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Selection of drone flight parameters for determination of post-disaster forest area profile based on aerial photographs

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Abstract: *Selection of drone flight parameters for determination of post-disaster forest area profile based on aerial photographs.* One of the main applications of unmanned aerial vehicles (UAV) is observation from the air of areas which are difficult to access. In forestry, this particularly concerns post-disaster areas with wind-fallen, wind-thrown and partly burned trees. The aim of the study was to assess usefulness of aerial photographs taken with a Microdrones MD4-200 drone from the point of view of detailed analysis of a wind damaged area. Investigations which allowed determining methodological requirements concerning the flight parameters and drone settings were carried out in a test area, whereas the verification investigation was performed on actual post-disaster areas. They constituted the basis for development of methodological guidelines regarding the use of drones for the assumed method of describing post-disaster forest areas.

Key words: aerial photographs, post-disaster forest areas, drone

INTRODUCTION

The search for new technological solutions to support military activities resulted in development of the unmanned aerial system (UAS). Its beginnings date back to World War I, when the armies of Great Britain and the United States of America undertook attempts to construct the first flying bombs supposed to take off independently and hit behind enemy lines without participation of a human. Yet, it was only after World War II that work on the proper unmanned aerial vehicle with a view to performing strictly military missions commenced [Austin 2010]. Initial trials of using such systems in civilian applications were undertaken towards the end of the 1970s, when the first flight testing their usability for photogrammetric purposes took place [Eisenbeiss 2004]. To date, the UAS have been tested in the Polish agricultural sector, among others, for monitoring the condition of buildings (mainly with respect to roofing), inspecting the condition of high plant cultures – such as energy willow [Cupiał 2009] and evaluating the spread of plant diseases [Nieróbca et al. 2007]. Worldwide, the UAS have mainly been applied in archaeological and geological purposes [Eisenbeiss et al. 2005] and in forestry for evaluating the gradation of pests and the condition of upper forest storeys [Hofman et al. 2009] as well as for monitoring of machines in forestry works [Nurek 2010].

The newest applications of the UAS include supporting observation of areas which are difficult to access. Areas damaged by earthquakes, volcano eruptions, typhoons and tornadoes, as well as flooded land frequently require quick and safe observation, including in order to find people who need help. Mediumand short-range UAS prove to be the best in such applications.

In forestry, images of forest areas which are difficult or impossible to access are sometimes also needed. Above all, this concerns post-disaster forest areas which require evaluation with respect to damage severity and condition of damaged tree stands, and preparing them for the clean-up process to be initiated as soon as possible [Brzózko and Kaluga 2010].

The aim of the study was to determine drone flight parameters allowing taking of aerial photographs suitable for determination of a profile of post-disaster forest areas. In particular, this concerned evaluation of the species of damaged trees and their spatial distribution. Such overviews may considerably facilitate planning clean-up activities in the damaged area.

INVESTIGATION METHODS, OBJECTS AND PROGRESS

The basis for proper profiling of a post-disaster area is good quality of photographs of the damaged area. Inaccessibility of post-disaster lands requires the use of UAS based techniques. Yet, the quality of aerial photographs may not be good enough in all conditions as to allow their practical use.

The investigation was carried out using a Md4-200 drone (Fig. 1), manufactured by Microdrones GMbH, serial number 433.

Its low load capacity (up to 200 g) allows fixing of a small photographic or film camera, but its small dimensions and weight allow easy transport nearby the post-disaster area. It may be used for photographing various objects, e.g. buildings, trees, water reservoirs, etc. Table 1 presents basic technical parameters of Microdrones Md4-200 UAS.

The main disadvantage of the device is short flight time on one battery and the need to land the device and replace the battery.

The aerial photographs were taken with a Pentax Optio A30 digital camera, with the lens focal length of 7.9–23.7 mm and maximum matrix resolution of 12 m pixels.

In order to obtain an objective evaluation of the quality of aerial photographs, preliminary investigation was carried out on a test area, not covered with trees. It involved taking a series of photographs of the test area at different flight altitudes and in different weather

FIGURE 1. Microdrones Md4-200

TABLE 1. Technical parameters of Microdrones Md4-200

Parameter	Value / Description
Weight [g]	900
Range [m]	500
Flight altitude [m]	150
Material	carbon fibre
Flight time [min]	up to 20
Number of engines [pcs]	4
Power supply	lithium-polymer battery

conditions. The investigators decided to substitute real, damaged trees with markers on the ground surface, thanks to which the results obtained on the test area were not dependent on the selected group of evaluators. Moreover, the panel of evaluators was extended to include persons picked at random from the whole community, not only specialist forresters.

To achieve the objective, 2 × 2 m yellow reference markers with Arabic digits written thereon were used. The dimensions of the digits were 1 × 1.45 m, whereas thickness of lines making them up was 0.18 m. Legibility of the digits was determined by showing photographs to five randomly picked persons. Their task was to state: “legible digits” or “illegible digits”. The following evaluation scale was applied:

- 5 out of 5 persons stating the numbers were legible meant very good legibility;
- 4 out of 5 persons stating the numbers were legible meant good legibility;
- 3 out of 5 persons stating the numbers were legible meant relatively good legibility;
- 1 or 2 out of 5 persons stating the numbers were legible meant a negative evaluation.

Because of the focal length of the camera and the possibility to use the zoom function, the decision was made to verify the size of areas presented on the photographs taken at different flight altitudes for the specific lens setting and to relate it to average values of parameters concerning the tree stands suffering wind damage in Poland.

The first test area was identified using five markers arranged so that four of them made up apexes of a rectangle, whereas the centre of the fifth marker identified the centre of the rectangle. Lengths of the edges of that area are presented in Figure 2.

Three markers placed in a straight line, as presented in Figure 3, were used to identify the second area.

The investigation consisted in registering flight parameters important to the obtained results: relative altitude and position stability based on GPS readouts, weather conditions including wind speed, temperature and atmospheric pressure. Analysis of the distance on the photographs was performed using Multiscan Basic software.

Series of test photographs were taken at the altitudes of 20, 40, 60, 80, 100, 120 m. An exemplary photograph is presented in Figure 4.

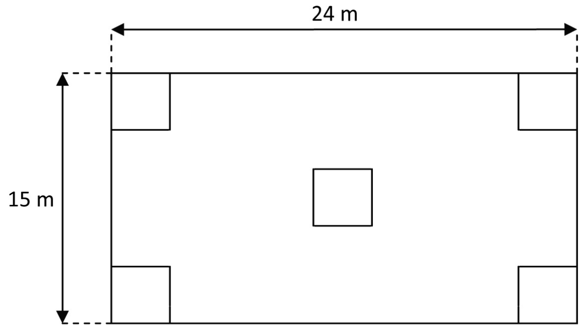

FIGURE 2. Test area 1

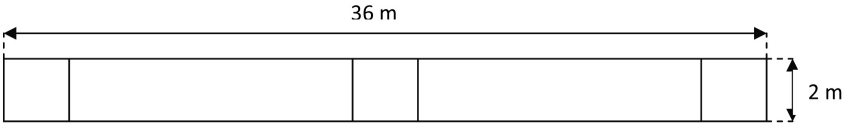

FIGURE 3. Test area 2

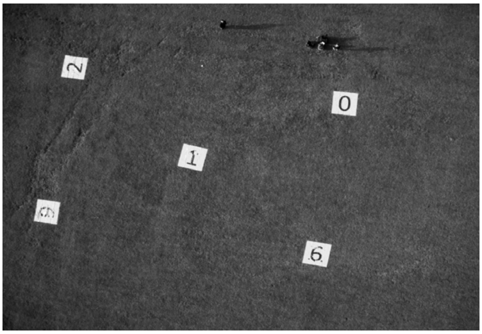

FIGURE 4. Aerial photograph of the test area (altitude: 40 m; wind speed: 2.5 m/s). Legibility of the digits evaluated for A4 format photographs: very good

RESULTS

Table 2 presents the results of evaluation of digit legibility, obtained during the investigation, and results of calculation of the areas presented on the photographs, for photographs characterised with good focus and specific zoom value.

Based on evaluation of the possibility to distinguish the kind of damage to individual trees, i.e. wind-fallen, wind--thrown and crossed trees, etc. and to determine the direction of their position with respect to the dominant direction

TABLE 2. Data obtained during the investigation and results of area calculations

Flight height [m]	Area [m]	Legibility of digits on markers	Wind speed [m/s]
20	16.95 × 22.03	very good	2.0–3.8
40	29.41 × 38.24	very good	2.5–3.6
60	41.67 × 54.17	very good	3.1–3.9
80	55.56 × 72.22	very good – good	3.1–4.8
100	71.43 × 92.86	negative	4.7–5.3
120	83.33 × 108.33	good – relatively good	4.0–4.3

[Brzózko 2014], the lowest and highest flight altitudes allowing analysis of the whole tree with the given average height on an aerial photograph was determined. Moreover, the average wind speed allowing taking of photographs characterised with sufficient quality was determined as 4 m/s. In case of an average wind speed below 2.5 m/s, photographs whose quality is evaluated as very good may be obtained.

Considering the average wind speed at the flight altitude, general guidelines related to photographing post-disaster areas using a Microdrones MD4-200 drone were developed (Fig. 5).

Data presented in Figure 5 ought to be interpreted as follows:

- for trees with the average height up to 17 m, photographs may already be taken at the flight altitude of 20 m;
- for trees with the average height up to 10 m, the flight altitude should not be greater than 40 m, whereas for trees up to 17 m height, correct detail quality may be obtained with photographs taken at the flight altitude of 60 m;
- for higher trees (up to 28 m of height), the minimum recommended flight altitude for photographing is 40 m, whereas the maximum flight altitude is 80 m for trees with the height up to 26 m, and 100 m for higher trees.

PRACTICAL APPLICATION

Results of the test investigation were verified on actual post-disaster areas. The investigation was carried out on a wind-damaged area in Opoczno Forest Inspectorate of the Regional Directorate for State Forests in Łódź. Series of photographs presenting tree stands in Białaczów Forest District, in section 108bc were taken, at the following flight altitudes: 30, 40, 60, 80, 100 and 120 m, at the average wind speed of 2.4––3.1 m/s. An example of a photograph taken during the investigation at a real post-disaster area is presented in Figure 6.

Particular kinds of damage to trees on perpendicular photographs were identified as follows: X – standing tree, L – lying part of a wind-fallen tree, Z – standing part of a wind-fallen tree, S – pile-up of trees, W – wind-thrown tree. This, together with identification of the direction of tree position, allowed determining the profile of a post-disaster area. An example profile is presented in Table 3.

The verification investigation in the above form was performed for four areas and different flight altitudes. The quality of estimation was determined by comparing the results with an estimation made from the ground. The results are presented in Table 4.

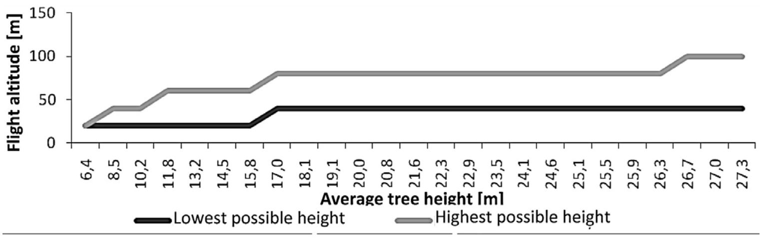

FIGURE 5. Most favourable heights for taking photographs with Microdrones Md4-200 + Pentax Optio A30 for average tree heights

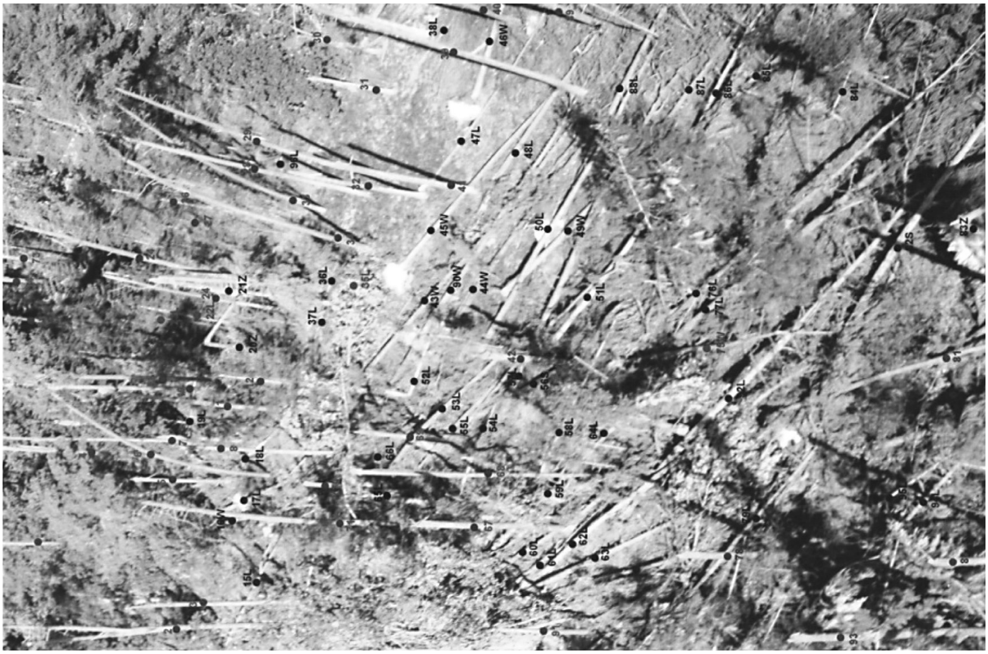

FIGURE 6. Post-disaster forest area in Opoczno Forest Inspectorate (altitude: 30 m, wind speed: 2.4 m/s)

TABLE 3. Determination of damaged tree parameters (kind of damage – as described in the text, zone: I – dominant direction, II–VI – main position directions)

L.p.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Strefa	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	II	I	I	I	I	I
Rodz. Usz.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	L	W	L	L	L	Z	Z	L	L	X	X	X	X	X

L.p.	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Strefa	I	I	I	I	I	I	VI	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Rodz. Usz.	X	X	X	X	X	X	L	L	L	L	X	X	X	X	W	W	W	W	L	L	W	L	L	L	L	L	L	S

L.p.	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Strefa	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	VI	II	I	I	I	I	I	I	I	I	I
Rodz. Usz.	L	L	L	L	L	L	L	L	L	L	X	X	X	X	X	X	X	L	W	L	L	X	L	X	X	S	Z	L

L.p.	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112
Strefa	I	I	I	I	I	I	I	I	I	I	I	I																
Rodz. Usz.	L	L	L	L	X	W	X	L	X	L	L	L																

TABLE 4. Specification of investigation results on a post-disaster area in Opoczno Forest Inspectorate

Area number	Flight altitude [m]	Number of analysed trees [pcs]	Estimation error [%]
1	40	96	27
2	30	96	22
3	40	141	30
4	30	82	32

In no case did the estimation difference exceed 32%, which, for post-disaster conditions, may be considered a good result.

CONCLUSIONS

1. Microdrone MD4-200 drone may be used for taking aerial photographs of post-disaster forest areas. To obtain good quality photographs, they should be taken at the average wind speed of no more than 4 m/s at the flight altitude.
2. To allow proper determination of the kinds of damage to trees and the direction of their position, the drone flight altitude ought to be adapted to the average height of the tree stand on the damaged area. For tree stands which are damaged most frequently in the Polish conditions, the flight altitude falls within the range of 20–120 m.
3. The difference in evaluation of the kind of damage to trees, based on photographs taken with a Microdrone MD4-200 drone and by means of ground inspection, did not exceed 32% in the conducted investigation.

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Streszczenie: *Dobór parametrów lotu drona do określania charakterystyki leśnego obszaru poklęskowego na podstawie zdjęć lotniczych.* W opracowaniu przedstawiono wyniki badań metodycznych realizacji zdjęć lotniczych wykonywanych dronem do analizowania charakteru leśnego obszaru poklęskowego. Ocenie poddano pułap lotu oraz wybrane warunki atmosferyczne, odnosząc je do możliwości oceny stanu lasu po klęsce według metodyki opracowanej przez Brzózko. Wykorzystano dron Microdrone MD4-200. Efektem badań jest zestaw praktycznych zaleceń dotyczących parametrów lotu drona oraz sprzyjających warunków atmosferycznych, które pozwalają na wykonanie zdjęć o praktycznej przydatności.

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