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INVESTIGATION OF THE ACCURACY OF SPATIAL DATA OF THE GRPK BUILDING LAYER IN THE TERRITORY OF LITHUANIA

Salkauskiene Vilma[1], Gudritiene Daiva[1,2], Abalikstiene Edita[1]
[1]Kaunas Forestry and Environmental Engineering University of Applied Sciences
[2]Vytautas Magnus University, Lithuania

Abstract
Spatial data is constantly evolving, and the accuracy of spatial data is constantly changing. The latest GRPK and orthophotographic map were used in the study. Accuracy is also affected by technological advances, which are driven by improvements in working methods, which include the development of work tools and the development of data sets that contain structured data. The data contained in the data sets are determined by a variety of methods, such as field measurements (GPNS receiver or tacheometer) and analysis of digital photographic images, which are determined using aircraft or satellite systems. The determined data is processed with the help of specialized software, which is selected depending on its functionality and capabilities, and with the help of which the determined data is processed as accurately as possible. Accurate spatial data in densely populated areas makes it easier to carry out planning and design work correctly. The study is performed to determine the accuracy of the coordinates of the selected structures using remote methods. The more similar studies are conducted, the more confident the GRPK data generated remotely will be of the required accuracy, reliability, and applicability to planning, forecasting, and other important tasks.
The article compares geodetic measurements and GRPK data and geodetic measurements and ORT10LT data, identifies coordinate differences, the size of the discrepancy and its average, and calculates the root mean square error.
The object of the research is spatial and cartographic data of different buildings.
The aim of the research is to determine and evaluate the accuracy of the coordinates obtained using remote sensing methods.
Key words: GRPK, ORT10LT, geodetic surveys, spatial data set, accuracy study

Introduction

The use and analysis of GRPK and ORT10LT data is relevant as it is constantly updated. Georeferenced data, as well as their updating or submission, are important because they help to plan and design and analyze processes related to land cover change (Gudritiene, 2016; Salkauskiene et al., 2017). Spatial data are analyzed by many scientists in various fields: Sustainable forest management and ventilation (Tiskutė-Memgaudiene et al., 2020), mapping of forest infrastructure objects Bikuviene et al., 2020), monitoring of land use changes (Jukneliene et al., 2021), mapping of damaged areas (Korol et al., 2021), landscape (Tykhenko et al., 2020) and others.
Accurate spatial data in densely populated areas makes it easier to carry out planning and design work correctly. The study is performed to determine the possibilities of the accuracy of static coordinates using remote methods. The more similar studies are conducted, the more confident the GRPK data generated remotely will be of the required accuracy, reliability, and applicability to planning, forecasting, and other important tasks.
The most accurate data from geodetic measurements are used for comparison in the coordinate accuracy study and will serve as a basis for analyzing the data found in orthophotographic maps. The data collected by remote methods will be compared with the data obtained from geodetic measurements in order to find out how accurately the visually determined coordinates of land cover objects - structures - can be determined remotely. The building layer data provided by GRPK are usually determined by camera interpretation of orthophotographic maps, which are collected and stored in the ORT10LT data set. GRPK data must be based on the photographic basis of the most recent orthophoto map. The coordinates provided by the GRPK and their accuracy depend directly on the quality, accuracy, resolution, interpretation and data entry of the orthophotographic map. ORT10LT and GRPK data are publicly available and used by professionals in many fields. This study will investigate the accuracy of the coordinates of the turning points of the buildings provided by GRPK, as well as find out the reasons for the discrepancy of the coordinates with the geodetic coordinates. The map will be interpreted in a camera way to determine the reasons. Thus, the study of the accuracy of remotely determining coordinates is relevant to assess whether such publicly available public data is of sufficient quality and meets the accuracy requirements.

The aim of the research is to determine the accuracy of the spatial data of the GRPK building layer in the Kaunas and Alytus district municipalities.
Objectives of the article are as follows:
1) To determine the accuracy of spatial data (building turning points, X and Y coordinates) provided by GRPK for one- and two-storey buildings and buildings that are not covered and are covered by surface objects.
2) After analyzing the obtained data, discuss the reasons that may have led to discrepancies in the obtained data.
3) Perform ORT10LT interpretation and compare the obtained data with GRPK spatial data.
Electronic tacheometers or GPS receivers are used for measurements in unoccupied areas, and there are no significant differences in measurement accuracy between these devices. However, it has been found that in urban areas, more accurate data are obtained by measuring electronic tacheometers (Balevicius et al., 2013). In order to evaluate the real (external) accuracy of the created orthophotographic map, it is necessary to determine the coordinates of the points in the orthophotographic photo by photogrammetric measurements and compare the results with the geodetic measurements in the area. To calculate the accuracy, the values of standard deviation and standard deviation are calculated (Ruzgiene et al., 2012; Ruzgiene, 2015).
2007 In Lithuania, the network of permanent stations of the global positioning system, LitPOS, has started operating in Lithuania. The main purpose of this network is to solve navigation tasks in real time, anywhere. R. Baniulis, K. Galinauskas, E. Parseliunas, and M. Petniunas (2017) discussed the principle of LitPOS operation and network renewal in 2015. With this network and the right GPNS equipment, users can determine coordinates in real time, even within one centimeter. These technologies are applied in the fields of land management, geodesy, cartography, and real estate cadastre.
The use of one or another satellite system does not guarantee the accuracy of the measurements, as it is also affected by the number and location of the satellites. The so-called PDOP has a direct effect on the measurement results depending on the number of satellites and their position in orbit. The lower the PDOP indicator (the higher the number of satellites), the more accurate the measurement results (Norkus, 2018; Piliciauskaite et al., 2020).
GRPK data consists of the GRPK spatial data set, which consists of spatial (lake polygons and others), linear (road axis lines and others), and point (geodetic base points and others) spatial objects, and a georeferenced base map with a scale of M 1: 10000 and which is based on orthophotographic or space maps (Gudritiene et al., 2015). GRPK data are updated with the help of remote methods when a digital and visual interpretation of orthophotographic maps using the camera method is performed (Gudritiene et al., 2015). Gudritiene and co-authors (2019) conducted research investigating the influence of a cartographer on the updating of spatial or linear data of a georeferenced cadastre. The data of the georeferenced cadastre were also studied by other authors, but none of the authors investigated the possible influence of the cartographer on updating such data. Research has shown that the accuracy of updated geographic reference cadastral and linear data depends on the cartographer, as the interpretation of the orthophotographic map differs depending on the person performing it (Gudritiene et al., 2019).
After analyzing the literature and scientific works on geodetic measurements and their accuracy, it was found that geodetic measurements are the most accurate way to collect data and determine coordinates, as they are direct fieldwork. Also, it is very important to mention that the main law governing spatial and cartographic data is the Law on Geodesy and Cartography. GRPK data need to be as accurate as possible, as they are very widely used and updating is necessary to improve and produce even more accurate data. GRPK data are collected using remote methods, the main method being the camera method, where digital and visual interpretation of the orthophotographic map is performed. The interpretation of the map takes place on the latest orthophoto map.

Methodology of research and materials

Part of the results of the work was prepared using the results obtained by field measurements (geodetic measurements), the interpretation of the orthophotographic map, the methods of graphical data modeling, and comparison and generalization of the obtained results were applied.
The electronic calculator of the Microsoft Office software package Microsoft Office Excel 2010 was used for the processing and systematization of the data collected during the research. GeoMap 2018 and AutoCAD software were used to compare the cartographic data compiled by different methods. To determine the coordinates of the turning points of the geodetic measurements, the building was measured in the area using a

GPNS receiver. The coordinates of the turning points of the buildings of the Georeferenced Base Cadastre (hereinafter - GRPK) and the Orthophotographic Maps (hereinafter - ORT10LT) were determined from the Lithuanian Spatial Information Portal. GRPK spatial data sets contain stable surface natural (lake and pond boundaries) and anthropogenic (building boundaries, road centrelines) data. The data of the building layer PASTAT were selected for the study (Fig. 1).

Figure 1. Graphic and raster examples of analyzed objects (compiled by the authors)

Due to possible inaccuracies, the same turning point was determined three times and the average value of the coordinates of the building turning point was used in the article. Coordinate differences (m) were calculated according to the formulas:

$$\Delta X = X_B - X_A, \quad (1)$$

Here: X_B – Coordinates of geodetic points m; X_A – GRPK or ORT10LT points m.

$$\Delta Y = Y_B - Y_A, \quad (2)$$

Here: ΔY-YkoordinačiųskirtumaiY_B – Coordinates of geodetic points m; Y_A – GRPK or ORT10LT points m.

All X and Y coordinate mismatch values are calculated according to the formula:

$$\Delta i = \sqrt{(X_B - X_A)^2 + (Y_B - Y_A)^2}, \quad (3)$$

Here: Δi – is the magnitude of the mismatch m; X_A, X_B, Y_A, Y_B – coordinates of points m.

The magnitude of the mismatch was calculated for each turning point in the building, and then the total average size of the mismatch is calculated for each building. It is calculated by summing and dividing all turning points by the number of pickets at those turning points.

To evaluate the accuracy of the data, the research methodology was chosen in such a way that the discrepancies of the coordinates provided by GRPK up to half a meter were considered very accurate, as it is a remote method for which high coordinate accuracy is determined. An error of 1 meter is perfectly permissible and such data can be considered to be moderately accurate, they meet the requirements of a map scale of 1: 10,000. For the visual comparison of GRPK and ORT10LT, the coordinates of GRPK and ORT10LT turning points were used, according to which the points were marked on the GRPK map (scale M 1: 10000) and in the latest orthophoto map "ORT10LT (2018-2020) - LR raster orthophotography map".

For the final generalization of the study results, the root mean square error of all single-storey buildings and all two-storey buildings is calculated. It is calculated according to the formula:

$$m = \sqrt{\frac{\sum_{i-1}^{n} \Delta_i^2}{n}}, \quad (4)$$

Here: m – root mean square error m; n – number of turning points units; Δi - the size of the mismatch m.

The article analyzes the buildings located in Kaunas and Alytus district municipalities. In the territory of Alytus district municipality, 20 buildings have been selected for demolition, which are divided into two groups - buildings that are not covered by surface objects and buildings that are covered by surface objects. 10 one-storey buildings and 8 two-storey buildings have been selected in Kaunas District Municipality, of which 15 buildings are residential and 3 non-residential buildings - two warehouses and a hangar. The following data were collected for the research: coordinates of turning points of geodetic survey buildings; Coordinates of building turning points provided by GRPK; ORT10LT coordinates of building turning points; GRPK and ORT10LT graphic image.

Discussions and results

The data collected for all selected buildings were presented in tables, an example of which is given in Tables 1 and 2. Details of other buildings will not be presented in the article, summarized research results will be provided. After comparing the spatial data of the turning points of the object obtained by different methods, the geodetic differences between the coordinates of the building angles and the coordinates of the building angles presented in the GRPK data set were determined, and the size of the discrepancy was calculated (Table 1).

Table 1.

Comparison of X and Y coordinates of geodesically measured turning points of a building located at K. Bielinio Street 24 in Kaunas District Municipality and submitted by GRPK

Geodetic coordinates (m)			Coordinates of points GRPK (m)		X Coordinate differences (m)	Y Coordinate differences (m)	The size of the discrepancy (m)
No	X_A	Y_A	X_B	Y_B	ΔX	ΔY	Δi
1	6089492.00	501541.01	6089492.16	501541.57	0.16	0.56	0.58
2	6089501.69	501536.62	6089502.60	501536.86	0.91	0.24	0.94
3	6089499.98	501533.06	6089500.91	501533.10	0.93	0.04	0.93
4	6089505.45	501530.43	6089506.14	501530.75	0.69	0.32	0.76
5	6089501.45	501521.95	6089502.01	501521.56	0.56	-0.39	0.68
6	6089486.27	501529.11	6089486.33	501528.62	0.06	-0.49	0.49

When comparing geodetically measured coordinates with remotely obtained GRPK coordinates, the magnitude of the mismatch varies from 0.49 m to 0.94 m. The largest discrepancy was found in pickets 2 and 3, and the smallest was less than half a meter in picket 6. The average accuracy of the coordinates of the turning points of the data obtained by the different methods is 0.73 m. Since the size of the discrepancy in all pickets is low and less than 1 meter, we can conclude that the collected data are sufficiently accurate. For a more detailed study, an interpretation was performed on the latest orthophotographic map of the Kaunas district in 2018 (Table 2).

Table 2.

Comparison of X and Y coordinates of geodetically measured and camera-determined coordinates of the turning points of a building located at K. Bielinio Street 24 in Kaunas District Municipality

Geodetic coordinates (m)			Interpretation of the orthophotographic map (m)		X Coordinate differences (m)	Y Coordinate differences (m)	The size of the discrepancy (m)
No	X_A	Y_A	X_B	Y_B	ΔX	ΔY	Δi
1	6089492.00	501541.01	6089492.93	501541.61	0.93	0.6	1.11
2	6089501.69	501536.62	6089502.58	501536.71	0.89	0.09	0.89
3	6089499.98	501533.06	6089501.26	501532.74	1.28	-0.32	1.32
4	6089505.45	501530.43	6089506.42	501530.49	0.97	0.06	0.97
5	6089501.45	501521.95	6089502.05	501521.23	0.60	-0.72	0.94
6	6089486.27	501529.11	6089486.44	501528.38	0.17	-0.73	0.75

The magnitude of the discrepancy was slightly larger. ranging from 0.75 m to 1.32 m. compared to the geodetic coordinates compared to coordinates determined by the camera orthophotographic interpretation. The average

discrepancy between the turning points of the data obtained by the different methods is exactly one meter. There is almost no shadow at this turning point. so the most accurate coordinates and the smallest misalignment are set for this point. The largest discrepancy was found in pickets 1 and 3, which may have been due to the falling shadow at these turning points and the size of the protruding roof cornice. As it can only be detected during the field survey. After analyzing these data, we can state that the specialist who determined the GRPK data using remote sensing methods determined more accurate coordinates than the authors of this work performed the interpretation of the orthophotographic map in a camera way. Comparing the geodetic measured coordinates of all selected buildings in Kaunas District Municipality with the coordinates determined by the camera method of orthophotographic map interpretation. The size of the discrepancy varies from 0.42 m to 1.84 m. When working remotely it was difficult to determine the exact coordinates. Due to a falling shadow and a tree blocking the building's pickets. The average mismatch of the turning points of the data obtained by different methods in all pickets is almost 1 meter - 0.96 m. Summarizing the coordinates determined by the data of the specialist working with GRPK and the X and Y coordinates determined by the authors. It can be stated that the maximum values of the discrepancy are determined at the same turning points. Therefore two main reasons for the size of the discrepancy have been identified: the first falling dark shadow and the second adjacent tree blocking the two corners of the building. After summarizing the data and comparing the geodetic measurements of one-storey buildings with the GRPK data the most accurate coordinates are determined for the second object in Saulėtekio str. 2 E. The total misalignment of the turning points is only 0.72 m. The maximum total size of the misalignment of the turning points is 1.56 m. It is determined for the fourth object located in Krivių str. 5. Comparing the geodetic measurements of one-storey buildings with the authors' interpretation of the orthophotographic map by the camera. The most accurate coordinates were also determined for the second object. The total misalignment of the turning points is only 0.70 m. And the maximum total size of the misalignment of the turning points is 1.72 m. it is determined for the seventh object in Žaisos str. 24. The main reasons for the possible discrepancies identified in the use of the orthophoto map are the poorly oriented orthophoto map. The high contrast of this map and the shadows falling from other objects. Inaccuracies sometimes occurred due to the protruding roof of the building or the abandonment of a large roof and the unnoticed shelter or terrace. Even when determining coordinates remotely. The skills and diligence of the specialist are very important. As the specialist working with GRPK data was more accurate than the author of this work interpreting the map in a camera way. A total of 56 turning points and their coordinates for buildings located in Kaunas District Municipality are analyzed. Based on the data accuracy assessment methodology precise coordinates are determined for 6 turning points. The average coordinate accuracy is determined for 21 turning points. And for more than half of the turning points – 29, inaccurate coordinates exceeding 1 meter error are determined. Thus the exact coordinates account for 10.7%, the average accuracy for 37.5% and the inaccurate coordinates for as much as 51.8%. Annex 3 already contains a table comparing the coordinates determined by the author's chamber method with the coordinates obtained during geodetic measurements. Precise coordinates were found for only 3 turning points, with the most accurate coordinates found at 22 turning points and the most inaccurate coordinates found at more than half of the 31 turning points and 55.4% inaccurate coordinates.

After analyzing the X and Y coordinate differences and mismatch sizes of the two-storey buildings and comparing the geodetic measurements with the GRPK data, the most accurate coordinates were determined for the first object in Pienių str. 1. A total of 56 turning points were also analyzed the fifteenth object located in Žaisos str. The differences and magnitude of the 15 coordinates are the largest, exceeding three meters in some places and the total average of all turning points is as high as 2.45 m. These large discrepancies are due to the protruding roof. Comparing the geodetic measurements of two-storey buildings with the author's interpretation of the orthophotographic map by the camera method. the most accurate coordinates are determined for the seventeenth object in Žaisos str. 24. The total average size of the mismatch at all turning points in this building is 1.02 m. The biggest inaccuracies are found in the 16th Žaisos str. 16. The overall average size of the turning point mismatch in this building is 1.95 m. The use of an orthophoto map has identified the main reasons for these discrepancies. The main reason is also the roof it is too neglected, so it is not clear exactly where the boundaries of the building are. The obtained results are summarized by evaluating the overall accuracy of the turning points of one and two-storey buildings therefore the mean square error is calculated for these turning points (Table 3).

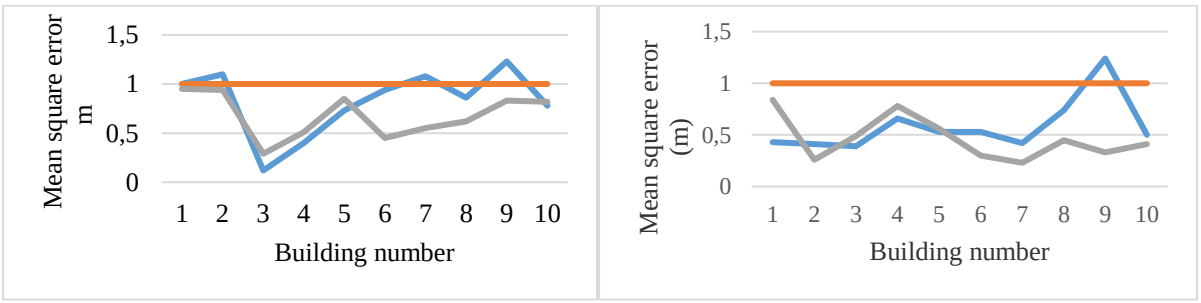
Table 3.

Mean square error of objects analyzed by different methods

The root mean square error		
Number of floors of the building	GRPK data	ORT10LT data
1st floor buildings	1.19	1.21
2st floor buildings	1.62	1.67

A comparison of these buildings by number of storeys shows that single-storey buildings are measured 36% more accurately than two-storey buildings. The camera method was performed by the authors interpreting the orthophotographic map and it was found that the total standard error of one-storey buildings is 1.21 m and that of two-storey buildings is 1.67 m. Comparing these buildings by the number of storeys it was found that single-storey buildings were measured 38% more accurately than two-storey buildings using the chamber method. It was also noted that the specialist working with GRPK data was more accurate in determining the X and Y coordinates of both high-rise buildings. Thus the coordinates of remotely assembled lower buildings are more accurate than the coordinates of taller buildings so it can be argued that due to the central projection.

Analyzing the data of the buildings in Alytus district municipality. The aim was to determine the causes of coordinate errors. GRPK and ORT10LT and geodetic data of the analyzed buildings were divided into two groups - buildings not covered by ground objects. they are in an open area (first group) and buildings covered by high ground objects (trees, shrubs, adjacent structures). The coordinates of the X and Y (Fig. 3) turning angles of the two groups of buildings were compared based on the GRPK and ORT10LT data, which were determined by calculations. Based on the results of the calculations a tolerance limit of 1 m has been set for the analysis as it meets the requirements of M 1: 10000.



a) b)

Figure 2. Mean square error of the X (a) and Y (b) coordinates of the first group of buildings GRPK and ORT10LT (compiled by the authors)

A comparison of the turning angles of the X and Y coordinates of the first group of buildings revealed:

• When comparing geodetic measurements and GRPK data. the mean square error ranged from 0.12 m to 1.23 m. and the mean error is 0.82 m. Comparing the data from geodetic measurements and ORT10LT the mean square error ranged from 0.29 m to 0.95 m. with a mean of 0.68 m.

• When comparing geodetic measurements and GRPK data the mean square error of the Y coordinate ranged from 0.39 m to 1.24 m. with a mean error of 0.59 m. Comparing the data from geodetic measurements and ORT10LT the mean square error ranged from 0.23 m to 0.84 m. with a mean of 0.47 m.

• A comparison of the turning angles of the X and Y coordinates revealed that the X coordinates are more accurate in the ORT10LT as the mean square error of the ORT10LT averaged 0.68 m and the GRPK 0.82 m. The Y coordinates were also found to be more accurate in the ORT10LT, as the mean square error of the ORT10LT averaged 0.47 m and the GRPK 0.59 m.

A comparison of the turning angles of the X and Y coordinates of the second group of buildings revealed:

• When comparing geodetic measurements and GRPK data the mean square error ranged from 0.32 m to 1.67 m. and the mean error is 0.70 m. Comparing the data from geodetic measurements and ORT10LT, the mean square error ranged from 0.27 m to 1.45 m. with a mean of 0.77 m.
• A comparison of the Y-coordinate turning angles revealed that when comparing geodetic measurements and GRPK data, the standard deviation ranged from 0.09 m to 1.12 m with a mean error of 0.57 m. Comparing the data from geodetic measurements and ORT10LT, the mean square error ranged from 0.31 m to 1.01 m, with a mean of 0.61 m.
• A comparison of the turning angles of the X and Y coordinates showed that the X coordinates are more accurate for GRPK, as the mean square error of GRPK averaged 0.70 m and that of ORT10LT was 0.77 m. Y coordinates were also found to be more accurate in GRPK as the mean square error of GRPK averaged 0.57 m and ORT10LT 0.61 m.
The analysis of GRPK and ORT10LT data revealed that the X coordinates are more accurate for the second group of buildings. As the mean square error averaged 0.73 m and for the first group 0.75 m. Y coordinates were also found to be more accurate for the first group of buildings. As the mean square error averaged 0.53 m and for the second group 0.59 m.
The performed research proves that GRPK data are collected by highly specialized specialists. Because comparing the performed ORT10LT interpretation and GRPK data, it was found that GRPK data are more accurate.

Conclusions and proposals

1. 1. After the analysis, it was established that out of 494 analyzed coordinate values in Alytus district municipality, the 1 m discrepancy limit did not exceed 407 coordinates. And the set limit was exceeded by 87 coordinate values. The largest mismatch between the X coordinate value was 2.90 m and the largest Y coordinate value was 1.99 m. The maximum mean square error for the X coordinate was 1.67 m and the smallest was 0.12 m. The maximum standard deviation for the Y coordinate was 1.24 m and the smallest was 0.09 m. Based on the performed calculations it can be stated that the Y coordinates are more accurate because their root means square error is smaller than the root mean square error of the X coordinates. Summarizing the data of turning points of 112 buildings located in Kaunas District Municipality it can be stated that the coordinates of turning points of GRPK 14 buildings are given accurately (with geodetic coordinates up to 50 cm), 38 - medium accuracy (discrepancies with geodetic coordinates do not exceed 1 m) and 60 coordinates are given inaccurate because it exceeds the 1 meter threshold.
2. After interpreting the orthophotographic map and comparing it with the results of geodetic measurements and data provided by GRPK, the following reasons for inaccurate coordinate determination were identified: orthophotographic map orientation inaccuracies, large and dark shadows falling from surrounding objects and covering part of the building, uneven does not allow to determine the exact boundary of the corner of the building. The roofing of the building and the covering of the yard sometimes have similar shades (lack of contrast); tree crowns block part of buildings; poor resolution of orthophoto map (blurred image).
3. GRPK spatial data were found to be more accurate for buildings that are covered by other objects or shadows (second group), and their mean square error averaged 0.63 m. Buildings that are not obscured by other objects or shadows (first group) are represented by the GRPK with less accuracy and have a mean square error of 0.70 m. The accuracy of the GRPK was not affected by the cladding of the buildings, as the mean square error of the buildings of the second group is smaller than that of the buildings of the first group.

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Information about authors:
Vilma Salkauskiene. Lecturer. Kaunas Forestry and Environmental Engineering University of Applied Sciences. Address: Liepų st. 1. Girionys. LT -53101. Kauno raj. Lithuania. e-mail: v.salkauskiene@kmaik.lm.lt.
Daiva Gudritiene. Lecturer. Kaunas Forestry and Environmental Engineering University of Applied Sciences. Address: Liepų st. 1. Girionys. LT -53101. Kauno raj. Lithuania. Vytautas Magnus University. Institute of Land Use Planning and Geomatics. Faculty of Land and Water Management. Address: Universiteto str. 10. LT – 53361 Akademija. Kaunas. Lithuania. Ph. (37) 752372. e-mail: d.gudritiene@kmaik.lm.lt.
Edita Abalikstiene. Associate professor. doctor. Kaunas Forestry and Environmental Engineering University of Applied Sciences. Address: Liepų st. 1. Girionys. LT -53101. Kauno raj. Lithuania. e-mail: e.abalikstiene@ kmaik.lm.lt.