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A Method for Estimating the Area of Damaged Croplands and Woodlands with the Use of Unmanned Aerial Vehicles (Drones)

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Abstract. Growing social demand for access to spatial information spurs the rapid development of measurement methods and systems for registering the results of spatial evaluations and analyses (Kwietniewski 2008). Any assessment of spatial development is carried out on the basis of information obtained from specific sources (Kowalczyk 2007). The main objective of this study was to propose a method for assessing the extent of damage caused by natural disasters to croplands and woodlands with the use of unmanned aerial vehicles (drones). The main aim was achieved through detailed goals, including determination of the causes of natural disasters, description of the field inspection procedure and development of loss assessment principles. The proposed method was verified in selected research sites, and the resulting damage report detailing cropland losses is presented in the study.

Keywords: undeveloped areas, damage to croplands and woodlands.

Conference topic: Technologies of geodesy and cadastre.

Introduction

The causes of climate change can be natural or human-caused. Human-caused changes increasingly often induce extreme natural phenomena that cause significant damage to croplands and woodlands. The most frequent causes of damage are: drought, hail storms, torrential rain, thunderstorms, spring freeze, floods, hurricanes, landslides and avalanches. The spatial distribution and severity of damage is determined by: season, latitude and longitude, landform, cropping structure, land use type. Land use types in Poland are presented in Tables 1 and 2.

Table 1. Land use types and area of coverage in Poland in 2015 (Source: Olsztyn Statistical Office)

Land use type	Area in ha
Agricultural farms	16 297 656
cropland	10 752 953
total farmland	14 545 270
arable land	10 887 020
cropland	10 752 953
fallow land	134 068
permanent meadows	2 658 126
permanent pastures	434 708
permanent crops, including orchards	390 979
other agricultural land	147 060
forests and woodlands	934 383
other land types	818 003

Table 2. Land use structure and the number of farms in Poland in 2015 (Source: Olsztyn Statistical Office)

Land use type	Area		Number of farms
	in ha	percentage of total farmland	
total farmland	14 545 270	100.0	1 404 933
farmland in good tilth	14 398 210	99.0	1 392 259
arable land	10 887 020	74.8	1 235 137

End of Table 2

Land use type	Area		Number of farms
	in ha	percentage of total farmland	
cropland	10 752 953	73.9	1 216 625
fallow land	134 068	0.9	59 773
home gardens	27 377	0.2	299 934
permanent meadows	2 658 126	18.3	878 299
permanent pastures	434 708	3.0	139 519
other agricultural land	147 060	1.0	67 970

In the total number of property damage claims which are handled by insurance companies and which result from unforeseeable natural phenomena, 75% are caused by extreme weather events. Most losses are caused by tornadoes and gale force winds (39%) which also cause damage to croplands. Other causes of property damage include floods (26%), hot spells and droughts (5%) and severe freeze (3%). Property losses are proportional to the frequency of loss events, and they amount to 35%, 27%, 8% and 2% of all losses (Münich Re 2005). Climate changes cause significant problems in agriculture and necessitate the search for new solutions and methods in agricultural production. Adverse weather phenomena that occur regularly in agricultural areas decrease crop yields and deteriorate soil quality by reducing its organic matter content which is the main determinant of soil fertility. The negative effects of climate change are also experienced in woodlands, where they lead to a drop in productivity, deterioration of forest health, complete forest damage, deterioration of soil health, loss of tree stands in the vicinity of areas affected by fire, and loss of non-productive forest functions. Losses sustained in croplands and woodlands have to be surveyed, and the extent of damage has to be assessed to determine the amount of compensation. Until recently, losses in forest stands were estimated during local inspections conducted by forest engineers based on different categories of timber. The volume and category of timber were assessed in the affected area. The procedure was quite dangerous due the risk of collapse of damage trees or trunks. The use of drones eliminates the need for human inspections and the associated risks. Aerial photographs taken by drones have very high resolution, and they support the localization and assessment of damaged areas and the volume of lost timber. Aerial photographs facilitate the identification of collapsed or damaged trees and the determination of the quantity and species of damaged and lost trees. The resulting information is helpful in assessing losses, managing areas affected by natural disasters and minimizing the risk of fire and spread of pests. The main aim of this study was to propose a method for assessing the extent of damage caused by natural disasters to croplands and woodlands with the use of unmanned aerial vehicles – drones.

Stages and principles of assessing the extent of damage to croplands and woodlands

Space is a limited good and must be subject to legal and administrative regulations (Szyszko, Cymerman 2000), and effective spatial management requires numerous evaluations and analyses (Podciborski 2014).

The affected site has to be surveyed to assess the extent of damage to croplands and woodlands. The survey procedure involves the following steps:

– The owner or the holder of a legal title to damaged property files a written claim within 3 days after the damage has been discovered. The following data has to be included in the claim: the claimant's (injured party's) address, date of the loss event or date of discovery if the former cannot be ascertained, location of damaged property, plot number in the land register, cause of damage, type of crop and total farm area, description of damage and estimation of loss;
– The insurance company receives the claim;
– The claimant is notified of the date of the inspection during which the extent of damage will be assessed, not later than 2 days before the planned inspection, unless agreed otherwise by both parties. The inspection and final loss adjustment will take place regardless of the claimant's presence;
– The inspection will take place within 7 days after the claim has been received by the insurance company;
– During the inspection, the points that determine the boundaries of damaged property will be marked;
– Aerial survey: development of an aerial survey plan, drone take-off, aerial survey and acquisition of aerial photographs (individual photographs are compiled to produce a general view of the inspected area), drone landing (often automatic or computer-controlled), analysis of the acquired data;
– In large plots of land, a database of minimum of 3 points separated by a distance of 100 meters will be established (the scale of an aerial photograph is established by identifying database points, determining their location and the relevant distance between points);
– Aerial photographs are taken by a drone;

- The area of the property affected by a natural disaster is determined with the use of a square grid method or a simplified square grid method;
- The information obtained during the field survey is included in the damage report;
- The damage report is signed by the surveyor and the claimant (the report template is presented in Table 3). If the claimant is absent during the inspection or refuses to sign the report, the surveyor makes a relevant note in the damage report and states the reason for the claimant's refusal to sign the report.

In land management, the level of economic and social activity varies considerably on a territorial basis. Rural areas are characterized by particularly significant variations in economic and social activity (Podciborski, Krzywnicka 2015). Drones are increasingly used in the loss adjustment process, and they facilitate the work of property appraisers. They are particularly useful for adjusting claims relating to large or difficult to access areas. Drones support the estimation of the extent of damage in real time, and they eliminate the need for loss surveys during or after harvest. As a result, the claim adjustment process is much simpler, less time-consuming and less costly.

The use of drones in the process of adjusting losses caused by natural disasters has numerous advantages:

- ease of transport to the surveyed site (low weight of the device),
- low flight cost,
- reduced survey time,
- in particular in large or difficult to access areas,
- improved safety by eliminating the need human inspections in dangerous areas,
- high effectiveness,
- high quality of the acquired images and videos,
- fklight routes are planned with high precision,
- wide range of operating temperatures (–20 °C to + 45 °C),
- high stability during strong winds (up to 65 km/h),
- precise localization and assessment of damaged crops,
- simplicity of use,
- no adverse impact on the environment.

Estimation of damaged area with the use of the grid-based method

Rapid economic growth, the introduction of new technologies, new energy sources and higher expectations for improved standards of living necessitate the development of new research models, concepts and methods that cater to the needs of modern societies (Koreleski 2009). In the simplest estimation method, which can be performed even under field conditions, the damaged area is measured with the use of a square grid (e.g. graph paper). The method delivers accurate measurements, it is relatively quick and non-laborious. The grid-based method involves the following steps:

- millimeter-scale tracing paper is placed on the measured object – in this case, a photograph taken by a drone, showing external plot boundaries (boundary strips) and the damaged area,
- the number of square millimeters covering total plot area and the damaged area is summed up,
- the number of full square centimeters is counted first, and the number of square millimeters between the contour line and the contours of previously determined squares with the area of 1 cm^2 is added,
- when counting square millimeters, full millimeters and fractions of a millimeter (squares that are intersected by a contour line) are counted separately,
- to avoid complications, the sum of all fractions of square millimeters are multiplied by 0.5,
- all calculations should be performed in triplicate to deliver reliable results (Jagielski 2008).

Based on the total area of the plot and the area calculated by the square-grid method, the proportion of the area damaged by a natural disaster to the remaining undamaged area is calculated. The information about the surface area of damaged property is used in decision-support systems (Gotlib 2007). The measurement of the area of a flat geometric object by the square-grid method is presented in Figure 1.

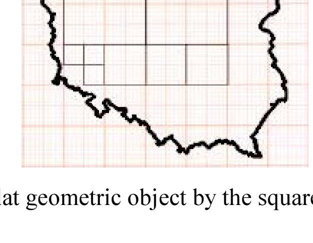

Fig. 1. Measurement of the area of a flat geometric object by the square-grid method (Source: Szaflarski 1965)

Estimation of damaged area with the use of a simplified square-grid method

In the simplified square-grid method, the calculated area is drawn on millimeter-scaled graph paper and:

- parallel horizontal or vertical lines are drawn at equal distance, generally 2 or 3 mm, depending on the size of the evaluated area,
- the length of all lines is measured with a ruler, and the result is written on the right and left side of the marked area interchangeably,
- the results all summed up and multiplied by the distance between lines. For example, if the combined length of all lines is 565 mm, and the distance between lines is 2 mm, a simple mathematical operation can be performed to estimate the area of the analyzed object.

Every measurement should be performed several times, and the mean value should be calculated. Based on the total area of the plot and the area calculated by the simplified square-grid method, the proportion of the area damaged by a natural disaster to the remaining undamaged area is calculated. All calculations should be performed in triplicate to produce reliable results. The measurement of the area of a flat geometric object by the simplified square-grid method is presented in Figure 2.

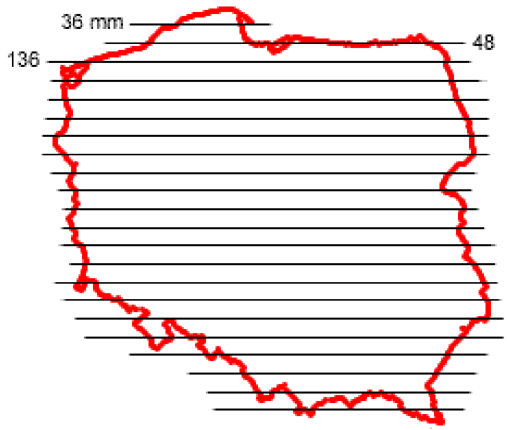

Fig. 2. Measurement of the area of a flat geometric object by the simplified square-grid method (Source: Szaflarski 1965)

Verification of the proposed method in a selected research site

Aerial photographs were taken by the DJI Phantom 4 drone on 5 May 2016. The drone was equipped with an optical positioning system, two IMU modules, two compasses for accurate measurements, and an obstacle avoidance system. The camera had chromatic aberration and distortion correction to improve image quality. The camera had full HD resolution with a frame rate of 120 fps in slow motion mode (where the field of view was limited to 47°). The analyzed plot had rectangular shape (quadrilateral plot). A damage report template developed during a survey of the damaged property is presented in Table 3.

Similar surveys were carried out in the remaining 20 research sites (croplands and woodlands) with the use of the Trimble R8 GPS receiver, Topcon total station and the DJI Phantom 4 drone. The results were used to describe various hardware options for assessing the extent of damage to croplands and woodlands (Table 4).

Table 3. Damage report of losses sustained in croplands and woodlands (Source: own study)

<table>
<tr><td colspan="3" rowspan="2">Full name and address of claimant:
JAN NOWAK, 10-720 OLSZTYN UL. KRUCZA 15</td><td colspan="3">Date of discovery:</td><td>Date of claim:</td></tr>
<tr><td colspan="3">14.05.2016</td><td>15.05.2016</td></tr>
<tr><td colspan="3">Full name and address of property owner/user:
JAN NOWAK, 10-720 OLSZTYN UL. KRUCZA 15</td><td colspan="4">Date and hour of final assessment (drone imaging):
20.05.2016 [12:30 pm]</td></tr>
<tr><td colspan="2">Location of affected cropland of woodland:
Jonkowo</td><td colspan="3">Cause of loss: drought</td><td colspan="2">Type of crop/ percentage of crop species: oats</td></tr>
<tr><td>Region:
Warmia and Mazury</td><td>Municipality:
Jonkowo</td><td colspan="2">District:
Jonkowo</td><td colspan="3">Number of plot/ forest district:
127/2</td></tr>
<tr><td colspan="4">Image with marked boundaries of damage or loss</td><td colspan="3">AREA:</td></tr>
</table>

End of Table 3

<table>
<tr><td rowspan="10"></td><td colspan="2">Plot/forest district [ha]: 2.4670</td></tr>
<tr><td colspan="2">Cropland [ha]: 2.4600</td></tr>
<tr><td colspan="2">Estimated area of damage* or loss*</td></tr>
<tr><td>[ha]</td><td>[%]</td></tr>
<tr><td>1.1562</td><td>47</td></tr>
<tr><td colspan="2">Reduced cropland area (total cropland area minus the area that was damaged or lost)</td></tr>
<tr><td>[ha]</td><td>[%]</td></tr>
<tr><td>1.3038</td><td>53</td></tr>
<tr><td colspan="2">Type/model of registering device: DJI PHANTOM 4 DRONE</td></tr>
<tr><td colspan="2">Drone operator:
Zenon Zych</td></tr>
<tr><td>Signature of loss adjuster: xxx xxxx
Signature of claimant: xxxx xxxxx
*reason for the claimant's refusal to sign the damage report:</td><td colspan="2" rowspan="2">Loss adjuster:
Joanna Wolszczak</td></tr>
<tr><td>* strike out where not applicable</td></tr>
</table>

Table 4. Hardware options for assessing the extent of damage to croplands and woodlands (Source: own study)

Equipment	Type of crop		
	Crop height up to 1 m (e.g. rapeseed, oats)	Crop height up to 2.5 m (e.g. corn)	Woodlands older than 40 years
DJI Phantom 4 drone	no limitations	no limitations	no limitations
GPS Trimble R8	no limitations	no limitations	certain limitations
Topcon GTS 800A total station	no limitations	difficult to survey	difficult to survey

Conclusions

According to estimates, the adverse consequences of climate change will be soon experienced by many sectors of the economy in Europe. Agricultural production will be influenced by lower precipitation in summer and higher temperatures. Climate change will support the cultivation of new crop varieties, but it will also increase pest populations and their activity. Soil fertility will be compromised by intensified leaching of nitrogen compounds that are essential for cereal growth. Extreme weather events will occur more frequently and will cause damage to croplands and woodlands. The proposed method supports the estimation of the extent of damage to croplands and woodlands resulting from natural disasters. The method was verified in a selected research object. The results of the study support the formulation of the following conclusions:

- the proposed method supports the estimation of the extent of damage to croplands and woodlands with the required accuracy,
- the use of aerial drones speeds up the surveying procedure and produces reliable photographic documentation,
- damage reports compiled during local surveys provide the insurer with indisputable data, speed up the loss adjustment process and the payment of compensation,
- the use of aerial drones facilitates surveys of locations that are not readily accessible and visual inspections of croplands and woodlands overgrown by tall crops, plants and trees,
- the proposed method speeds up the loss adjustment process and reduces the relevant costs.

Disclosure statement

The authors declare that they have no competing financial, professional, or personal interests.

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