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USE USING UAVS FOR THE ORGANIZATION OF FORESTRY LANDS

The aims of our paper are to study the territory organization of the forest fund lands of the Skhidnytsya village council (Lviv region), performing their forest management with the development of a system of activities aimed at ensuring scientifically based multifunctional forestry management, protection and rational sustainable use. The possibility of performing cadastral works for the territorial organization of forestry lands using unmanned aerial vehicles (UAVs) is important for science and practice. The paper considers the main direction of sustainable development of forest areas with a recreational function, aimed at strengthening ecological, social and economic functions and protection of these forests, their rational use. Based on the division of forests into categories, their functional significance, the regime of forestry and forest use for the next revision period, the following economic units were formed: health and recreational forests with a special regime of use in the mountains. The distribution of the total area of health and recreational forests by functional zones, types of landscape, classes of aesthetic assessment, pedestrian accessibility, recreational assessment, resistance to recreational loads, stages of recreational digression, additional assessment is presented. The results obtained prove the practical significance of the use of UAVs for performing work on the organization of the territory (certain category of land), and the resulting cartographic materials fully comply with the instructive accuracy. The developed provisions of this study correspond to the basic principles of sustainable forest management, provide for a combination of economic, environmental and social aspects of forestry activities.

Key words. forest fund land; forest management; forestry zoning of the territory; sustainable development strategy; UAV.

Introduction

An important socio-economic, ecological and biospheric role is played by the lands of the forest fund, as the most complex and powerful plant group, which has the most positive effect on the environment. The introduction of a set of measures aimed at the protection, reproduction, rational and balanced use of natural resources and the use of useful properties of the forest is a prerequisite for an effective management system for the forest sector of the economy.

Exhausting and uncontrolled anthropogenic exploitation of forest lands has led to a decrease in forest resource potential, excessive disturbance and deterioration of their age structure, species composition, increased erosion processes and other negative phenomena. Solving these problems with the help of scientifically based solutions is an important practical task of the present for the implementation of state policy on sustainable development and reform of the forestry sector.

The draft Strategy of Sustainable Development and Institutional Reform of Forestry of Ukraine for the period up to 2022 (2017) developed by the State Forest Agency defines the goals, principles, priorities and main activities to ensure sustainable management and administration of forestry and hunting. Therefore, forest management is one of the important areas of forestry activities, through which it is possible to carry out a number of activities aimed at ensuring effective organization and scientifically based forest management, protection, rational use, increasing the ecological and resource potential of forests, forestry culture, obtaining reliable and comprehensive information about the forest fund of Ukraine [Instructions for arranging the forest fund of Ukraine, 2006].

In the 21st century, technology is evolving very rapidly. Outdated equipment is replaced by digital and laser. The use of various new technologies is replacing traditional methods of aerial photography. Along with the usual methods of aerial photography, it is becoming increasingly necessary to shoot with the help of unmanned aerial vehicles (UAVs). Especially this process is observed in recent years – against the background of the exponential growth of the popularity of ultralight UAVs aircraft (the common name of these UAVs abroad– drones) and helicopter types.

In our opinion, it is advisable to use UAVs to perform cadastral work on areas of more than 20 hectares. There are significant prospects for the use of drones in the forest sector to monitor forest lands to rationally use them and clarify the relevance of the boundaries.

Analysis of the latest scientific research on the issues of balanced development and reform of forestry, organization of their territories, application of GIS technologies, is covered in the scientific works of famous domestic and foreign scientists, among which should be noted the following [Barba, et al., 2019; Chen, et al., 2014; Cryderman, et al., 2014; Shershun, 2013; Lendel and Zhulkanych, 2018; Mazurenok, 2014; Kozka, 2020a, b; Silva A. M. & Silva, D. C., 2015; UVS, 2021]. Despite the significant number of scientific publications, today the peculiarities of the application of UAVs for the organization of the forest lands remain insufficiently studied.

Purpose

Sustainable forest management involves a combination of economic, environmental and social aspects of forestry activities to conserve, sustainably use forests and maintain their multifaceted functions in the long term. Determination of the main directions for the balanced development of forestry in the Lviv region, aimed at strengthening the ecological, social, and economic functions, protection and conservation of forests, their rational use, and reproduction, is provided by the regional target Program for the development of forestry in the Lviv region for 2017–2021 [Regional target Program…, 2017; Strategy…, 2017]. To achieve this goal, it is necessary to characterize the territory and forest growing conditions of the research object; to give the main provisions of the organization of forestry; to investigate the possibility of using unmanned aerial vehicles for organizing the territory of the forest fund, which will meet the requirements of rational environmental management.

In the article [Barba, et. al., 2019; Glotov, Gunina, 2014] it is stressed that today unmanned aerial vehicles are widely used for aerial photography because it is cheaper alternative choice to traditional photography from airplanes, helicopters, gliders and satellites.

In the research done by [Chen, et al., 2012; Glotov, Gunina, 2014], application of unmanned systems in Shanxi (China) are described. The information obtained has been used to create a mapping plan on the scale of 1 to 1000 as well as the main stages and key technology of UAV system. 1024 aerial photographs of the research area have been taken. The result of the research shows that the UAV system has such advantages as high accuracy of aerial photographs and large-scale DLG (Digital Line Graphic).

Pictures obtained by having used aircraft and satellites cannot always provide the accuracy of large-scale mapping. This is why the only possibility to obtain pictures on the scale of 1 to 1000 and large scale DLG is to use UAVs. Due to the altitude and the flight speed, higher precision of aerial photographs can be achieved. After processing, DRG, DEM, DOM and DLG, can be received satisfying all the needs.

In articles [Matiichik, 2013; Glotov, Gunina, 2014] the reason and the directions of UAV development are considered. The current state of the market of unmanned aircraft is analyzed. Recently, unmanned systems have become popular in a variety of commercial, industrial, public, academic, and military activity. They fulfill the following tasks: photography infrastructure maintenance monitoring of the flood areas, fire suppression, monitoring of the area, controlling forests in order to detect fires at once, damage of power lines and pipelines. They are applied to make photographs necessary for agricultural production in fields and gardens. Analysis of the development of used unmanned systems in the world today shows a high tendency to increase their size and weight, flight altitude, and duration.

UAVs permit aerial photography to efficiently and objectively obtain data about buildings in the territory as the pictures are the real document which can be always applied in determining the position and borders of the set area.

In the article [Zhang et al., 2015; Gurman, 2019], the authors have made some conclusions. Our opinion fully concurs with the authors', that the real estate estimation by applying UAVs should be done in following steps:

- it is necessary to provide maximum flight stability using the corresponding gyrostabilization equipment;
- the availability of geodetic GPS-receiver on the board, is very important because they determine kinematic mode of sufficient accuracy (10–20 cm) and linear exterior orientation pictures;
- it is important to set the navigation equipment to implement the manual, semiautomatic and automatic control of the device;
- availability of aerial device equipped with mini rotary-optical sensors, which helped to determine the angular exterior orientation within accuracy of a few seconds;
- the security of UAVs itself and the equipment on the board that include a parachute system, radio beacons, , are very important;
- availability of a powerful digital camera with object glass, with sufficient distinguishing ability (not less than 20–60 MP);
- obligatory metrological examinations of digital cameras in order to determine distortion and elements of interior orientation;
- it is important to determine the in-flight drift angle and its automatic settings in aerial photography;
- the possibility of providing UAV flight is not less than an hour;
- the possibility of transporting UAV without any special equipment;
- limited airfield.

Materials and methods

The object of our study is the lands of the Skhidnitsia village council forest fund, located in the southwestern part of the Lviv region in the Drohobych administrative district and subordinate to the Borislav city council, with a total area of 100, 5 hectares.

According to the forest-vegetation zoning, the territory of the object is attributed to the central deciduous zone, the central province of the East Carpathian sub-province of beech-fir forests. The climate of the area where the object is located is transitional from moderately warm Western European to continental Eastern European. Among the climatic factors that negatively affect the growth and development of forest plantations, the following are important: late spring and early autumn frosts; sharp and frequent changes in temperature in winter; strong winds causing windbreaks and windfalls. In general, the climate of the area where the object is located is favourable for the growth of such tree and shrub species as fir, spruce, larch, oak, beech, poplar, ash, hazel, elderberry and other species.

The territory of the region (by the nature of the relief) is represented by a geomorphological region – a low-mountainous region of the marginal ridges. Two large ridges can be traced in the relief. On the mountain ridge stretching from north-west to southwest with prevailing heights of 700–800 m above sea level, there are the main forests. The most widespread are sod-podzolic and brown mountainous soils. According to the degree of moisture, 100 % of soils are classified as wet. The territory of the object is located in the basin of the Stryi river. The Skhidnytsya River flows in the Skhidnychanka settlement, which is the left tributary of the Stryi River (Dniester basin).

The forest cover of the administrative district, on the territory of which the object of study is located, is 35.1 %, the forest cover of the city of Borislav is 8.5 %. Forests on this territory are located in separate tracts. The area of the object location is characterized by a well-developed network of public transport routes. The total length is 52.5 km, the length of forest roads on the territory of the object is 0.3 km.

This forest inventory was primary and was carried out by the 2nd grade, under the requirements of the current regulatory documents. The main indicators of the implemented forest management are presented in the Table 1.

Forest management was carried out using the age class structure method, based on the formation of economic units, economic sections, consisting of a set of tree stands that are homogeneous in composition and productivity, united by the same age and the way of forest felling. The primary accounting unit is the taxation division, and the primary accounting unit is the economic section. The primary unit of account is the appraisal section, and the primary unit of account is the economic section. All calculations are based on the results of the distribution of areas and stocks of plantations of economic sections by age classes.

Table 1

The main indicators of the implemented forest management

Indicators	Unit of measurement	Volumes
1. Total forest management area	hectare	100.5
including using orthophoto maps, aerial photographs, satellite images, etc.	hectare	100.5
2. Number of quarters	pcs	1
3. The average area of the quarter	hectare	100.5
4. Number of taxation divisions	pcs	84
5. Average area taxation division	hectare	1.2
6. Sites of sample taxation methods have been formed	pcs	8
7. Sites for determining the sums of the areas of cross-sections of forest stands have been formed	pcs	10
8. Test plots laid – total:	pcs	–
including on logging supervision	pcs	–
9. Number of tablets	pcs	1

During forest management works [Verkhovna Rada of Ukraine, 1991; 1994] and other legislative acts of Ukraine were guided. The implementation of the basic forest inventory is due to the need to produce forest inventory materials (according to Articles 47 and 48 [Verkhovna Rada of Ukraine, 1998], these materials are mandatory for forestry, planning and forecasting the use of forest resources). Preparatory works were performed in the process of field forest management works. To create a geodetic basis for the compilation of planning and cartographic materials, the state acts for the corresponding land plots, orthophotomaps of the 2007–2009 survey, satellite images, topographic maps of scale 1:10000 were used. These materials were provided by the territorial bodies of the State Geocadastre. The final forest area of Skhidnytsia village council was adopted based on the results of fieldwork and also agreed with the territorial bodies of the State Geocadastre. Given the presence of orthophotos, a sufficient number of visible running lines (roads, power lines, etc.), the cutting of taxis visors was not carried out. Forest management works were carried out taking into account the division of forests into categories following [Verkhovna Rada of Ukraine, 2007], which corresponds to the economic purpose, natural and economic conditions of the area where the object is located.

Based on the above, following the Procedure for the division of forests into categories and the allocation of especially protective forest areas, the division of the forests of the object into categories, their functional significance, the forestry regime and forest use established in them for the next revision period, such economic units were formed: recreational and health forests (namely – health and recreational forests with a special regime of use in the mountains). The health and recreational forests with a special regime of use include forests within cities, towns and other settlements. In the organization of economy and economic sections, forest management was based on the species composition of plantations, their productivity and other features that determine the application of various standards and systems of economic measures, as well as forestry goals defined by the Basic Provisions of forestry organization and development. The condition and dynamics of forest lands on the territory of the object of study are as follows. Forest areas are used effectively in practice. Low-yield (5 and lower bonitet class) plantations are absent. Plantations with a density of 0.3–0.4 occupy an area of 2.6 hectares or 2.9 % of forest areas covered with forest vegetation. Their presence is due to the growth on the slopes of ravines and river valleys. The diagnostic characteristics of forest types are set out in the Basic Provisions for the Organization and Development of Forestry in Lviv Oblast. Plantations with dominant species that do not correspond to forest types cover an area of 17.0 hectares (18.8 % of forest areas covered with forest vegetation). In mountain forests, most of the slopes are gentle slopes – 68.2 hectares (75.3 % respectively). The existing distribution of tree species by age groups differs from the optimal one and is due to the age structure of forest stands. The distribution of the area of forest land by category is given in Table 2.

Table 2

Distribution of forest land by categories

Categories of lands	The area as of 01.01.2019	
	hectares	%
1. The total area of forestry land	100.5	100
2. Forest areas – total	96.3	95.8
2.1. Forest areas covered with forest vegetation – total	90.6	90.1
including: forest crops	4.7	4.7
2.2. Forest areas not covered with forest vegetation – total	5.7	5.7
including:		
– meadows, wastelands;	5.0	5.0
– biofields;	0.2	0.2
– forest paths, clearings, fire breaks, forest drainage canals	0.5	0.5
3. Non-forest land – total	4.2	4.2
including:		
– water;	0.1	0.1
– roads;	3.4	3.4
– other non-forest areas	0.7	0.7

Table 3

Distribution of the area of forests for recreational and health purposes by classes, hectares

Classes	Aesthetic assessment	Pedestrian accessibility	Recreational assessment	Resistance to recreational loads	Stage of recreational digression	Additional assessment
Public recreation area						
1.0	1.8	–	2.0	–	90.6	–
2.0	1.2	–	35.7	15.7	–	4.4
3.0	50.0	90.6	52.9	47.8	–	–
4.0	16.1	–	–	20.0	–	–
5.0	27.4	–	–	7.1	–	86.2
Total	96.5	90.6	90.6	90.6	90.6	90.6
Middle class	3.7	3.0	2.6	3.2	1.0	4.9

The landscape taxation in the forests of the object of study was carried out. Based on the natural features of the area and the purpose of the forests, functional zoning of the territory was carried out. It was found that the object of study was allocated to a mass recreation area during the distribution of the total area of 100.5 hectares of recreational and health-improving forests. The dominant type of landscape in recreational forests (Table 3) is the closed type. The share of closed, semi-open and open landscapes is 87.0 %, 6.8 %, 6.2 %. According to the optimal norms, the ratio of landscape types should be 70–80 %, 15–20 %, 5–10 %, respectively. The actual landscape structure is close to optimal.

Plantations of health and recreational forests are characterized by rather high indicators of recreational characteristics. The distribution of the area of forests for recreational and health purposes by classes of aesthetic assessment, pedestrian accessibility, recreational assessment, resistance to recreational loads, stages of recreational digression, additional assessment is presented in Table 3.

The area of the study object was not exposed to radiation pollution. The condition and dynamics of the forest fund make it possible to assess the overall ecological condition of forests for the year of forest management. The safety and protection of forest plantations were carried out at the proper level, the economic activity did not harm the environment, since no forestry activities were carried out at this object and the sources of harmful effects on the forest fund lands were not found. In general, the territory of health and recreational forests is characterized by high recreational indicators, which was taken into account when designing activities for the improvement of this area (table 4).

Table 4

The designed volumes of activities for the improvement of forests for recreational and health purposes by functional zones

The designed activities	Unit of measurement	The volume of activities	Deadline
1. Public recreation area			
1. Installation of full houses	pcs.	10	revision period
2. Manufacture and installation of small architectural structures (forest furniture)		30	
3. Manufacturing of small architectural forms (awnings, gazebos)		30	
4. Arrangement of picturesque panels		5	
5. Equipment for smoking areas		2	
6. Installation of guide schemes		5	
7. Terrenkurs construction		9	
8. Construction of suspension bridges		8	
9. Equipment of sources		7	

The rapid development of UAVs as an element of obtaining remote sensing data of the Earth is caused by the shortcomings of 2 traditional remote sensing methods [Gurman, 2019]:

- with the help of artificial satellites of the Earth;
- with the help of large manned aircraft.
- In turn, aerial photography with UAVs has the following advantages:
- large spatial resolution of images;
- high frequency of shooting and efficiency;
- low cost;
- economic feasibility in large and small areas;
- high speed of obtaining ready-made results (orthophoto map, digital terrain model) shooting in difficult conditions without risk to life (mountainous terrain, swamps, etc.).

The results of the absolute orientation of aerial photographs are shown in Table 5.

Further, we will perform external orientation of aerial photographs using two single photographs. External orientation is performed to bind the created model to the terrain coordinate system. The model can be bound to the terrain system using the coordinates of the terrain points. The exterior orientation section is designed to calculate the exterior orientation parameters of a digital model. The results of the external orientation are recorded in a digital model file.

Comparing the accuracy of the results obtained during the external orientation and preliminary accuracy assessment, we can conclude that the orientation was performed well because the errors of external orientation do not exceed the errors of a priori accuracy assessment. A project of horizontal and vertical positioning using a dual-frequency GPS receiver in RTK mode is created. As a result of calculating a preliminary (a priori) estimate of the accuracy of determining the coordinates and performing an exterior orientation, we obtained the following results:

The results of a priori accuracy assessment:

$$\begin{cases} m_{Xf} = 0.28\,m \\ m_{Yf} = 0.31\,m \\ m_{Zf} = 0.38\,m \end{cases}.$$

The results of external orientation:

$$\begin{cases} m_{Xf} = 0.27\,m \\ m_{Yf} = 0.28\,m \\ m_{Zf} = 0.21\,m \end{cases}.$$

Table 5

Absolute orientation results two single photos

ID	*X*, m	*Y*, m	*Z*, m	*DX*, m	*DY*, m	Stat
1	5,455,766.532	670,899.537	579.420	0.077	–0.212	On
2	5,455,641.653	670,978.313	582.273	0.448	–0.141	On
3	5,455,819.723	670,984.031	575.947	–0.459	0.002	On
4	5,455,661.188	671,053.100	577.120	0.396	0.218	On
5	5,455,745.956	670,983.399	575.964	0.235	0.294	Off
6	5,455,794.027	670,926.668	578.929	–0.035	0.276	On
7	5,455,702.989	670,933.050	580.743	0.092	–0.196	On
8	5,455,683.095	670,995.199	581.556	–0.131	0.077	On
9	5,455,760.788	671,010.822	576.338	0.398	0.622	On
10	5,455,727.438	670,932.075	580.014	–0.261	–0.446	On
11	5,455,674.649	670,954.561	581.333	–0.206	–0.277	On
12	5,455,715.757	670,964.372	580.768	–0.166	0.104	On
Root mean square 0.286 0.287 Average deviation 0.014 0.002						

Orientation elements
X0, m: 5455735.0 Y0, m: 670951.082 Z0, m: 682.521
Alpha, deg: 0.937433 Omega, deg: –3.525309 Kappa, deg: 25.691158

ID	*X*, m	*Y*, m	*Z*, m	*DX*, m	*DY*, m	Stat
1	5,455,766.532	670,899.537	579.420	–0.177	–0.184	On
2	5,455,641.653	670,978.313	582.273	0.594	–0.181	On
3	5,455,819.723	670,984.031	575.947	–0.199	0.078	On
4	5,455,661.188	671,053.100	577.120	0.291	0.244	On
5	5,455,745.956	670,983.399	575.964	0.297	0.035	Off
6	5,455,794.027	670,926.668	578.929	–0.150	0.366	On
7	5,455,702.989	670,933.050	580.743	0.148	–0.281	On
8	5,455,683.095	670,995.199	581.556	–0.195	0.145	On
9	5,455,760.788	671,010.822	576.338	0.508	0.587	On
10	5,455,727.438	670,932.075	580.014	–0.332	–0.463	On
11	5,455,674.649	670,954.561	581.333	–0.069	–0.378	On
12	5,455,715.757	670,964.372	580.768	–0.200	0.042	On
Root mean square 0.302 0.312 Average deviation 0.020 -0.002						

Orientation elements
X0, m: 5455739.6 Y0, m: 670982.839 Z0, m: 682.901
Alpha, deg: 1.187686 Omega, deg: –4.492080 Kappa, deg: 26.691406
Stereo model

ID	*X*, m	*Y*, m	*Z*, m	*DX*, m	*DY*, m	*DZ*, m	Stat
1	5,455,766.532	670,899.537	579.420	0.106	–0.260	–0.095	On
2	5,455,641.653	670,978.313	582.273	0.565	–0.175	0.127	On
3	5,455,819.723	670,984.031	575.947	–0.256	0.081	–0.256	On
4	5,455,661.188	671,053.100	577.120	0.335	0.302	–0.087	On
5	5,455,745.956	670,983.399	575.964	0.145	0.030	0.862	Off
6	5,455,794.027	670,926.668	578.929	0.135	0.207	–0.298	On
7	5,455,702.989	670,933.050	580.743	0.177	–0.148	0.272	On
8	5,455,683.095	670,995.199	581.556	–0.243	0.172	–0.217	On
9	5,455,760.788	671,010.822	576.338	0.369	0.555	0.119	On
10	5,455,727.438	670,932.075	580.014	–0.257	–0.436	0.055	On
11	5,455,674.649	670,954.561	581.333	–0.014	–0.288	0.322	On
12	5,455,715.757	670,964.372	580.768	–0.129	0.078	0.197	On
Root mean square 0.276 0.282 0.206 Average deviation 0.072 0.008 0.013 Relative error in height is 1/3312							

The results obtained prove the feasibility of using UAVs to carry out work on the territory organization of forest lands and the final cartographic materials fully comply with the instructive accuracy.

Results

The scheme of the designed routes is shown in Fig. 1. Since the survey area is not rectangular, and the calculations are made according to the rectangular area, therefore, the calculated number of routes differs from the actual one by 2 routes. Here is the calculation of the location of the planned-high-altitude ground control points according to preliminary calculations.

The technological scheme for calculating the location of the planned-high-altitude ground control points is shown in Fig. 2 [GNSS receiver South S82. User manual, 2020].

In the case when the UAV is equipped with a geodetic GPS receiver, it is possible to determine the coordinates of the reference points in the discharged form (up to 5 points per block), which are located according to the scheme (Fig. 3).

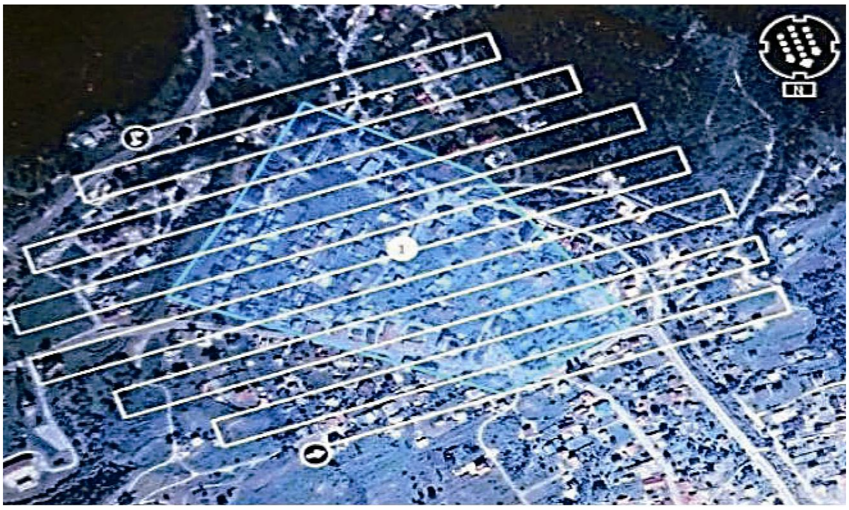

Fig. 1. The scheme of designed routes

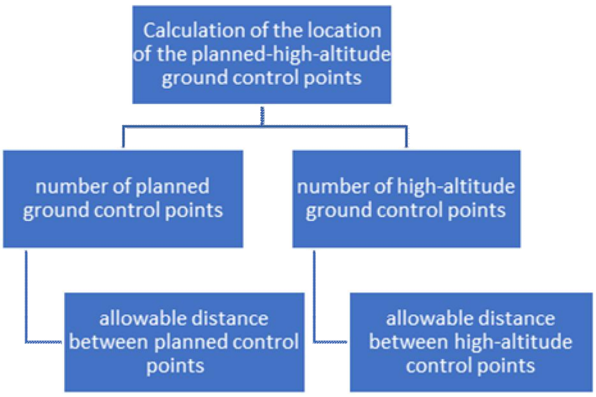

Fig. 2. Technological scheme for calculating the location of planned-high-altitude ground control points

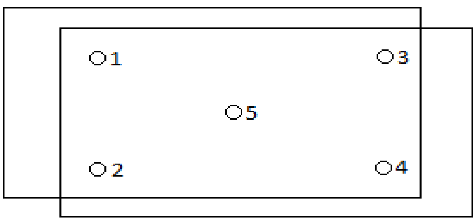

Fig. 3. The layout of the reference points

If there is no geodetic GPS receiver, it is necessary to calculate the number of ground control points, both in plan and in altitude.

The number of planned ground control points:

$$n = 11 \cdot \sqrt[3]{\left(\frac{M}{m}\right)^2} = 5, \quad (1)$$

where M – is the denominator of the scale of the created map; m – is the denominator of aerial survey scale.

The number of altitude ground control points:

$$n' = 2.08 \cdot \sqrt{\left(\frac{b_x \cdot m_{zc}}{f \cdot m \cdot m_q}\right)^2} = 1, \quad (2)$$

where m_{zc} – is the root mean square (RMS) of determination of height; m_q – is the RMS of determination of transverse parallaxes; f – is the focal length.

Permissible distance between planned ground control points:

$$L = n \cdot B_x = 145m, \quad (3)$$

where B – is the ground survey basis.

Permissible distance between high-altitude ground control points:

$$L' = n' \cdot B_x = 30m. \quad (4)$$

Further, we present the calculation of a preliminary estimate of accuracy for determining the spatial coordinates of object points. To calculate the a priori estimate of the accuracy, we use the following formulas [Geosistema, 2005; Pix4Dmapper Getting Started 2020]:

$$\begin{cases} X_f = \frac{B}{p} \cdot x_l \\ Y_f = \frac{B}{p} \cdot y_l \\ Z_f = \frac{B}{p} \cdot z_l \end{cases}. \quad (5)$$

Since all arguments in formula (5) have errors, it is necessary to take the total differential of X_f, Y_f, Z_f. And immediately performing the replacement:

$$p = \frac{B \cdot f}{H}. \quad (6)$$

As a result, we receive:

$$\begin{cases} dX_f = \frac{H}{f} \cdot \frac{x_l}{B} dB + \frac{H}{f} \cdot dx_l + \frac{H^2 \cdot x_1}{B \cdot f^2} \cdot dp \\ dY_f = \frac{H}{f} \cdot \frac{y_l}{B} dB + \frac{H}{f} \cdot dy_l + \frac{H^2 \cdot y_1}{B \cdot f^2} \cdot dp \\ dZ_f = \frac{H}{B} dB - \frac{H}{f} \cdot df + \frac{H^2}{B \cdot f} \cdot dp \end{cases}. \quad (7)$$

Then the RMSs will be equal:

$$\begin{cases} m_{Xf} = \sqrt{\left(\frac{H}{f} \cdot \frac{x_l}{B}\right)^2 \cdot m_B^2 + \left(\frac{H}{f}\right)^2 \cdot m_{Xl}^2 + \left(\frac{H^2 \cdot x_l^2}{B \cdot f^2}\right)^2 \cdot m_p^2} \\ m_{Yf} = \sqrt{\left(\frac{H}{f} \cdot \frac{y_l}{B}\right)^2 \cdot m_B^2 + \left(\frac{H}{f}\right)^2 \cdot m_{Yl}^2 + \left(\frac{H^2 \cdot y_l^2}{B \cdot f^2}\right)^2 \cdot m_p^2} \\ m_{Zf} = \sqrt{\left(\frac{H}{B}\right)^2 \cdot m_B^2 + \left(\frac{H}{f}\right)^2 \cdot m_f^2 + \left(\frac{H^2}{B \cdot f}\right)^2 \cdot m_p^2} \end{cases}. \quad (8)$$

We used the following parameter values for calculations: H = 200 m; x_l = 12 mm; y_l = 18 mm; f = 35 mm; B = 28.68 m; m_B = 0.1 m; m_x = = 0,05 mm; m_p = 0.005 mm. As a result, we obtain the following RMS values:

$$\begin{cases} m_{Xf} = 0.28\, m \\ m_{Yf} = 0.31\, m \\ m_{Zf} = 0.38\, m \end{cases}.$$

The results obtained prove the high efficiency of the use of UAVs for the implementation of cadastral works on the organization of the forestry land territory.

It has been determined that unmanned aerial vehicles are cheaper than alternative choice to traditional photography from airplanes, helicopters, gliders and satellites. UAV photography has additional advantages in comparison to traditional technologies, in particular the possibility of obtaining high accuracy images (one point per centimeter) of the territory; it gives the possibility to make detailed photos of small objects and small areas when it is no value or technical possibility to do it by using other methods such (for example, in urban conditions). The other advantages of UAV photography are its mobility; high efficiency; the environmental purity of flights.

It can be used as arecommendation and conclusion by estimators in their work. It can be applied in studying the requirements for the processing of digital pictures obtained from UAVs for real estate estimation with required accuracy and quality of digital photo-systems.

Scientific novelty and practical significance

It is proved that the work performed on the organization of the territory of the forest fund lands will ensure the reasonable use of forest resources, an increase in productivity and high-quality composition of forests, an increase in their protective functions, etc. It has been established that forest management, forest inventory and the design of forestry activities must be carried out on a soil-typological basis using tables of diagnostic characteristics of forest types.

Engineering-geodetic and land surveying, carried out only by ground-based survey methods, take much more time than the corresponding work performed using the UAV. Aerial photography using UAVs will have an even greater advantage, not only in terms of speed of the execution but also the quality, accuracy and content of topographic and cadastral plans will significantly increase in the case when the process of performing work on coordinating the boundaries of the functional zones of forestry lands will be correctly constructed. The proposed method will significantly reduce the percentage of poor quality cadastral work, eliminate the shortcomings of land field research, and thus, it is an opportunity to save material resources and time for manufacturers. All this will bring cadastral works to a high scientific and technical level.

Conclusions

The territory organization of the forest fund lands of the Skhidnytsia village council was developed based on sustainable development of forestry, as it provided for by the current Forest Code of Ukraine (Articles 2, 34, 48, 55, 56) (Verkhovna Rada of Ukraine, 1994). The developed provisions of this study correspond to the basic principles of sustainable forest management, provide for a combination of economic, environmental and social aspects of forestry activities to conserve, sustainably use forests and maintain their multifaceted functions in the long term.

Further Research Prospects. There is practical realization in this set of theoretical investigations. It can be used as recommendation and conclusion of land managers, surveyors and appraisers in their work. It can be applied in studying the requirements for the processing of digital pictures obtained from UAVs for forestry tasks.

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ВИКОРИСТАННЯ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ ДЛЯ ОРГАНІЗАЦІЇ ТЕРИТОРІЇ ЗЕМЕЛЬ ЛІСОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ

Мета роботи – дослідження особливостей організації території земель лісогосподарського призначення Східницької селищної ради Львівської області, їх лісовпорядкування із розробленням системи заходів, що спрямовані на забезпечення науково обгрунтованого багатофункціонального ведення лісового господарства, їх охорони, захисту та раціонального невиснажливого використання. Можливість виконання кадастрових робіт для організації території лісових ділянок із рекреаційною функцією за допомогою безпілотних літальних апаратів (БПЛА) важлива для науки і практики. В роботі розглянуто основний напрям збалансованого розвитку земель лісогосподарського призначення, націлений на посилення екологічних, соціальних та економічних функцій, охорону і захист цих лісів, їх раціональне використання та відтворення через систему ефективної організації території із застосуванням сучасних технологій. Основним напрямом організації та розвитку території об'єкта нашого дослідження є екологічно обґрунтоване ведення лісового господарства, з урахуванням стану та перспектив економічного і соціального розвитку регіону, розроблене відповідно до чинних нормативно-правових актів, які регулюють процедуру організації об'єкта лісовпорядкування. На основі наведеного поділу лісів на категорії, їх функціонального значення, встановленого в них режиму ведення лісового господарства і лісокористування на наступний ревізійний період утворено такі господарські частини: рекреаційно-оздоровчі ліси з особливим режимом користування у горах. Подано розподіл загальної площі рекреаційно-оздоровчих лісів за функціональними зонами, за типами ландшафту, за класами естетичної оцінки, пішохідної доступності, рекреаційної оцінки, стійкості до рекреаційних навантажень, стадіями рекреаційної дигресії, додаткової оцінки. Встановлено, що територія рекреаційно-оздоровчих лісів характеризується високими рекреаційними показниками. Виконано порівняння точності отриманих результатів (із застосуванням БПЛА) під час виконання зовнішнього орієнтування та попередньої оцінки точності. Обґрунтовано, що похибки зовнішнього орієнтування не перевищують похибки апріорної оцінки точності. Доведено, що виконані роботи з організації території земель лісогосподарського призначення забезпечать розумне використання лісових ресурсів, зростання продуктивності та високоякісного складу лісів, підвищення захисних їх функцій тощо. Встановлено, що лісовпорядкування та лісоінвентаризацію, проєктування лісогосподарських заходів необхідно здійснювати на ґрунтово-типологічній основі із використанням таблиць діагностичних ознак типів лісу. Отримані результати доводять практичну значущість застосування БПЛА для виконання робіт із організації території цієї категорії земель, а створені картографічні матеріали повністю відповідають інструктивній точності. Одержані результати відповідають основним принципам сталого ведення лісового господарства, що передбачає поєднання економічних, екологічних та соціальних аспектів лісогосподарської діяльності.

Ключові слова: землі лісогосподарського призначення; лісовпорядкування; лісорослинне районування території; стратегія сталого розвитку; БПЛА.

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