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INFLUENCE OF CLOUD COVER AND LIGHT INTENSITY ON THE QUALITY OF PHOTOGRAPHIC MATERIAL OBTAINED DURING NADIR PHOTOGRAMMETRIC FLIGHTS

Summary. The current research aimed to compare RGB images taken during nadir photogrammetric flights made in different seasons of the year and different times of the day, which resulted in the collection of material taken in different light intensities and during different levels of cloud cover (in conditions without precipitation). The flight was carried out in an area with a varied land cover, which was reflected in the accuracy of the details visible in the photos (land, buildings, vegetation, vehicles, reservoirs, watercourses, etc.). The flights were carried out at an altitude of 120 m AGL, with the size of the ground pixel being no larger than 0.04 m and the overlap at the level of 85%. An unmanned aerial vehicle (DJI Matrice 210 v2 with a DJI Zenmuse X5S camera and an Olympus M.Zuiko 12 mm lens) was used. The obtained material was processed in the Pix4D Mapper program, which allowed us to compare photos taken at different light intensities (at different degrees of cloudiness); in this way, they were assessed in terms of clarity of detail. The same flight parameters (including setting the AutoFocus option) made it possible to indicate how the lighting intensity affects the quality and quantity of recognized details, with the distinction of the type of buildings, land, vegetation, vehicles, and water objects. It was found that the details visible in orthophotomosaics created from photos taken in low light intensity are characterized by a less visible raster texture, which causes difficulties in assessing the material of which the object is made. With low light intensity, however, the geometry of cubature objects is better exposed, making it easier to determine the type of architecture and the development boundaries. Orthophotomosaics created from photos obtained at high light intensity are characterized by much greater contrast, which is an important parameter in recognizing soil and vegetation. The issue of the size of an object that can be considered in terms of clarity has not been fully resolved. The dimensions of many point and linear objects are usually below the resolving power of orthophotomosaics. However, the variety of shapes and similar colors and shades sometimes limit the recognition and differentiation of objects from the soil and vegetation category in orthophotomosaics. The minimum degree of sky coverage with clouds, expressed as a percentage, was determined: low light intensity appears from 62% cloud cover, medium intensity from 37%, and high intensity from 19%. A SWOT analysis showed the low costs of UAV operations and the relatively short time of data acquisition, as well as the rapidly growing UAV market.

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1. INTRODUCTION

The use of unmanned aerial vehicles (UAV) systems in photogrammetric acquisition platforms [5, 6] in low-level flights [21], as a much cheaper equivalent of manned (aerial, classic) photogrammetry [18, 25], is one of the fastest developing fields of remote sensing technology [7]. However, UAV photogrammetry [5] is viable only when it provides the required accuracy and is economically competitive with other measurement technologies [20]. Most often, photogrammetric flights are performed with the camera directed vertically downwards (nadir flights), and their result is an orthophotomap (surface flight) or orthophotomosaic (linear flight). Flights with the camera tilted at an angle other than 90° are used to obtain a three-dimensional model of an object [11].

Unmanned aerial vehicles are advancing and finding widespread application because there has been a rapid increase in the demand for timely, precise, and accurate data [15], such as forestry and agriculture or infrastructure [10]. UAV photogrammetry has also found its place among others in hydraulic modeling [14], modeling of ecosystem productivity [11], mapping of semi-development areas [23], precision agriculture [25], tourism [2, 4, 12], environmental monitoring [7], and the study of natural hazards, especially in dangerous and hard-to-reach places [13, 17, 24].

The accuracy (minuteness) of the obtained material, which determines its suitability for further use and processing, is defined and ensured, by several elements. Firstly, by the UAV system including both the unmanned platform and the camera mounted on it. Secondly, by a well-thought-out and well-organized flight plan. Thirdly, by image acquisition, which includes, among other things, appropriately defined flight altitude, required and specified overlap, drone speed, appropriate and correct camera configuration.

When processing the obtained photographic material, the aforementioned accuracy and precision are ensured by photogrammetric software (ensuring, among other things, appropriate image alignment, the creation of a dense point cloud, and ground filtering) [3, 8]. The role of appropriately used sensors was discussed in [1, 22], and the issue of the importance of resolution was addressed in [9], while the key importance of mission planning for effective data acquisition in complex environments was noted in [16].

A new function in photogrammetry and remote sensing is the collection of data in various variable meteorological conditions (including lighting) throughout the year [19]. The differences in the obtained material, which were observed many times, allow us to conclude that its quality depends on many factors. One of the most important factors (apart from those previously mentioned) is the lighting conditions depending on the weather, especially cloud cover. These conditions change depending on the season and successively from the time of day (morning, noon, afternoon/evening), which is associated with covering the sky with clouds.

This made it possible to justify undertaking research in this direction. The current study compared RGB images taken during nadir photogrammetric raids taken both at different times of the year and at different times of the day, which resulted in the collection of material taken in different light intensities and during different levels of cloud cover for comparison and evaluation.

2. METHOD

The study area was located in the south of Poland, near Gliwice, in an area with varied land cover, as reflected in the accuracy of details visible in the photos. The catalog of objects to which these details referred contained land, buildings, vegetation, vehicles, water courses, etc., all of which were included in the appropriate categories and classes of objects (Tab. 1).

The flights were made along the designated route with a length of 629 m, at a constant altitude of 120 m AGL, with a ground pixel no larger than 0.04 m, and an overlap level of 85% (Fig. 2).

Photogrammetric flights were carried out using an unmanned aerial vehicle (DJI Matrice 210 v2 with a DJI Zenmuse X5S camera and an Olympus M.Zuiko 12 mm lens; Fig. 1).

Table 1

Catalog of objects included in the research

Category	Class	Example
1. Structures	1.1. Buildings	Houses, garages, sheds, sheds, containers, etc.
	1.2 Fences	Mesh fences, masonry fences, etc.
	1.3. Landfills	Bulk materials, scrap, tires
	1.4. Parking lots	
	1.5. Point objects	Poles, towers, masts
2. Land	2.1. Prisms	Point prisms, longitudinal
	2.2. Excavations	Point and longitudinal excavations
	2.3. Water reservoirs	Natural and artificial water reservoirs
	2.4.Watrcourses	Natural and artificial watercourses
3. Vehicles	3.1. Vehicles	Passenger cars, vans, trucks, semi-trailers, construction vehicles, agricultural vehicles, etc.
4. Vegetation	4.1. Trees and bushes	
	4.2. Forest areas	
	4.3. Burnt grass	

Fig. 1. DJI Matrice 210 v2 unmanned aerial vehicle during photogrammetric flight

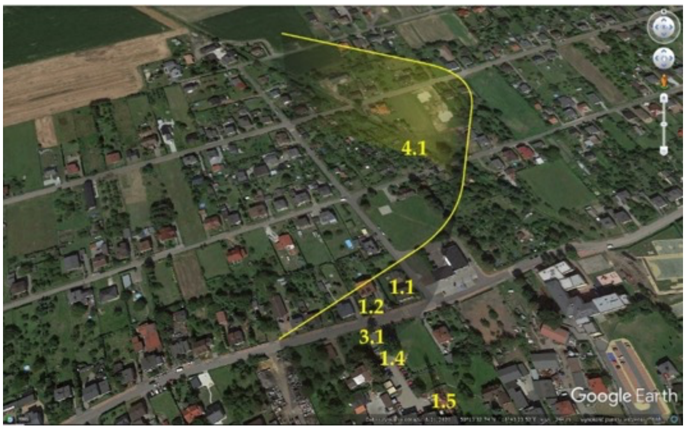

Fig. 2. Example of objects on the photogrammetric flight route according to the items from the objects catalog

Three ranges of light intensity were distinguished in the tests: <10000 lux (low), 10,000–25,000 lux (medium), and >25,000 lux (high). These were compared with the cloud cover scale used in meteorology (Tab. 2).

Before each flight, the light intensity was measured using a Voltcraft LX-10 luxmeter (Fig. 3).

Fig. 3. Luxometer LX-10

These intervals were verified using Forecasti Airdata UAV weather applications (Fig. 4).

a) b) c)

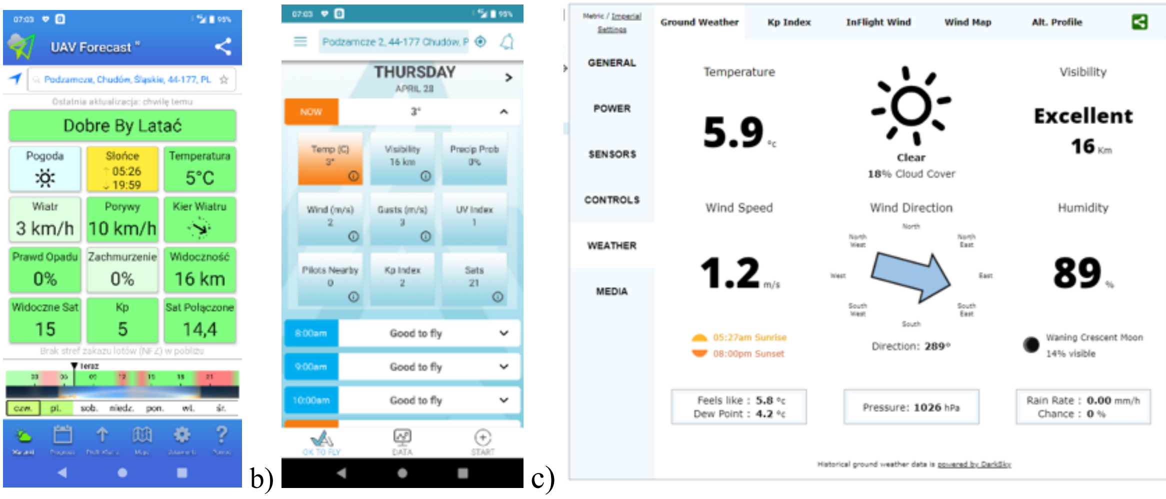

Fig. 4. Examples of weather application indications: a) UAV Forecast, b) Airdata UAV, c) Airdata log Weather, ground weather

The material obtained in this way was processed using Pix4DMapper photogrammetric software, which made it possible to compare the photos taken and evaluate them in terms of the clarity of details. As mentioned earlier, the same parameters of the flights (including setting the AutoFocus option) allowed us to indicate the impact of lighting intensity on the quality and quantity of the recognized details of the analyzed objects.

3. RESULTS

Thirty-one photogrammetric flights were made (Tab. 2), during which material was collected in the form of photos in *.jpg format (Fig. 5). The recorded image material was the basis for generating orthophotomosaics in the Pix4DMapper program (Fig. 6).

4. DISCUSSION

Based on the analysis of the obtained materials, we conclude that the details visible on the orthophotomosaics created from the photos taken at a low light intensity are characterized by a less visible raster texture, which causes difficulties in assessing the material from which the object is made (Fig. 7).

On the photographic material obtained at a low light intensity, the geometry of cubature objects (residential buildings, garages) is exposed, making it much easier to determine the type of architecture and the development boundaries (Fig. 8).

Table 2

Schedule of photogrammetric flights

No.	Season	Time of day	Date	Time	Light intensity	Lux	Cloudiness	Cloudiness scale	Cloudiness description
1	Spring	Afternoon	2022.04.13	16:45	-	-	4%	0/8	Clear/cloudless
2	Spring	Afternoon	2022.04.23	15:38	-	-	34%	3/8	Slightly/partly cloudy
3	Summer	Morning	2022.09.13	7:29	Low	4164	62%	6/8	Mostly cloudy
4	Summer	Morning	2022.09.14	8:06	Medium	12,910	99%	9/8	Overcast/sky obscured
5	Summer	Morning	2022.06.30	8:29	High	30,880	23%	2/8	Clear/scattered clouds
6	Summer	Noon	2022.09.14	11:05	Low	9169	100%	9/8	Overcast/sky obscured
7	Summer	Noon	2022.09.13	12:06	Medium	20,480	76%	7/8	Nearly overcast/mostly cloudy
8	Summer	Noon	2022.06.30	11:07	High	81,880	19%	1/8	Clear/sunny
9	Summer	Afternoon	2022.09.17	15:41	Low	7902	100%	9/8	Overcast/sky obscured
10	Summer	Afternoon	2022.09.12	17:33	Medium	16,960	71%	7/8	Nearly overcast/mostly cloudy
11	Summer	Afternoon	2022.06.30	15:29	High	41,730	51%	5/8	Cloudy/partly cloudy
12	Autumn	Morning	2022.12.09	9:49	Low	6653	93%	9/8	Overcast/sky obscured
13	Autumn	Morning	2022.10.19	9:29	Medium	11,670	75%	7/8	Nearly overcast/mostly cloudy
14	Autumn	Morning	2022.10.18	8:39	High	29,690	94%	9/8	Overcast/sky obscured
15	Autumn	Noon	2022.11.10	10:20	Low	4010	100%	9/8	Overcast/sky obscured
16	Autumn	Noon	2022.10.01	14:19	Medium	15,870	94%	9/8	Overcast/sky obscured
17	Autumn	Noon	2022.10.19	10:21	Medium	20,900	68%	6/8	Mostly cloudy
18	Autumn	Noon	2022.10.14	13:24	High	42,730	88%	8/8	Overcast
19	Autumn	Afternoon	2022.11.23	14:52	Low	2521	99%	9/8	Overcast/sky obscured
20	Autumn	Afternoon	2022.10.01	17:33	Low	4792	99%	9/8	Overcast/sky obscured
21	Autumn	Afternoon	2022.10.23	14:50	Medium	15,130	37%	3/8	Slightly/partly cloudy
22	Autumn	Afternoon	2022.10.11	14:46	High	43,060	88%	8/8	Overcast
23	Winter	Morning	2023.01.20	9:27	Low	2908	96%	9/8	Overcast/sky obscured
24	Winter	Morning	2023.02.05	10:03	Medium	20,550	85%	8/8	Overcast
25	Winter	Morning	2023.02.06	9:47	High	35,435	84%	8/8	Overcast
26	Winter	Noon	2023.02.07	12:54	Low	8462	76%	7/8	Nearly overcast/mostly cloudy
27	Winter	Noon	2023.01.08	11:42	Medium	14,410	46%	4/8	Partly cloudy
28	Winter	Noon	2023.01.02	11:14	High	38,440	49%	4/8	Partly cloudy
29	Winter	Afternoon	2023.03.09	14:52	Low	9456	83%	8/8	Overcast
30	Winter	Afternoon	2023.01.07	13:35	Medium	18,660	50%	5/8	Cloudy/partly cloudy
31	Winter	Afternoon	2023.01.08	13:35	High	42,740	46%	4/8	Partly cloudy

Explanation: For technical reasons, no light intensity measurements were taken during the test flights in the spring period (Items 1 and 2).

Fig. 5. An example photo from the photogrammetric flight (spring, afternoon, high light intensity)

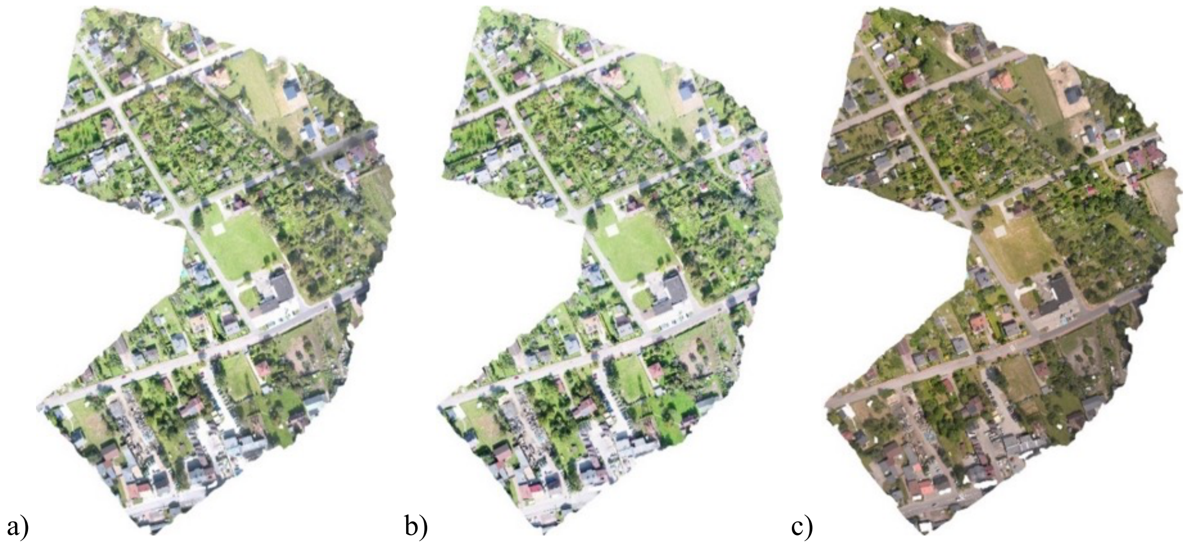

Fig. 6. Examples of orthophotomosaics: summer, noon, light intensity a) low, b) medium, and c) high

Fig. 7. Comparison of raster textures on example photographs taken with a) and c) low light conditions and b) and d) high light intensity

The orthophotomosaic created from images obtained at a high light intensity (Fig. 6c) is characterized by a much higher contrast than that created from images obtained at low intensity (Fig. 6a), which is an important parameter for recognizing soils and vegetation.

The issue of the object's size, which can be considered in terms of clarity, has not been fully resolved. The results for point objects (e.g., poles, towers, masts) and linear objects (e.g., fences) are debatable because their dimensions are usually below the resolving power of orthophotomosaics. Due to the variety of shapes and similarity of colors and shades, similar observations relate to the possibility of recognizing and distinguishing (discerning) objects from the soil and vegetation category on orthophotomosaics.

Fig. 8. Comparison of the geometry of cubature objects on the example photographs taken at a), c), and e) low light intensity and b), d), and f) high light intensity

The authors are aware of the existence and possibility of using methods of preliminary image processing before analyzing them, such as brightness normalization, translation into other color spaces, and binarization, which could increase the efficiency of using the methods under consideration. However, they were not used in this research, which is limited to the capabilities of the photogrammetric software used. Modern photogrammetric software significantly simplifies the process of analyzing image data, allowing for the quick and more effective development of the results of the photogrammetric flight in the form of collected photographic material. This is a significant issue concerning the accuracy of measurements made on photographic material obtained in this way. Accuracy in photogrammetric terms is usually defined by the value of the so-called ground sample distance (GSD) coefficient, which specifies the number of centimeters in reality per one pixel of the photo (cm/px). Its value depends on the distance (or, in this study, the flight height) from the photographed object and the camera mounted in the drone. Geometric accuracy is ensured by photogrammetric software calculations, which find all common points in individual (neighboring) photos taken. The skillful selection of the type of camera used to obtain the images significantly impacts the GSD coefficient value.

Despite all the advantages of photogrammetry listed above, a noticeable disadvantage of photogrammetric measurements is the dependence of the obtained results on atmospheric conditions. The atmospheric conditions that determine the photogrammetric flight are usually associated with wind conditions and the possibility of precipitation. However, assuming that the flight will not be carried out in windy conditions and during precipitation, the most important weather element that determines the appropriate accuracy and precision of measurements based on the obtained photographic material is cloud cover, which is closely related to lighting conditions.

As indicated in Tab. 3, it was impossible to completely link the light intensity with the amount of cloud cover (covering the sky with clouds). Separate intensity ranges (low, medium, and high) are associated with very different degrees of cloudiness. This made it impossible to strictly assign the cloud cover range, both in terms of percentage and octas, to a particular (and already very wide) range of light intensities. This indicates the need for further research utilizing a much larger dataset.

Nevertheless, it is worth paying attention to the clearly outlined minimum degree of cloud cover expressed as a percentage (based on the Airdata application logs in Fig. 4c). Low light intensity appears from 62% cloudiness (6/8 – mostly cloudy), the medium intensity appears from 37% (3/8 – slightly/partly cloudy), and high intensity appears from 19% and (it can be assumed) up to 0/8 – cloudless.

Table 3

Comparison of the observed cloudiness with separated light intensity ranges

Light intensity range	Light intensity, lux		Cloudiness		Scale of cloudiness		Cloudiness description	
	Min	Max	Min	Max	Min	Max	Min	Max
Low <10,000 lux	2521	9456	62%	100%	6/8	9/8	Mostly cloudy	Overcast/sky obscured
Medium 10,000–25,000 lux	11,670	20,900	37%	99%	3/8	9/8	Slightly/partly cloudy	Overcast/sky obscured
High >25,000 lux	29,690	81,880	19%	94%	1/8	9/8	Clear/sunny	Overcast/sky obscured

The difference between the minimum and maximum values of this parameter is interesting. The smallest spread was found for low-intensity values, then for medium ones, and finally, high ones (Fig. 9, 10). Values from double/repeated flights were omitted for comparison.

The above graphs show that the lowest light intensity values are associated with autumn evenings and winter mornings, which are characterized by overcast and obscured ies. These conditions are meteorologically related to fog, haze, and low layered clouds (Stratus, St) during this period and, consequently, the possibility of precipitation (most often a drizzle or light rain). As expected, the highest light intensity values are observed in the afternoon throughout the year (there are also cases when such a situation occurs at noon). Then, clear/sunny conditions occur, usually associated with the lack of clouds or characteristic “good weather” clouds (Cumulus, Cu) in the summer.

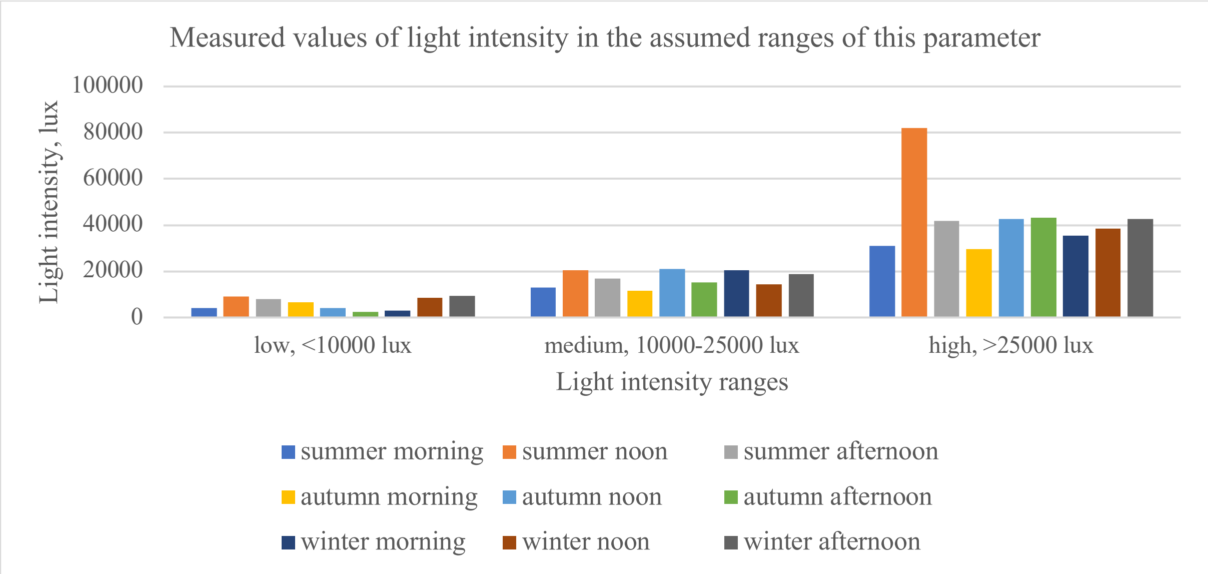

Fig. 9. Measured values of light intensity in the assumed ranges of this parameter

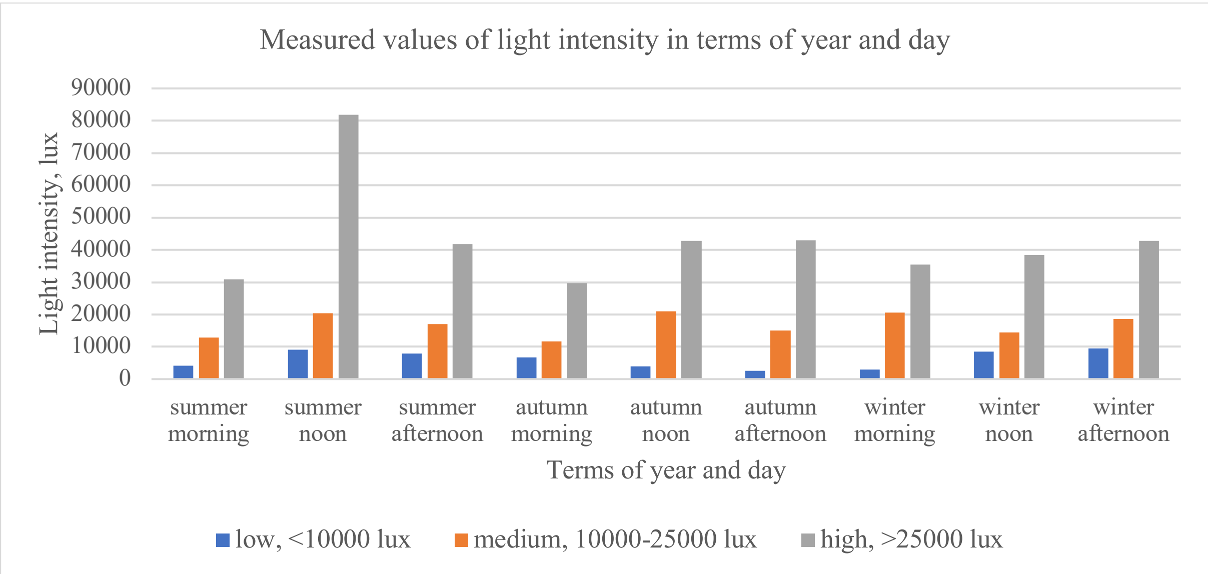

Fig. 10. Measured values of light intensity in terms of year and day

5. CONCLUSIONS

The relevance of the research topic is currently best verified by the situation in Ukraine, where the role of unmanned aerial vehicles was repeatedly verified during the ongoing war. In addition to the indisputable military advantages (fighting the enemy), an important role was played by the ability to recognize weapons (vehicles) based on their shape. Such verification made it possible to properly plan a raid from the least armed side and to make an attack there, among other advantages.

The present results highlight the influence of meteorological conditions on obtaining the appropriate level of detail in unmanned aerial vehicle flights, which, in turn, determines the correct identification of objects. As mentioned, this study ignored wind conditions and precipitation time, which are normal elements of the weather when flights are conducted in battlefield conditions.

The observations reported in this paper present opportunities for further research. Obtaining the appropriate accuracy and detail of photographic material is a current research problem concerning the automatic identification of objects in a military sense as well as in other contexts. Research on the automatic identification of objects and in developing algorithms for learning programs can be observed in various branches of the economy, including transport, construction, forestry, agriculture, rescue, geodesy, and geology.

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