farming. To implement it, it is necessary to solve the following tasks:
1. At the stage of the preparatory work, it is necessary:
a) to develop a comprehensive methodology for the automated assessment of the agricultural landscape, the degree of land degradation, land management characteristics (compactness, far-land, small contours, etc.) of the farm lands, the existing use of the farm lands; for identification (classification, recognition) and assessment of areal objects, it is recommended to use modern information and analytical methods based on the theories of deep neural networks; wavelets.

b) carry out:
-zoning of the territory for environmental and industrial purposes;
- integration (combination) of cadastral data on an object with a geoinformation base;
-agrochemical analysis throughout the farm in the form of an electronic atlas, including maps (layers) for each soil characteristic; at the same time, it is envisaged to produce two types of maps in an automated mode: soil maps, maps of soil characteristics;
c) develop an automated technology for creating soil maps taking into account the characteristics of soils; to provide for a complex of works on differentiated fertilization;
d) to identify the boundaries of the impact territories both in terms of their legal and technological state;
e) determine the prospects for the development of rural settlements;
f) integrate the geographic information system of digital land management with Web-technologies (Public Cadastral Map, other graphic and textual materials of the Internet environment existing in the Republic of Belarus, Geoportal ZIS of the Republic of Belarus);
g) develop a task for organizing the territory of an agricultural enterprise.
2. To develop an automated technology for substantiating land areas for the development of the enterprise in the future. At the same time, take into account the market needs for agricultural products, evaluate the efficiency and payback of costs for the development of areas, taking into account the transformation of land.
3. Create a layer of the organization of the territory for each year of crop rotation with the adjustment of the soil characteristics of the newly created fields. To increase soil fertility, it is necessary to carry out annual monitoring of their condition and correct information, develop a methodology for correcting soil maps.

Conclusions and proposals

Based on the results of the obtained information on the geoinformation support of land management in the Republic of Belarus, it can be concluded that the database and digital basis for the production of land management documentation has been fully formed, the functions of remote editing of spatial information have been implemented, through the use of individual modules of the Geoportal LIS of the Republic of Belarus, but at the same time, there is no separate web-resource for the implementation of land management design.
Based on the review of literary sources on the use of geoinformation systems for the development of the agro-industrial complex, most of the developments are reduced to the system of introducing precision farming in agricultural enterprises. At the same time, the results of implementation are given pointwise, in individual farms.
For the mass introduction of precision farming technology, it is necessary to carry out a high-quality, timely, with the required accuracy procedure for on-farm land management in order to obtain planning and cartographic material, in particular:
- compile yield maps;
- compile maps of soil types and soil differences;
- to draw up maps of the content of organic substances and microelements;
-conduct agrotechnical monitoring of agricultural land with the definition of the boundaries of the plots and draw up their cadastre;
- to carry out an agrochemical survey of soils with the definition of fertilizer application rates, planning and calculation of liming rates.

References

1. Геопортал ЗИС Республики Беларусь (The Geoportal of the land information system of the Republic of Belarus). Дата доступа 20.01.2021, (https://gismap.by) (in Russian)
2. Кодекс республики Беларусь о земле. (Land Code of the Republic of Belarus) 2008. Принят 17 июня Палатой представителей № 425-З (https://etalonline.by/document/?regnum=hk0800425) (in Russian)
3. Об информации, информатизации и информационной безопасности (About information, informatization and information security). 2008. Принят 10 ноября Палатой представителей № 455-З. Закон Республики Беларусь, (https://pravo.by/document/ ?guid=3871&p0=H10800455) (in Russian)
4. Ольшевский, А. (2011) Технология предоставления и редактирования картографических материалов схем землеустройства в сети Интернет (Technology for providing and editing cartographic materials of land management schemes on the Internet). Земля Беларуси, № 4, С. 39 – 45 (in Russian)
5. О составе государственных информационных ресурсов, порядке их формирования и пользования документированной информацией из государственных информационных ресурсов (On the composition of

state information resources, the procedure for their formation and use of documented information from state information resources). 2009. Утвержден 26 мая Постановлением Совета Министров Республики Беларусь № 673, 1– 27 с. (in Russian)
6. Фоменко, П. Н.(2012) Геоинформационное обеспечение организации земель при внутрихозяйственном землеустройстве (Geoinformation support organization of land for on-farm land management). Вестник ПГУ. Серия F, № 8, С. 153 – 159 (in Russian)

Information about authors:

Olga Pisetskaya, PhD, Dean of the Faculty of Land Management, Belarusian State Agricultural Academy, Republic of Belarus, Leninsky Boulevard, 4, Gorki, Mogilev region, +375-22-33-79644, e-mail: piseckaja@tut.by. Geodesy, Land Management, GIS

Yanina Isayeva, MS, Chief lecturer of the Faculty of Land Management, Belarusian State Agricultural Academy, Republic of Belarus, Leninsky Boulevard, 4, Gorki, Mogilev region, +375-22-33-79656, e-mail: ianinaisaeva88@gmail.com. Geodesy, Land Management, GIS

DOI: 10.22616/j.balticsurveying.2021.14.007

INVESTIGATION OF THE CHANGE OF WOODED AREAS IN FOREST LAND IN RAUDONE ELDERSHIP

Puziene Ruta
Vytautas Magnus University, Lithuania

Abstract

Under the conditions of a global reduction in forest areas and climate change, it is important to preserve as many tree-covered areas as possible and understand change trends. The article purpose – aims at identifying forest area change trends of 19th-20th c. in the current forest land of the eldership Raudonė. In the research, historical topographic maps compiled during different periods, and 2019 data from the forest registry are used. The research method of a comparative analysis is employed. The change in forest areas was analysed, and forest areas that remained unchanged for 200 years were identified. The comparison of current forest areas reflected in the cadastral data and forest areas of the considered period allowed identifying the tendency of assigning land the purpose of forest land. During the research, the period with largest forest areas was determined to be the 19th c., and with the smallest – 1st half of the 20th c. During the Soviet period, forests areas were increasing, but did not achieve the same level as in the 19th c.

Key words: maps of 19th-20th c., forest cadastre, forest areas, comparative analysis.

Introduction

In order to properly assess the current situation and plan future actions, knowledge and understanding of the past is required. Only by understanding past processes, their change trends, taking into account different factors influencing forest areas, we can understand and manage current processes, as well as plan the future in order to achieve the optimal result. Forests play an important role in improving the ecological situation and managing the climate change. Currently, during the time of global warming that may have catastrophic consequences, it is vital not to reduce forest areas and further expand them (Dagiliute, Kaktyte, 2013).

The forest change is a constant process that was taking place in the past and is still happening now. Before humans populated Europe, the forest change was caused by natural processes. When people started living here, an anthropogenic factor was added to the natural factors. Before the industrial revolution, the impact of humans on forests was of low significance due to small human population, primitive tools, low demand for timber and its products. In the conditions of scientific and industrial development and urbanization, this demand grew, and it negatively impacted forest areas (Birks, Tinner, 2016; Fedotova, Loskutova 2015; Hansen *et al.* 2013).

In order to understand the scale of the reduction of forest areas, it is important to identify former forest areas, simulate their change, taking into account the growth of the human population, as well as industrial, agricultural and urban development. For this purpose, it is expedient to identify the change in forest areas during different periods in order to analyse the impact of the anthropogenic influence that has been rapidly increasing during the past 300 years due to scientific achievements, industrial development and the population growth.

Former forest areas were researched a lot in the past by employing a palaeobotanical method on the basis of preserved historical documents and statistical data (He *et al.*, 2008; Ralph *et al.*, 2014; West, 1980). As the development of the cartography science progressed, an opportunity arose to monitor relatively recent changes by using topographic maps, including on the territory of the Republic of Lithuania. The current territory of the Republic of Lithuania was mapped for the first time when the Russian empire was compiling military topographic maps, then during the Lithuanian Interwar period and during Soviet times. The analysis of the area situation depicted in these maps allows observing changes of forest areas recorded in the cartographic works.

First, we must determine what will be considered forest in the scope of the present research. The definition of a "forest" differs from country to country, it may also differ within the same country, based on the changes in the legal base. "Forest" is understood differently in the spoken language and in legal definitions. Therefore, before starting the research, what is to be considered forest needs to be defined. Whether it is an area with trees growing on it, a legally regulated definition, or a forest definition chosen by the researcher.

Legally, the notion of a forest is defined by the Law on Forestry of the Republic of Lithuania. Due to this law being amended, forest was understood differently as well. In 1996, a forest was defined in this law as follows: "Forest is a land area not less than 0.1 hectare in size covered with trees, other forest plants or vegetation-lost forest (cutting areas, burnt areas). Tree groups and narrow lines of trees up to 10 meters of width in fields, at roadsides, water bodies, in cities, in residential areas, and cemeteries, green hedges, single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests" (Lietuvos Respublikos..., 1994).
Amendment that came into force in 2001 defines a forest as follows: "a land area not less than 0.1 hectare in size covered with trees, the height of which in a natural site in the maturity age is not less than 5 meters, other forest plants as well as thinned or vegetation-lost forest due to the acts of nature or human activities (cutting areas, burnt areas, clearings). Tree groups and narrow lines of trees up to 10 meters of width in fields, at roadsides, water bodies, in residential areas and cemeteries, green hedges, single trees and bushes, parks planted and grown by man in urban and rural areas are not defined as forests" (Lietuvos Respublikos..., 1994).
Amendment that came into force in 2015 defines a forest as follows: "a land area not less than 0.1 hectare in size covered with trees, the density of which is not less than 0.3 and the height in a natural habitat in the maturity age is not less than 5 meters, other forest vegetation, as well as a land area not less than 0.1 hectare in size, in which a stand is thinned or temporarily without tress due to human activities or natural factors (clearings to be planted with, cutting areas, dead stands). Greenery planted along road lanes, trees and shrubs growing in non-forest land plots managed on the basis of the right of trust by a manager of the public railway infrastructure, narrow – up to 10 metres – tree lines, green hedges, single trees and shrubs as well as the greenery planted on the non-forest land in urban and rural areas are not considered a forest" (Lietuvos Respublikos..., 1994).
As we can see, the initial legal regulation defines forest as a land area not less than 0.1 hectare in size covered with trees, later a condition is added that trees must be no less than 5 meters in height, and, finally, as a mandatory condition, their density is also added (Lietuvos Respublikos..., 1994).
Due to the changing definition of a forest, the accounting for forest areas may differ, therefore, for the research, a slightly different interpretation of the definition of a forest was chosen. From the 19th c., when an area was mapped, an area covered with trees was marked by conventional signs denoting a forest, which, on the basis of its size, is appropriate to be depicted on a map. Therefore, the term "forest" will be used as a term denoting an area covered with trees (forest areas).
The legal base includes a term "forest land". It is not an analogous term for "forest". In the Law on Forestry of 2015, it is defined as "an area covered with forest – forest stands, as well as non-forest covered areas – cutting areas, dead stands, forest clearings, nursery areas, forest seed orchards, raw-material plantations, collections of clones, land assigned to afforestation. Forest roads, blocks, technological and fire break lines, areas covered by timber storage houses and other forest-related equipment (ditches, culverts, bridges, fire towers, etc.), recreation grounds, animal feed grounds, are ascribed to forest land as well. "As evident, forest land is not limited to only land covered with trees, it also includes land plots unrelated to growing trees, as, for example, timber storage houses" (Lietuvos Respublikos..., 1994).
The change of forest-covered areas is a pressing issue for the Republic of Lithuania, as well as Europe. In order to plan and regulate forest areas, it is important to know and understand their change trends. It is important to understand which forest areas remained unchanged throughout centuries, how many areas were cut/reforested.
The article purpose – aims at identifying forest area change trends of 19th-20th c. in the current forest land of the eldership Raudonė.

Methodology of research and materials

In accordance with the European practice, forest cover is calculated by forest land divided by the area of a selected territory. For the analysis of the declared forest cover of the 21st c. eldership Raudonė, a forest registry was chosen in order to compare the current declared forest cover of the area with the former forest cover of the territory calculated in accordance with the actual forest cover situation depicted in the cartographic materials. In this case, the notion of "forest cover" is ambiguous, but, for the purpose of this research, this exact variant was chosen intentionally. The aim is to compare the actual former forest cover with the current declared cover which is accepted as official. Moreover, the forest registry allows pinpointing areas of forest land. As a result, when having a forest registry and comparing

it to areas previously covered in forests, tendencies of the basis for assigning a forest land purpose for an area on a certain territory can be identified.
For the analysis of the change in forest-covered areas, the eldership Raudonė located in the district of Jurbarkas (Fig. 1) was selected; its area is 102.4 km^2.

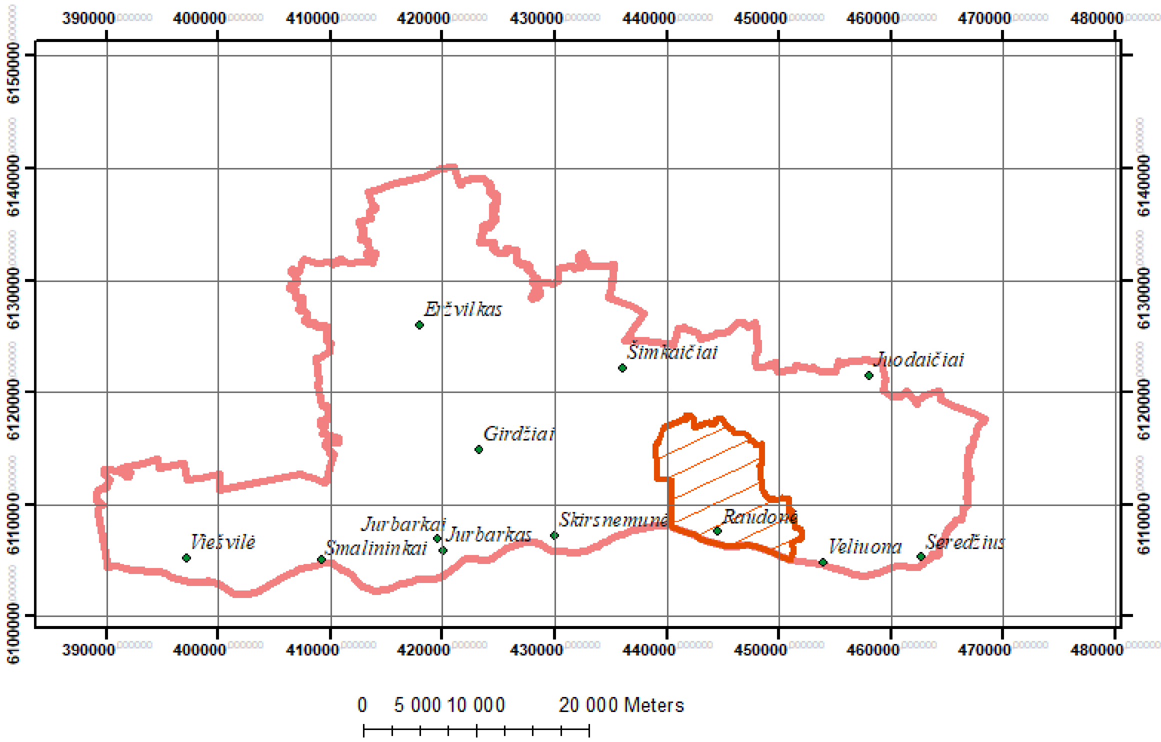
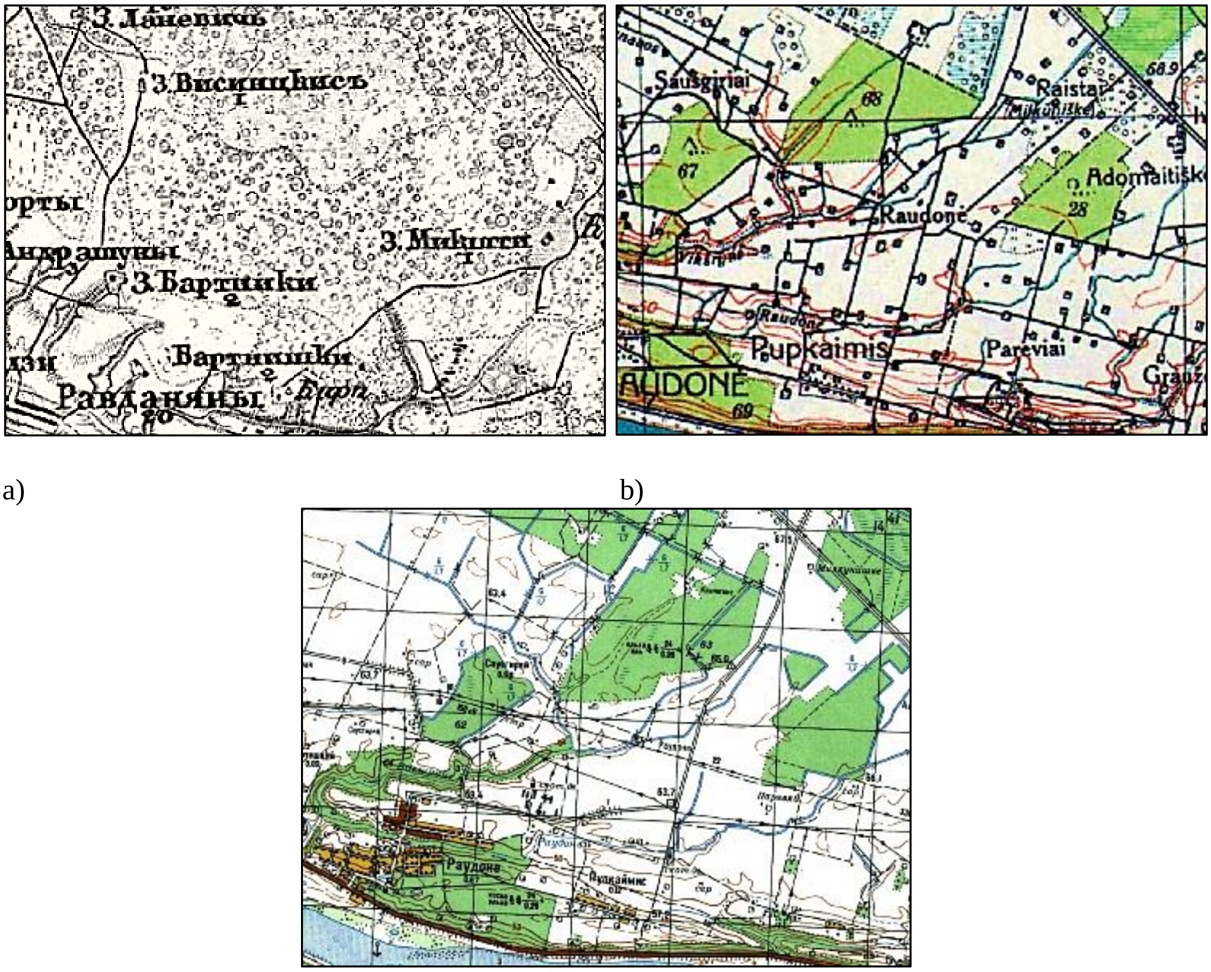


Fig. 1. Raudone eldership (district of Jurbarkas)

For analysing the change in forest areas, among other methods, topographic maps can be used. They allow monitoring the change of the Earth's cover, including the change of woodlands. Due to a generalization inherent to maps as well as cartographic methods, the outline of the depicted forest land is generalised, therefore, the macroscale change of the forest land may be analysed without expecting each line turn of a conventional sign to ideally match the outline of the forest land and reflect small configurations of land boundaries. Nevertheless, generalizing does not result in significant loss of forest areas, therefore, it can be stated that the absence of microscale changes does not have a significant impact on the result, and main forest change processes are sufficiently accurate and informative.
More accurate topographic maps of the Republic of Lithuania were started to be compiled in the 19th c., when the triangulation network started to be developed, a need for military purposes arose for topographic maps with sufficient accuracy. As time went by, the territory of the Republic of Lithuania was mapped several times, therefore, the following maps were employed for the research:

- Topographic maps compiled by the Military Topography Department of the Tsarist Russia (Fig. 2, a)). Topographic maps of the European part of the empire compiled in the second half of the 19th c. in the Tsarist Russia were published in 1860-1890. The scale is 1 English inch to 3 miles, what corresponds to M 1:126,000. The map page is rectangular, 58x42cm, it corresponds to 73x53 km at the location. The measurement accuracy of important objects is 50-200 m, of unimportant – 100-300 m. In some instances, the tolerance reaches 500 m and more.
- 1:25,000M maps published by the Military Topography Department of Lithuania during the interwar period (Fig. 2, b)). The works of compiling topographic 1:25,000M maps during the interwar period in Lithuania were started in 1924. The published materials map the territory of the country of that time, the map page size is 47x45 cm. The publishing activities were performed by the Military Topography Department of the Military Headquarters, years of publication: 1930-1939.
- Soviet 1:50,000M topographic maps. Soviet 1:50,000M maps were compiled after the 1956-1957 renewal of the cartographic data and published in 1988 (Fig. 2, c)). For the renewal, aerial photos

and location studies were used. The map was compiled in accordance with the coordinate system of 1942.



a) b)

c)

Fig. 2. Fragment of maps: a) 1860-1890, b) 1930 – 1939, c) 1988

The data from the forest registry was used in the research (State Forest Service, 2019) (Fig. 3); formed forest land plots can be seen, each land plot has its own cadastral number.

Fig. 3. Fragment of forest cadastre, 2019

The method of comparative analysis, ArcGIS software, maps of the 19th-20th c. and the data from the forest registry were used in the research. Due to the 19th c. maps being scanned, they had no orientation

after being uploaded into the software. Objects remaining unchanged throughout time, e. g. churches, were selected for the orientation (construction years of churches as well as their affiliation with a faith-based community were thoroughly analysed in order to avoid instances when, after a church burned down, it was established in another building or mistaking churches of different faiths located relatively close to one another). A few of orientation corrections were carried out on the basis of bridges remaining from the 19th c. after studying their construction year and history. The remaining maps were downloaded from Geoportal website, they are provided to the user already with orientation.
The coordinate system LKS94 was chosen. Using the vectorisation method, forest layers of different periods were digitalised; their area was calculated. A layer of the forest registry was added on top, and the obtained results were compared.

Discussions and results

Forest-covered territories account for some land plots that, as time went by, were converted into agricultural land. Districts where conditions are not as favourable for agriculture are characterised by larger areas covered with forest and smaller agricultural land plots. The opposite is true as well: the more favourable conditions for agriculture are, the smaller areas are left for the forest. The district of Jurbarkas is located in central Lithuania, where the soil is characterised by the highest productivity score. The land productivity score in the district of Jurbarkas is 49.77, and in the eldership Raudonė – 50.71 (https://www.geoportal.lt/map/). The relief is favourable for the agricultural development (https://www.arcgis.com/apps/webappviewer/index.html?id=d29c96b53bc740e38fb79f8532753544), its unevenness is observed only in river valleys and along Nemunas. Due to these reasons, the forest cover of the eldership is currently not large, however, it was different in the past, when the population was lower and farmers only had primitive tools for agricultural use.
After orienting and vectorising forest areas, a model vector forest layer is obtained in the 19^{th} c. map. The analysis of this data allowed determining forest areas. Borders of forest areas are not strict geometric lines, they curve, are of a natural configuration, are not restricted by plots of cultivated land, roads, river beds. There is less forest in the vicinity of the river Nemunas, along which, in the old times, trading used to be carried out using the waterway, it was also convenient to use the river for log driving. There are many homesteads in the forest, with small territories around them cut for agricultural purposes. However, the cartographic materials reveal documented cutting of forest areas as well. The map (Fig. 4) shows large areas of cut forest that constitute 8.5% of the total forest area of that time (Table 1):

Table 1

Change of forest areas in the 19th century

	Forest areas, hectare
Area of felled forests	306.64
Forest area after felling	3289.97
The total forest area before felling	3596.61

After the vectorisation of forest areas depicted in the maps of the Interwar period, we can see a completely different forest cover situation. The forest areas are significantly reduced, the borders of their land plots are strictly limited in geometrical shapes, there are no lines of natural growth, it is evident, that a significant amount of forest was cut in an organised manner, entire land plots were deforested. A forest usually ends with roads, streams. The majority of forests are surrounded by large cultivated land plots (Fig. 4).
The analysis of vectorised forest areas of the Soviet times reveals that forest areas are much larger in the Soviet maps when compared to the Interwar period. Forest areas are not as fragmented, a part of cultivated land was changed to forest. After the war, when some land was left uncultivated, in some places, the forest grew back on its own, in other places, a planned afforestation was carried out, therefore, the forest-covered areas increased.
The results of the forest area change analysis are provided in Table 2 and in Figure 4:

Table 2

Comparison of forest areas in the 19th-20th centuries

Period \ Forest areas:	Hectare	From eldership area, %	Difference between areas, hectare
19^{th} c., to deforestation	3596.61	35.1	-
19^{th} c., after deforestation	3289.97	32.1	-360.64
The 1^{st} half of the 20^{th} c.	1626.09	15.9	-1663.88
The 2^{st} half of the 20^{th} c.	2394.11	23.4	768.02

The analysis of the 19^{th} c. map reveals that 306.6 ha of forest was cut during that period. The comparison of the 19^{th} c. forest area with the forest area provided in Interwar maps reveals that in the 19^{th}-the 1^{st} half of the 20^{th} c. the eldership lost as much as 1663.9 ha of forest, and, during the Soviet times, the forest area increased to 768 ha. The worst forest cover situation was during the Interwar period, when forest areas decreased by as much as 16.2%.

During the Soviet times, the forest was partially restored, but it did not achieve the forest area of the 19^{th} c. During that time, the forest cover of the territory exceeded 30%, that corresponds to the current European aspirational task and the territorial forest cover recommendations.

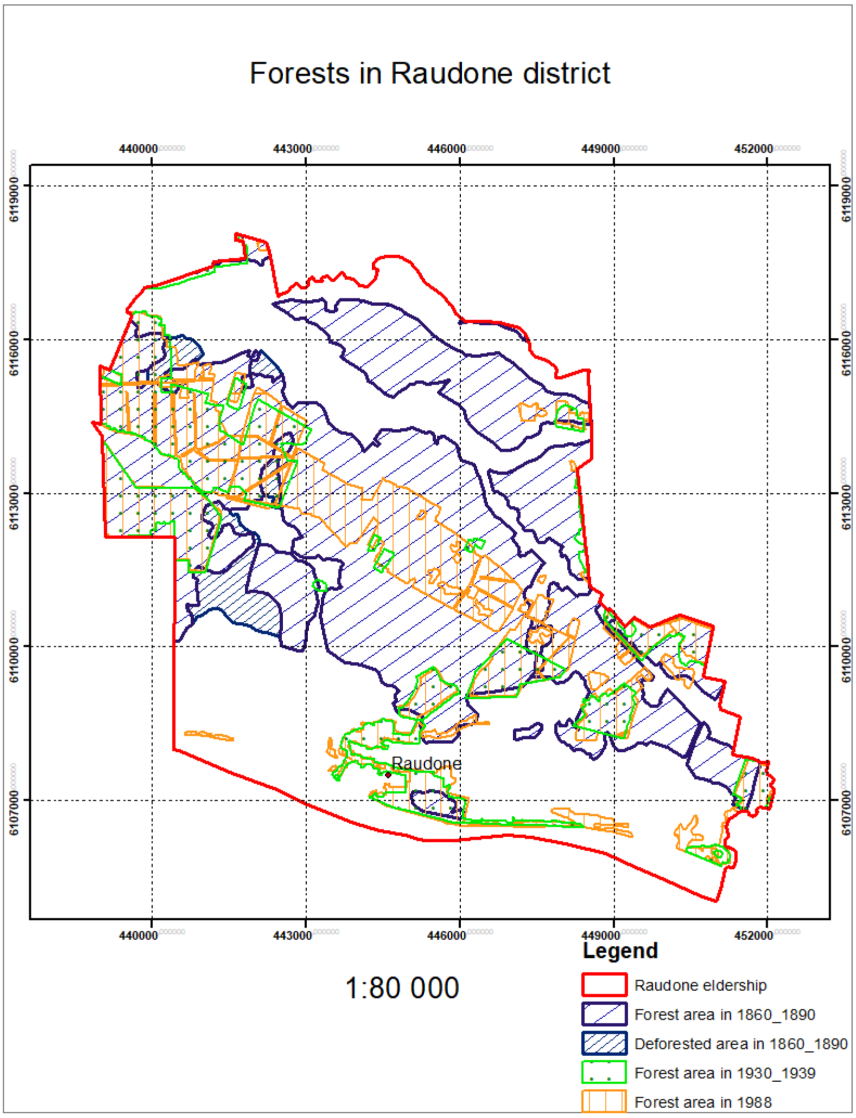


Fig. 4. Change of forest areas in the 19th - 20th c.

Carrying on with the research, vectorised forest areas were overlapped, and there were areas identified that retained forest-covered areas for the entire 200 years. These areas cover an area of 1137.37 ha, i.e., 11.1% of the entire area of the eldership (Fig. 5), and mostly corresponds to the forest existing in the 1st half of the 20th c. Here, the forest remained during the entire 19th-20th c. period – during the entire analysed period, trees were growing and no agricultural activities were carried out. It is possible (it was not documented in the maps, so only an assumption can be made), that the forest was cut in some places, but later they were replanted or they regrew on their own, and there was no anthropogenic activity carried out that would destroy forest areas. These are the most stable forest areas, a kind of "centres" of forests, around which, as time went by, the forest developed/withered. These "centres" avoided the anthropogenic influence that conditioned the area change and remained unchanged during the analysed period – over two centuries. From the point of view of ecological sustainability, these territories are most stable.

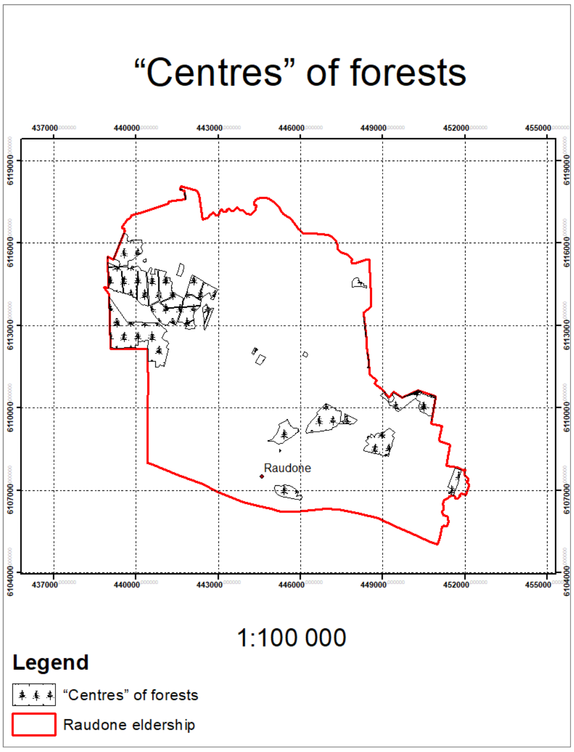
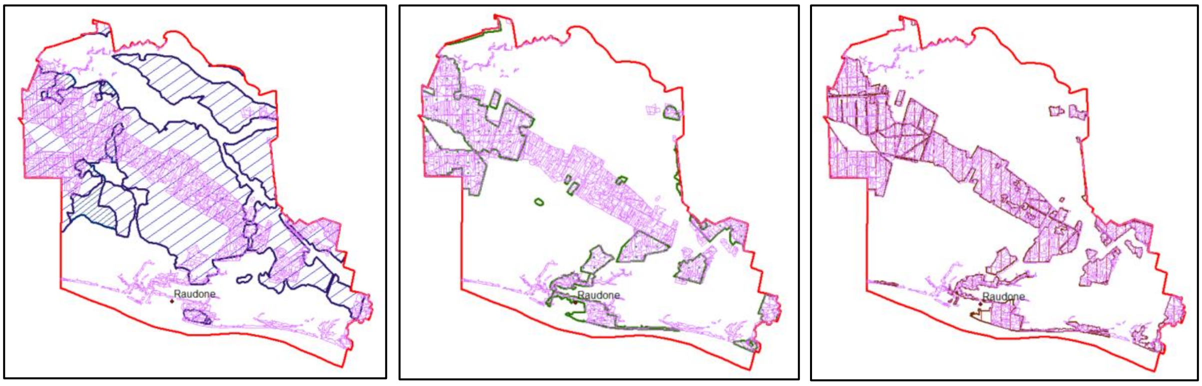


Fig. 5. "Centres" of forests (19th-20th c.)

The layer of cadastral data allows comparing the current declared forest cover situation (the forest cover, in accordance with forestry land area, is 25.7%) with the former situation of forest-covered areas (Fig. 6). Moreover, the analysis of the tendencies of the layout of modern forests on the territory of the eldership can be carried out. We can see that the current forest land is the same actual place as former forest areas during the Soviet times. The cadastral data allows observing the tendencies of the land being assigned to "forest land" – in essence, with few exceptions, land plots that were covered in forests during the Soviet times are assigned this purpose. We can make an assumption that forest areas in the Raudonė eldership have underwent no significant changes when compared to former forest areas of the 2nd half of the 20th c. The current forestry land area is as if a certain reflection of the centre of a former midwood – where the midwood once stood, there, through its centre, the current forest land lies today.



a) b) c)

Fig. 6. Overlap of 21st c. forest register data layers and vectorized areas: a) 1860-1890, b) 1930 – 1939, c) 1988

Conclusions and proposals

- The forest cover of the Raudonė eldership is smaller than the average of the Republic of Lithuania and constitutes 25.7%. This percentage of forest cover is predetermined by favourable conditions for agricultural activity – a high soil productivity score and a relatively even relief.
- The forest cover level in the analysed territory in the 19th c. was not low, it was a little above 30%, but, due to intensive cutting in the 1st half of the 20th c., it fell to 15.9%. In the 2nd half of the 20th c., forest areas increase significantly and reach 23.4%. These areas are smaller than in the 19th c., but 7.5% larger than in the 1st half of the 20th c. that constitute 768 ha.
- During this entire period, forest borders changed significantly. In the 19th c., natural forest borders without strict contours may be observed. In the 1st half of the 20th c., forest borders are strictly defined, the impact of the anthropogenic activity is observed. In the 2nd half of the 20th c., forest borders partially naturalise, it is particularly evident along the shores of water bodies. A speculation can be made that the forest was allowed to regrow naturally at those locations.
- The purpose of forestry land assigned to land plots corresponds with the former forest areas of the Soviet times. A conclusion can be made that the current dislocation and volume of forestry land was influenced by the forest areas formed during the Soviet times, which, when comparing their cadastral data with the vectorised data, remained almost unchanged.
- The Raudonė eldership has only about 11.1% of forests that have not been converted into agricultural land or other land for two centuries and have remained unchanged and always have had trees growing in them. These are the most ecologically stable areas, but there are very few of them.

References

1. Birks H.J.B., Tinner W. (2016) Past Forests in Europe. In book: European Atlas of Forest Tree Species Publisher: Publication Office of the European Union. (https://boris.unibe.ch/80787/1/Past_forests_of_Europe.pdf).
2. Dagiliute R., Kaktyte L. (2013) Miškingumo pokyčiai Lietuvoje ir įtaka klimato kaitai 2010-2020 m. (Changes in forest cover in Lithuania and the impact on climate change in 2010-2020). Žmogaus ir gamtos sauga. pp. 48-51. (http://sauga.asu.lt/wp-content/uploads/sites/8/2016/01/48-51_Dagiliute_1.pdf). (in Lithuanian).
3. Fedotova A., Loskutova M. (2015) Forests, Climate, and the Rise of Scientific Forestry in Russia: From Local Knowledge and Natural History to Modern Experiments (1840s–early 1890s). New Perspectives on the History of Life Sciences and Agriculture (pp.113-132). DOI: 10.1007/978-3-319-12185-7_7
4. Greg C. Liknes, Mark D. Nelson, and Daniel J. Kaisershot. (2013) Net Change in Forest Density, 1873-2001: Using Historical Maps to Monitor Long-term Forest Trends. (http://www.nrs.fs.fed.us)
5. Hansen M. C., Potapov P. V., Moore R., Hancher M. Turubanova S. A., Tyukavina A., Thau D., Stehman S. V., Goetz S. J., Loveland T. R., Kommareddy A., Egorov A., Chini L., Justice C. O., Townshend J. R. G.

(2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science, Volume 342, pp. 850-853. DOI: 10.1126/science.1244693

6. He F., Ge Q., Dai J., Rao Y. (2008) Forest change of China in recent 300 years. J. Geogr. Sci., 18, pp. 59–72. https://doi.org/10.1007/s11442-008-0059-8
7. Geoportal.lt. https://www.geoportal.lt/map/ [2021-01-02].
8. Lietuvos reljefas. https://www.arcgis.com/apps/webappviewer/index.html?id=d29c96b53bc740e38fb79f8532753544 [2021-01-02].
9. Lietuvos Respublikos Miškų įstatymas (The Republic of Lithuania Law on Forests), (1994) No. I-671 Vilnius. (https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.6036/kvlNKCdVIL). (in Lithuanian).
10. Ralph M. F., Woodbridge J., Neil R. (2015) From forest to farmland: pollen-inferred land cover change across Europe using the pseudobiomization approach. Global change biology, Volume 21, Issue3, p.p. 1197-1212. https://doi.org/10.1111/gcb.12776
11. West R. G. (1980) Pleistocene forest history in east Anglia. New Phytologist, Volume 85, Issue 4, pp. 571-624. https://doi.org/10.1111/j.1469-8137.1980.tb00772
12. William B. Meyer and B. L. Turner. (1992) Human Population Growth and Global Land-Use/Cover Change. Annual Review of Ecology and Systematics, Volume 23, pp. 39-61. https://doi.org/10.1146/annurev.es.23.110192.000351

Information about author:

Ruta, Puziene, doctor, associated professor, Institute of Land management and Geomatics, Vytautas Magnus University Agriculture Academy. Studentų str. 11, LT-53361 Akademija, Kaunas distr., +37037 752 272, ruta.puziene@vdu.lt. Fields of interest: geographic information systems, surface modelling, history of geodesy and cartography.

DOI: 10.22616/j.balticsurveying.2021.14.008

ENGINEERING INSPECTION ASSOCIATED ARTIFICIAL INTELLIGENCE FOR APPRAISAL OF THE PROPERTY IN NITEROI, RIO DE JANEIRO, BRAZIL

Surgelas Vladimir, Arhipova Irina, Pukite Vivita
Latvia University of Life Sciences and Technologies

Abstract
The construction sector is linked to the general development of a country. There is a lot of data scattered and not properly explored in relation to the buildings constructed. However, if these scattered data on the behavior of the real estate market are organized, combined with knowledge of civil engineering, this merger of information can mitigate some evaluation problems, especially those that are overvalued for unknown or dubious reasons. Thus, there is a need for models capable of working with limited data to analyze the causal relationships between explanatory variables and sales prices and, from there, predict property values. The purpose of this article is the innovative use of simple building inspection strategies to predict the market price for residential apartments. For this, 19 samples of residential apartments are used in the city of Niterói, Rio de Janeiro, Brazil, in February 2021. The methodology uses the results of the survey of civil engineering and converts them into heuristic terms predicting the price of the property. With this, the imprecision, uncertainty, and subjectivity of human expression combined with the knowledge of civil engineering result in a plausible solution and easy application in the market. Finally, the use of fuzzy logic in the evaluation of properties is an adequate unconventional method, in addition to avoiding repetition in regression coefficients in binary logic. To check the reliability of the method, the comparison between the market values of the samples and the values predicted by the fuzzy logic is used. The result according to the mean absolute percentage error (MAPE) can be interpreted as a good result (7%).
Keywords: appraisal, artificial intelligence, civil engineering, ambiguous logic, inspection

Introduction

When examine the heuristic approach applied to the associated real estate market, a range of dispersed data not properly treated is found, which could somehow generate knowledge. Because, dispersed data is useless, but aggregated data can generate rules, rules can generate forecasts, forecasts generate knowledge, and knowledge generates income and increases the added value for the civil engineering sector and consequently leverages the economy in general. Therefore, the integration of different types of information and the recognition that the environment is constantly evolving creates the need to know how information is created, handled, and transmitted (Delgado et al., 2020). Based on that, the use of technology must be seen as a fundamental tool, meeting this constantly evolving scenario. In this sense, machine learning can be used in Civil Engineering (Manu, 2019). However, some precautions must be taken to consider a successful task. Thus, when the dispersed data becomes knowledge, there will be positive aspects for science, education, economics, job and income generation, social (ILO, 2018). Moreover, the methodology with Fuzzy Logic techniques is a weighted inference method that allows users to insert inaccurate data and heuristic observations and draw correct conclusions (Jochheim-Wirtz, 2013). In addition, the real estate market involves human expression heuristics affecting the property valuation by these heuristic variables (Renigier-Biłozor et al., 2021). However, if added to inspection criteria based on the technical knowledge of civil engineering, combined with rules of association of artificial intelligence, fuzzy logic, and heuristic perception, it results in the correct prediction of apartment prices, without the occurrence of regression instability. Moreover, the mining tools and applications make the scientific community pay attention to engineering, this can bring fascinating results (Arvindhan, Prasanna, 2016). From this, this fuzzy methodology becomes ideal for situations in which it is necessary to consider subjective aspects that are difficult to measure. As well as those aspects inserted as the subjective value of a property. Another aggravating factor is related to the existing abnormality in the building, useful life, and engineering systems involved (Abbott et al., 2007). In this context, the physical state of the building reflects its functional performance (NEN 2, 2006). Thus, that progressive deterioration of buildings has damaged the urban image of Portuguese cities and afflicted the habitability of many rented units (Pedro et al., 2008). Consequently, this status of conservation is reflected in the market price. Furthermore, the lack of inspection of buildings in buildings can result in an early loss of engineering systems (Syamilah et al., 2016). So, the earlier an anomaly is detected in a building, the more efficient and less costly the intervention in the future will be (Che-Ani et al., 2015). In this way, in order to make a diagnosis of a pathological manifestation in the building, it is necessary to carry out, initially, a visual inspection to make a collection of data, apparently dispersed (Garrido Vasquez et al., 2016).On the other hand (Mansuri, Patel, 2021) demand the automated use of building inspections. Alleging a decrease in human errors at the time of inspection. Anyway, some precautions must be followed in order to avoid errors in the inspection. Thus, it is necessary to follow some basic procedures, such as:

a) Inspection for mapping symptoms. This procedure begins with a visual inspection, where the aim is to identify the symptoms of existing anomalous in the structure through a mapping of the evidence;

b) Collection of data and scattered information. Furthermore, in several countries, the physical condition of a building is assessed and inspected based on the diagnosis of the degree of deterioration of the building elements (Costa Branco De Oliveira Pedro, et al., 2008). The Portuguese method of building inspection allowed for an extraordinary update of the lease agreements signed in that country. To that proposal, the National Civil Engineering Laboratory (LNEC) developed the "method to assess the state of conservation of buildings" within the legal framework of Portugal (Pedro et al., 2009). The same authors saws that the resource with only visual inspection was considered adequate because it allows the detection of the most notorious anomalies and at the same time contributes to the balance of time and resources with the low cost of the process. The method allows converting the anomaly index (expressed on a continuous scale from 1.00 to 5.00). That scale reflects the status of conservation of the under appraisal (expressed in a nominal scale from poor to excellent). For practical purposes, anomalies in buildings are classified into 5 basic categories. 1) Very light (excellent), 2) Light (good), 3) Medium (average), 4) Serious (bad), 5) Very serious (terrible). The anomaly index (AI) building's conservation status are: very light $5.00 \geq AI \geq 4.50$; Light $4.50 > AI \geq 3.50$; Medium $3.50 > AI \geq 2.50$; Serious $2.50 > AI \geq 1.50$; very serious $1.50 > AI \geq 1.00$ (Pedro et al., 2008). So, heuristics are ideal for solving poorly structured problems (Abel, 2003). In this context, they also provide acceptable solutions to complex problems, if supported by artificial learning algorithms. This cognitive heuristic form influences the decision, which starts to be made based on a balance between reasons for and against the various alternatives. This source of discovery of motives occurs in situations of uncertainty, conflict (Tversky, Kahneman, 1974). Thus, among the most important characteristics of the property, in the particular case of the real estate market (Libby, Kyle, 2014) it has some differentiating characteristics, such as strong influences on the location and heterogeneity of assets, in addition to operating under imperfect competition. So, the purpose of this article is to use simple building inspection strategies to predict the market price for residential apartments. For this, only 19 samples of residential apartments are used in the city of Niterói, Rio de Janeiro, Brazil in February 2021. Thus, the process of appraisal follows by the Fuzzy method combined with the incorporation of the association rules originated from Weka "apriori" algorithm (Witten et al. 2011). In Mandami defuzzification process, the interpretation of the ambiguous set of output inferred carried out, to obtain a numerical value. So, the InFuzzy software was chosen to discover the prices of the residential flats. To verify the reliability of the method, a comparison between the market values of the samples and the values predicted by the fuzzy logic was used, by the mean absolute percentage error (MAPE).

Materials and Methods

This experiment uses the samples with only 19 residential apartments in Niterói, Rio de Janeiro in February 2021. So, for a better understanding of the methodology used it was divided into 5 phases described below. Phase 1 – selecting scattered data, Phase 2 - Preparing files to association rules, Phase 3 – Generating association rules, Phase 4 - Fuzzy Inference process, Phase 5 - Interpretation of the precision of the experimental model. So, detailing the phases.

Phase 1 - Search for the data source available on the World Wide Web. The variables evolved are the dependent variable Y is housing price (Euro per m^2) and following factors or independent variables were chosen: AREA (m^2), CONSV_AP = apartment conservation (index from inspection), CONSV_BUILD = building conservation (new (1), renewed (2), old (3)), ROOMS = number of rooms (1), (2), (3), (4); PARKING = car parking (inside build (1), outside build (2), no parking(3)), AIR CONDITIONING = comfortable (direct (1), uncomfortable (2)), VIEW = environmental / OCEAN VIEW (direct (1), no direct (2)). Performs a practical survey of the real estate market in the city of Niterói in Rio de Janeiro, Brazil and collects scattered data from this real estate market. This is related to offers for the sale of 1, 2, 3 and 4 rooms residential apartments. Determines the heuristic variables to be used in the evaluation process.; Analyzes the characteristics of these apartments using civil engineering inspection techniques.; It describes the state of the apartment's degree of anomaly according to the score (Table 1) obtained on the field application form (Pedro et al., 2008).; compiles all the dispersed data obtained in the civil engineering inspection and selected heuristic variables.

Phase 2 - The data is organized by the author to aggregate the attributes of each apartment. The author created the ARFF file on the Notepad++ with the content of the price /square meter ratio. The application of the ARFF file is developed by the author is later launched in the Weka software (Witten et al., 2011).

Phase 3 - From the data obtained in phase 2, the use of artificial intelligence to obtain association rules begins. For that, data mining is necessary. Weka Software will generate association rules that will present a pattern of behavior (Steven et al., 2019), which in this case are related to the data collected from the property samples. For this task, the "apriori" algorithm was chosen. Apriori performs the mining of association rules. This algorithm is suitable for a small amount of data, ideal for this experiment.

Phase 4 - In this part, the InFuzzy software is used (Posselt et al., 2015). It is a tool for the development of diffuse system applications. In this task, the author inserts the association rules of interest chosen for this experiment, as selected in Step 3 which will insert in the InFuzzy software to generate association rules used in Fuzzy Logic. In this important phase, the price of the property is forecast, using the InFuzzy Software for modeling the diffuse system. The modeling of a tree is done using linguistic terms to generate a function per variable. From that, the methodology is based on ambiguous logic and precedes the following basic steps (Figure 1) Moreover, the range is chosen based on the experience of this researcher. In this way, the variables, scope, classification, parameter, and association function are defined. To define the parameter item in the area variable, the author chooses a Gaussian function, defined below. For this, was checking the relevance of the samples by Chauvenet's exclusion criterion. By this criterion, the sample is relevant if the quotient between its deviation (which is the difference in absolute value between the sample value and the mean) and the standard deviation is lower than the tabulated Chauvenet critical number. Applied statistical theory: where t_c= percentile values for the distribution "t" Student to "n" samples and "n-1" degrees of freedom with the confidence of 80%. The confidence limit is defined by the model

Phase 5 - The purpose of this step is to interpret the precision of the experimental model. It is about reporting the results of step 4 and checking for compatibility. This compatibility and precision of these results are accomplished by the following metrics, the mean percentage absolute error (MAPE).

Results and Discussion

Phase 1 – selecting scattered data. 19 samples of apartments advertised on the World Wide Web are used to compose the learning of the "apriori" algorithm, 37 construction items are analyzed visually through a form, involving various specialties within the field of engineering science. The linguistic terms are introduced after the comparison with the information in Table 2 and after transcribed in Table 1 and Table 2. The Icarai beach at Niterói City 53% roughly are residential flats in good condition, these are among new and reformed residential apartments.

Table 1

Abnormalities took from inspection (inside) (Source: author)

Variable	Number of anomalies found after civil engineering inspection inside of the apartment building				
	Very light (excellent) 5.00 > IA ≥ 4.50	Light (good) 4.50 > IA ≥ 3.50	Medium (medium) 3.50 > IA ≥ 2.50	Serious (bad) 2.50 > IA ≥ 1.50	Very serious (terrible) 1.50 > IA ≥ 1.00
Consv_ap	9	10	0	0	0

Table 2

Result of examination on residential flats in Niterói city (Source: author)

	Variables			The linguistic term used in "consv_ap"	The linguistic term used in "consv_build"
	Index: consv_ap	Area (m^2)	Index: consv_build		
1	4,79	70,00	1.00	excellent	new
2	3,96	85,00	3,00	good	old
3	3,95	100,00	3,00	good	old
4	4,33	90,00	1,00	good	new
5	4,34	88,00	3,00	good	old
6	4,01	180,00	3,00	good	old
7	4,63	110,00	1,00	excellent	new
8	4,79	200,00	2,00	excellent	renewed
9	4,03	240,00	1,00	good	old
10	4,07	94,00	1,00	good	old
11	4,08	95,00	1,00	good	old
12	4,52	372,00	1,00	excellent	new
13	4,57	180,00	1,00	excellent	new
14	4,56	250,00	1,00	excellent	new
15	4,60	91,00	1,00	excellent	new
16	4,66	150,00	2,00	excellent	renewed
17	4,19	90,00	1,00	good	old
18	4,51	93,00	1,00	excellent	new
19	4,63	94,00	1,00	excellent	new

Phase 2 - Preparing files to association rules. The author created the ARFF file on Notepad++ with the content of the price /square meter ratio. It was possible to analyze the purpose of price prediction in this first result, 90 best rules following 70% (confidence) were chosen. Figure 1 shows a partial view construction of the ARFF file extension. Thus, phase 3 starts only from the creation of this file.

```
@relation price_per_square_meter
@attribute area_m2
{70.00,85.00,100.00,90.00,88.00,180.00,110.00,200.00,240.00,94.00,95.00,372.00,180.01,250.00,9
1}
@attribute cons_ap {terrible, bad, medium, good,excellent}
@attribute cons_build {new, renewed, old}
@attribute ocean_view {no_view, indirect, direct}
@attribute rooms {small, normal, good, very_good}
@attribute air_conditioning {comfortable, uncomfortable}
@attribute parking {inside, outside, no_parking}
@attribute price? {low, average, expensive}
@data
70.00, excellent,new,no_view,normal,comfortable,inside,average
85.00, good, old, no_view, normal, uncomfortable, inside, expensive
100.00, good, old, no_view, normal, comfortable, no_parking, low
90.00, good, new, no_view, very_good, uncomfortable, no_parking, low
```

Figure 1. Partial view of ARFF file creates in Notepad++ (Source: author)

Phase 3 – Generating association rules. The file format required for the Weka software to understand is not obtained automatically. The domain of the attribute is described by the author. Thus, the Weka software generated 2,189 association rules. It occurs due to the learning/data mining algorithm called "apriori". The criterion established by the researcher was 70% confidence. After analyzing the purpose of the price forecast, 90 best rules were selected with the price as a consequence. In this context some of these rules are presented below.

IF (air_conditioning = comfortable) AND (parking = inside) THEN (Price = average)

Phase 4 - Fuzzy Inference process. By the way, in this step, the price of the property is forecast, using the Infuzzy software for modeling the diffuse system. In the defuzzification activity. The rules´s association from Weka were written in InFuzzy software. Fuzzy outputs are converted into discrete values needed to drive the control mechanism. The method of defuzzification used is the center of gravity. Sample number 12 was eliminated after verification by the exclusion criterion "Chauvenet". Chauvenet's criterion makes the assumption that the values in a dataset are normally distributed. Therefore, of the 20 samples were used. Nevertheless, only 19 remained. For this, the calculation below defines the maximum and minimum values, mean, the standard deviation of the variable "area". These values will be necessary to write the Gaussian function in the Infuzzy software. Where:

Calculation of sample average ……………...…	$(\bar{x})$	=	140.63 m^2
The standard deviation of the sample..……...…	(S)	=	78.81
Sample – maximum area found ……………..……	Max		372.00
Sample – minimum area found ………………..	Min		70.00
Sample numbers ……………..…..………………..	(n)	=	19
Degrees of freedom …………..….……………	$(n\text{-}1)$	=	18 (with 80% confidence)
Percentile values for Student's t-distribution…...	(tc)	=	1.33 (table value)

Table 3

Variables		Range	Classification	Parameters		Function
In-put	AREA	[0, 375]	low	0.00	116.58	Left ramp
			normal	140.63	78.81	Gaussian
			big	164.68	375.00	Right ramp
	CONSV_AP	[0, 5]	terrible	0.0	1.5	Left ramp
			bad	1.5/ 2.0	2.5	Triangle
			medium	2.5/ 3.0	3.5	Triangle
			good	3.5/ 4.0	4.5	Trapezoidal
			excellent	4.5	5.0	Right ramp
	CONSV_BUILD	[0, 3]	new		1	Discreet
			renewed		2	Discreet
			old		3	Discreet
	OCEAN VIEW	[0, 3]	no view	0.5	1.2	Left ramp
			indirect	0.8/ 1.65	2.5	Triangle
			direct	2.1	3.0	Right ramp
	ROOMS	[0, 4]	small		1	Discreet
			normal		2	Discreet
			good		3	Discreet
			very good		4	Discreet
	AIR CONDITIONING	[0, 2]	comfortable		1	Discreet
			uncomfortable		2	Discreet
	PARKING	[0, 3]	inside		1	Discreet
			outside		2	Discreet
			no parking		3	Discreet
Output	PRICE	[0, 3200]	low	150	1100	Left ramp
			average	700/ 1400	2200	Triangle
			expensive	1900	3500	Right ramp

Summary Fuzzy sets (Source: author)

Confidence limits were defined by the Chavenaut criterion, according to the following model.

$$Xmaxmin = \bar{x} \pm tc \times \left(\frac{S}{\sqrt{n-1}}\right)$$

$X_{max} = 164.68\ m^2$
$X_{min} = 116.58\ m^2$

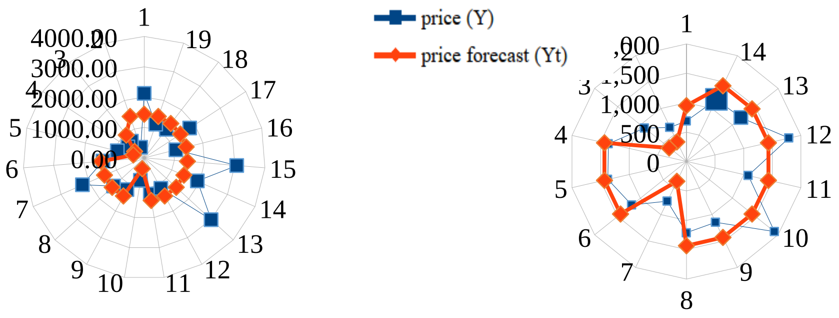
Table 3 shows a summary of Fuzzy sets. So, by the simple analysis of the conventional statistical operation, the parameters of the variable "area" found

Thus, filling the form with the rules is occupied with heuristic data brought by the investigator as reported at the time of the inspection of the building and the apartment. After that, the computer simulation begins. Figure 2 shows part of the output variable (price) and the result obtained by the reference point of the center of gravity.

consv_ap	area	consv_build	ocean_view	room	air_conditioning	parking	"PRICE"
4.79	70.00	1.00	0.50	2.00	1.00	1.00	1,433.33
3.96	85.00	3.00	0.50	2.00	1.00	1.00	1,433.33
3.95	100.00	1.00	0.50	2.00	1.00	3.00	953.42
4.33	90.00	1.00	0.50	4.00	2.00	3.00	372.64

Figure 2. Partial view of the simulation on Infuzzy software (Source: author)

Next, figure 3 shows the results of the simulation in the Infuzzy software. The result using 19 samples to obtain a property price forecast was analyzed using the center of mass defuzification procedure. This shows the final variable of the process (Price at 1,433.33 Euro per m^2).



MAPE 58% **MAPE 7%**

Figure 3. The results get by the center of mass reference poin (Source: author)

However, when removing samples 1, 2, 7, 13, 15 for having the hotspot or heuristic effect of the influence of the ocean view (beach), there was a substantial improvement in the margin of error according to MAPE (7%) (Table 4). This demonstrates that the method used meets the purpose for which it is intended. Thus, the price forecast adjusts better to the values offered in the market. The small variation is due to the effects of conditions and pathologies found at the time of building inspections.

Table 4

Summary MAPE (Source: author)

price (Y)	Price forecast (Yt)	Y-Yt	(Y-Yt)/Yt	$(Y\text{-}Yt)^2$	abs(Y-Yt)	$[(Y\text{-}Yt)/Yt]^2$
690,72	953,42	-262,70	-0,38	69011,29	262,7	0,14
646,38	372,64	273,74	0,42	74933,59	273,74	0,18
915,73	372,64	543,09	0,59	294946,75	543,09	0,35
1363,59	1433,33	-69,74	-0,05	4863,67	69,74	0,00
1373,77	1433,33	-59,56	-0,04	3547,39	59,55	0,00
1188,84	1433,33	-244,49	-0,21	59775,36	244,49	0,04
751,14	372,64	378,50	0,50	143262,25	378,5	0,25
1211,80	1433,33	-221,53	-0,18	49075,54	221,53	0,03
1150,86	1433,33	-282,47	-0,25	79789,30	282,47	0,06
1916,32	1433,33	482,99	0,25	233279,34	482,99	0,06
1079,52	1433,33	-353,81	-0,33	125181,52	353,81	0,11
1790,77	1433,33	357,44	0,20	127763,35	357,44	0,04
1193,84	1433,33	-239,49	-0,20	57355,46	239,49	0,04
1171,84	1433,33	-261,49	-0,22	68377,02	261,49	0,05
				1391161,83	4031,04	137%
				270,59	**212,16**	**7%**
				RSME	**MAE**	**MAPE**

Phase 5 - Interpretation of the precision of the experimental model.
This research demonstrates that the heuristic knowledge of a civil engineering inspection process based on "in loco" experiments can be translated into a price estimation system with the aid of artificial intelligence tools. It should be added that the current proposal to improve the property evaluation process does not present the obstacles or the search for statistical strategies present in many cases in multiple regression. It should be added that the present evaluation method, as it has heuristic precepts, artificial intelligence and fuzzy logic associated with each other, does not present effects of multicollinearity or redundancy in the variables involved. Allied to the result as good or close to the conventional statistical process. In addition, this academic proposal has the advantage of establishing linguistic terms and parameters that are easy to handle and currently used by real estate appraisers, without the need to resort to complex statistical foundations such as those present in the multiple regression method. Table 3 provides the area parameters. The range of parameters for specific ratings overlaps a little, which can lead to errors if we try to predict the price using conventional statistics. However, in the proposed methodology, this possible error is absorbed by the elasticity promoted by the heuristic. In fact, after several tests eliminating extreme areas, the results of the apartment price forecast have remained unchanged. Because the focus here is correlated to the indexes derived from the standard form of construction inspection and to the precepts of civil engineering and to the reality of the value of the real estate market in the region under study. Thus, the study was not carried out on a larger data set, as it sought to feed the database of the artificial learning algorithm with few elements. The objective is to simulate the reality found by professional evaluators. In general, these professionals do not have, in practice, many similar samples to perform the evaluations. Therefore, it was thought to use about 20 samples in the same area as the study. From this, it was observed in this study the behavior of the methodology and the results obtained reflect a market equivalence in the forecast of the apartment price. The results of this stage 5 refer to the contrast of the market prices offered for the real estate samples with the values calculated and predicted by the ambiguous logic. The result achieved with the sending of error metrics to evaluate the forecasts with the absolute average percentage error (MAPE), was around 58%. In some areas, for example, when working with human subjectivity, it is fully expected that forecast values will also have a high coefficient of variation in the data generation process. This does not mean that the forecast model is incorrect. For, several external factors may have interfered with the forecast. In other words, this apparently high value reveals, in fact, the existence of some samples with very high values in relation to the average of the same inquired offers. This is due to the location of

these same samples. Some of them are located a few meters from the beach and have a direct view of the sea. This differential causes the value to rise a lot in relation to the average of the other samples of residential apartments. Thus, the average rate that the model is using in percentages for each forecast has an error rate of around 58%. Thus, the Fuzzy model associated with the inspection techniques of civil engineering is better suited to the reality of prices in the city of Niterói. However, when the researcher removed samples 1, 2, 7, 13, 15 for having the hotspot or strong heuristic effect of the influence of the sea view (beach), there was a substantial improvement in the margin of error, and according to the MAPE it was only 7% (seven). In addition to presenting a visual diagnosis on the state of conservation of the apartment and building. In this bias, if we compare the average value of the prices offered 1,433.91 euros per m2 with the average price of the fuzzy model 1,240.59 euros per m2, this represents a difference of only 15% between them. Thus, in the case of real estate offer values, this percentage of 15% can be understood as a discount to be applied to the offered value. This being a common form of negotiation, in practice exercised by the real estate market (Thomas et al., 2015).

Conclusions

The methodological analysis in Niterói concerns knowledge of civil engineering, artificial intelligence, and linguistic terms appropriate to the real estate market. Thus, the values obtained are very close to each other. The fuzzy process is better understood due to the ease with which linguistic terms are used in relation to the conventional statistical game. Furthermore, without presenting the drawback of multicollinearity. Therefore, with regard to the linguistic rules relevant to human behavior and the rules of association created by the "a priori" algorithm, this study concludes that the use of fuzzy logic in the evaluation of properties is an appropriate unconventional method, in addition to avoiding repetition in regression coefficients in the binary logic. The good consequences of the know-how were harmonious with the market value. Over time, the experiment acquires fabulous results in this first experiment carried out in the city of Niterói, Rio de Janeiro, Brazil.

References

1. Abel, C. F. (2003). Heuristics and Problem Solving. New Directions for Teaching and Learning. 53-58. DOI 10.1002/tl.113.
2. Abbott, G., McDuling, J., Parsons, S., Schoeman, J. (2007). Building condition assessment: a performance evaluation tool towards sustainable asset management. Viewed 29 April, 2021, (http://hdl.handle.net/10204/1233)
3. Arvindhan, M., Prasanna, S. (2016). Study on various techniques of text mining. International Journal On Engineering Technology and Sciences – IJETS™ ISSN(P): 2349-3968, ISSN (O): 2349-3976. Volume III, Issue V, May
4. Che-Ani, A. I., Ismail, I., Johar, S., Abd-Razak, M. Z., Hamzah, N. (2015). Condition Survey Protocol: A system for building condition assessment. In Applied Mechanics and Materials (Vol. 747, pp. 347-350). Trans Tech Publications Ltd.
5. Costa Branco De Oliveira Pedro, J. A., Vasconcelos de Paiva, J., Vilhena, A. (2008). Portuguese method for building condition assessment. Structural survey 26 (4), 322-335.(2008). Viewed 30 April, 2021, (https://repository.tudelft.nl/islandora/object/uuid:8bb4f41f-1281-40c0-a881-e3413330efba?collection=research)
6. Delgado J. M. D., Oyedele L., Demian P., Beach T. (2020). A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics, Volume 45, 2020, 101122, ISSN 1474-0346. Viewed 28 Arpril, 2021, (https://doi.org/10.1016/j.aei.2020.101122).
7. Faqih F., Zayed T. (2021). A comparative review of building component rating systems. Journal of Building Engineering, Volume 33, 2021, 101588, ISSN 2352-7102. Viewed 27 April, 2021, (https://doi.org/10.1016/j.jobe.2020.101588).
8. Garrido Vazquez E., Naked Haddad A., Linhares Qualharini E., Amaral Alves L., Amorim Féo I. (2016) Pathologies in Reinforced Concrete Structures. In: Delgado J. (eds) Sustainable Construction. Building Pathology and Rehabilitation, vol 8. Springer, Singapore. Viewed 26 April, 2021, (https://doi.org/10.1007/978-981-10-0651-7_10).
9. ILO, International Labour Office-Geneva. (2018). World Employment and Social Outlook 2018 – Greening with Jobs.
10. Jochheim-Wirtz, Christoph. (2013). The Official Real Estate Appraisal in Germany. Geonauka 01(03):1–5.
11. Libby W., Kyle M. (2014). Transaction Cost Economics and the Cognitive Perspective: Investigating the Sources and Governance of Interpretive Uncertainty. AMR, 39, 344–363, Viewed 29 April, 2021, (https://doi.org/10.5465/amr.2011.0463).

12. Mansuri L. E., Patel D. A. (2021). "Artificial intelligence-based automatic visual inspection system for built heritage", Smart and Sustainable Built Environment, Vol. ahead-of-print No. ahead-of-print. Viewed 29 April, 2021, (https://doi.org/10.1108/SASBE-09-2020-0139).
13. Manu Mitra. (2019). Machine Learning in Civil Engineering. J Archit Sci Civ Eng. 2019; 1 (1): 1-2.
14. NEN, 2. (2006). Condition Assessment of Building and Installation Components. Dutch: NEN.
15. Pedro, J. B., Vilhena, A., Paiva, J. V., & PINHO, A. (2009). Método de avaliação do estado de conservação de imóveis: Desenvolvimento e aplicação. (Method of Assessing the State of Conservation of Real Estate. Development and Application). Revista Engenharia Civil, (35), 57-73. Viewed 29 April, 2021, (http://www.civil.uminho.pt/revista/artigos/n35/Pag.57-74.pdf). (in Portuguese)
16. Posselt, E., Frozza, R., Molz, R. (2015). INFUZZY: Ferramenta para desenvolvimento de aplicações de sistemas difusos (INFUZZY: Tool for developing diffuse system applications). Revista Brasileira de Computação Aplicada. 7, 1 (fev. 2015), 42-52. Viewed 29 April, 2021, (https://doi.org/10.5335/rbca.2015.3960). (in Portuguese).
17. Renigier-Biłozor, M., Janowski, A., Walacik, M. et al. Human emotion recognition in the significance assessment of property attributes. J Hous and the Built Environ (2021). Viewed 29 April, 2021, (https://doi.org/10.1007/s10901-021-09833-0).
18. Steven Lang, Felipe Bravo-Marquez, Christopher Beckham, Mark Hall, and Eibe Frank. (2019). WekaDeeplearning4j: a deep learning package for Weka based on DeepLearning4j. Knowledge-Based Systems, 178. Pages 48-50, ISSN 0950-7051. Viewed 28, April, 2021, (https://doi.org/10.1016/j.knosys.2019.04.013).
19. Syamilah Yacob, Azlan Shah Ali, and Au-Yong Cheong Peng. (2016). Building Condition Assessment: Lesson Learnt from Pilot Projects. The 4th International Building Control Conference 2016 (IBCC 2016). MATEC Web Conf. Volume 66. Viewed 30 April, 2021, (https://doi.org/10.1051/matecconf/20166600072).
20. Thomas, S. P., Manrodt, K. B., Eastman, J. K. (2015). The impact of relationship history on negotiation strategy expectations: A theoretical framework. International Journal of Physical Distribution & Logistics Management, 45(8), 794-813.
21. Tversky, A., Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. Science, 185, 1124-1131.
22. Witten, I. H., Eibe F., Hall. M. A. (2011). Data mining: practical machine learning tools and techniques.—3rd ed. / Ian H. Witten,. — (The Morgan Kaufmann series in data management systems) ISBN 978-0-12-374856-0 (pbk.), Viewed 30 April, 2021, (https://www.wi.hs-wismar.de/~cleve/vorl/projects/dm/ss13/HierarClustern/Literatur/WittenFrank-DM-3rd.pdf).

Information about authors:
Vladimir, Surgelas, Ph.D student at Latvia University of Life Sciences and Technologies. dr.engenho@gmail.com
Irina, Arhipova, Vice-Rector of Sciences at Latvia University of Life Sciences and Technologies. zinpror@llu.lv
Vivita, Pukite, Dr.oec., Professor, Latvia University of Life Sciences and Technologies, Latvia. vivita.pukite@llu.lv