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THE USAGE OF THE FAE FIXED WING UAV FOR THE EVALUATION OF AFFECTED RAPESEED CULTURE DUE TO PEST ATTACKS

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Abstract

The paper aims to evaluate the potential of using aerial images captured from FAE Fixed Wing UAV in order to determine the density of plants and areas affected by pests. Based on the unsupervised classification of the orthophoto map obtained with the help of UAV, the re-sowing plan of the affected areas with a spring culture was created. For this purpose, we use professional equipment to gather images, GPS RTK to provide advanced precision, as well as software such as, Agisoft to compose the orthophoto, ArcMap for georeferencing the orthophoto map and LeoWorks to process and classify the resulting images.
The utilized method has allowedfor a way to obtain an estimate of the degree of destruction of the rapeseed culture and to facilitate making the optimal decision with the help of a sowing plan. The usage of this method offset the losses due to pest attacks.

Key words: *drones for agriculture, sowing plan, pixel classification.*

INTRODUCTION

Plant density is a key factor influencing crop functioning with consequences on many aspects including yield, water and fertilizer requirements as well as susceptibility to pathogens (Xiuliang Jin et al., 2017).
Determination of the plant number per hectare represents an important index to assess plant density as well as field emergence (Gnädinger F. & Schmidhalter U., 2017).
The current methods used are based on visual plant counting in thefields over a predefined sampling area. They are repetitious, time consuming and prone to human errors. Further, the soil conditions, particularly in case of rainfall or frost, may limit the time slots when walking in thefield is possible without damaging the crop (Xiuliang Jin et al., 2017).
Most studies on plant density estimation are using ground level non-contact measurements, mainly focusing on relatively large plants such as maize that are further regularly spaced. Most techniques are based on plant identification using RGB images (Jia et al., 1991; Nakarmi & Tang, 2012; Nakarmi & Tang, 2014; Shrestha & Steward, 2003; Shrestha & Steward, 2005; Tang & Tian, 2008a; Tang & Tian, 2008b), or LiDAR systems (Shi et al., 2015).
For many applications, UAV-based airborne methods offer the possibility for cost-efficient data collection with the desired spatial and temporal resolutions (Ejia H. et al., 2013; Trif A. et al., 2018).
Due to the lack of precipitation from 30 August to 10 September 2017, agricultural crops have suffered, as it is the period of their growth and accumulation of the soil water reserve. Therefore, the lack of water has led to a slowdown in the development of the rapeseed culture located in Dichiseni, Calarasi County and after the hectic days developed the black flea of rape (*Phyllotreta atra*), which attacked in a very short time 40 hectares, the plants that were poorly developed. Therefore, a diagnosis has been made on the land to estimate the damage for taking a decision on this sole.

MATERIALS AND METHODS

The parcel with the area of 132.46 ha was sown with rapeseed (Pedro hybrid) with a density of 55 germinal grains/sqm.
In order to acquire the aerial images, the FAE 1718 FIXED WING (Figure 1) and the Agisoft

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software for the composing of the orthophoto mapwere used.

Figure 1. UAV FAE 1718 Fixed Wing
(Source: http://fae-drones.com/FAE-1718-FIXED-WING-47.html)

FAE 1718 Fixed Wing is an automated drone-based machine for fast and accurate data acquisition, covering extensive areas (over 500 ha) and large distances. This is usedfor precision farming or to collect supporting data for territorial and environmental planning.
Following the flight, 558 images were obtained. The flight altitude was 149 m, the ground resolution was 3.5 cm/px, and the target area was 140 ha.
The Trimble RTK L1 + L2 GNSS receiver was used to determine the coordinates of the control points for a better accuracy in georeferencing of the orthophoto map.
Image classification was performed in the LeoWorks 4.2 specialized software to determine the plant density.

RESULTS AND DISCUSSIONS

Figure 2 shows the orthophoto plan obtained from the flight in RGB format. It was subjected to the pixel classification process which uses the supervised classification method.
Within this method, several samples were selected from each class that needs to be represented.
The entire classification process and an exemplary workflow in the LeoWorks processing software can be seen in Figures 2 and 3.
The first sequence in the program shows the selection of samples and the creation of density classes according to the *in situ* measurements. The second shows the result obtained following the supervised classification.

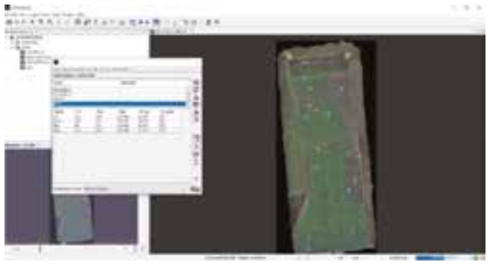

Figure 2. Defining the samples in each class for supervised classification

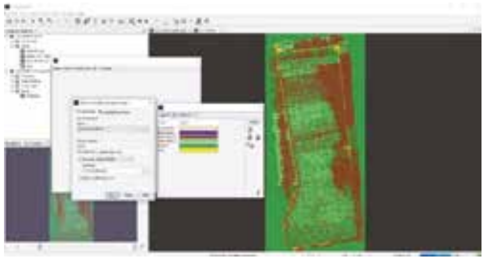

Figure 3. Sharing the classes obtained from the image classification

The next step was to define the areas with different densities according to the classification and the field measurements (Figure 4).

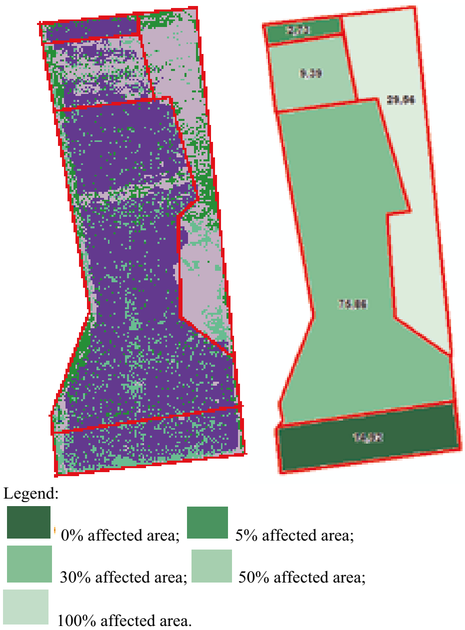

Figure 4. Classifying the pixels of plants and affected areas

Figure 5 shows the values (in meters) of the corresponding sides of the determined areas in order to obtain the sowing plan of the affected areas. This is useful to the farmer for the field work.

Figure 5. Area delimitation/Determination of different density areas

Using GIS tools, the affected areas were delineated to highlight areas with different densities as:
- an area of 14.92 ha with a density of 55 plants/sqm normally developed in 4-6 leaf phenophase has been delineated (I);
- an area of 2.73 ha with a density of 50 plants/sqm (II);
- an area of 75.86 ha with a density of 45 plants/sqm (III);
- an area of 9.39 ha with a density of 15 plants/sqm (IV);
- an area of 29.56 ha with a density of less than 5 plants/sqm (V).

It is possible to observe: 100% of the 29.56 ha being attacked by flea beetles, 50% for the 9.39 ha area, 30% for 75.86 ha area and 5% for the 2.73 ha area. For the 14.92 ha area there was no recorded attack by flea beetles.

The area affected by the flea attack, determined based on the orthophoto plan, obtained by the drone had a 29.56 ha Density V surface and a 9.39 ha Density IV surface which together represents a non-uniform yield of the crop. Therefore, the area with the surface of 38.95 ha was re-sowed.

Following the analysis, the sowing lines were drawn according to the seeding-machine with a width of 6 m.

Figure 6 represents the re-sowing plan according to the density of plants obtained from the entire pixel classification study. This method of pixel classification is a fast method with high accuracy as Trif A. et al (2016) said, when comparing other modern methods of assessing the damage suffered by rapeseed crops. Those methods were the digitization on the image, and the method in which a GPS is used resulting in the affected areas being determined in the field.

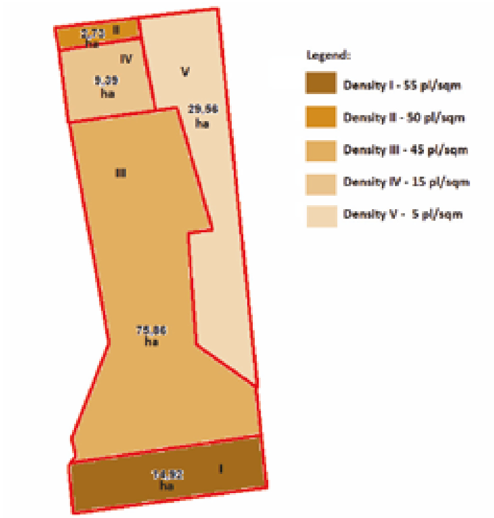

Figure 6. Density of plants

The sowing process was carried out in March 2018 according to the drawings represented in Figure 5. The marginal lines of the 38.95 hectares plot were followed, thus facilitating the work of the mechanizer, which reduces the fuel consumption, the number of passes and overlaps of the sowing operation of the new cultures.

This decision was also taken after the determination of economic efficiency and the profit rate for each identified density area.

An overview of the vegetation state of the plot cultivated with rapeseed and peas can be seen in Figure 7.

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The 38.95 ha land was seeded with 92 germinal grains per square meter of peas and 82 beans during sunrise. The plants grew on 4 to 5 levels with an average of 3 grains in the podwith a mass of 100 grains.

Figure 7. Overhead image taken with DJI Phantom 3 Professional

The obtained yield from the area with density I was 2300 kg/ha, 2100 kg/ha from the area with density II, and 1900 kg/ha from the area with density III planted with rapeseed (Table 1).
The obtained yield from the areas with density IV and V cultivated with peas was 1800 kg/ha. (Table 1). Thus, the obtained yield for each density area can be seen below:

Table 1. Obtained yield (rapeseed and peas)

Rapeseed					Peas
Class	Surface ha	Density pl/sqm	Yield kg/ha	Total Yield tons	Yield kg/ha
I	14.92	55	2300	34.31	-
II	2.73	50	2100	5.73	-
III	75.86	45	1900	144.13	-
IV	9.39	15	-	-	1800
V	29.56	5	-	-	
Total :	132.46		1969	**184.17**	**70.11**

The plant density was between 55 plants/sqm and 5 plants/sqm, so the last two classes were not considered as viable to maintain the rapeseed culture.
According to Table 1, a yield of 184.17 tons of rapeseed was estimated for the surface of 93.51 ha, and 70.11 tons of peas for the surface of 38.95 ha after replanting.
Table 2 shows the costs in lei (Romanian currency) per hectare. Costs include the mechanical work, materials including the seeds, plant protection products, the scanning service with drones, harvesting and transportation.
They are between 0.93 and 1.13 lei/kg for rapeseed and 1.05 lei/kg for peas. Thus, a production price was obtained for each density class.

Table 2. Costs

Class	Costs lei/ha	Yield kg/ha	Production price lei/kg
I*	2143	2300	0.93
II*	2143	2100	1.02
III*	2143	1900	1.13
IV**	1897	1800	1.05
V**	1897	1800	1.05

*rapeseed; **peas

If the rapeseed crop was maintained on the 9.39 ha and 29.56 ha surfaces with 5 and 15 plants per square meter, no profit would have been obtained on these areas; The production price would have reached 10.72 lei/kg, compared to the selling price of 1.5 lei/kg (Table 3).

Table 3. Costs

Class	Costs lei/ha	Yield kg/ha	Production price lei/kg
I	2143	2300	0.93
II	2143	2100	1.02
III	2143	1900	1.13
IV	2143	650	3.30
V	2143	200	10.72

Table 4 shows the sale prices for rapeseed and peas, the incomes per hectare for each surface with different density, and the total incomes for each surface.

Table 4. Income

Class	Yield kg/ha	Selling Price lei/ha	Income lei/ha	Total Income
I	2300	1.5	3450	51474
II	2100	1.5	3150	8599,5
III	1900	1.5	2850	216201
IV	1800	1.5	2700	25353
V	1800	1.5	2700	79812

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Income ranged between 2850 lei and 3450 lei per hectare for rapeseed and 2700 lei per hectare for peas. There is a difference of 600 lei per hectare between the two classes of density: 3450 lei per hectare for the first class with 55 plants/sqm, and the third class with 45 plants/sqm.
In Table 5 the profit per hectare was also determined for each different density class. Thus, it can be seen that the profit rate of the density zone I differs by 28 percent compared to the density zone III. Also, the profit rate of the area with density III is smaller than the IV and V zones by 9.3 percent.

Table 5. Economic efficiency

Class	Costs lei/ha	Income lei/ha	Profit lei/ha	Total Profit	Profit Rate %
I	2143	3450	1307	19500	61.0
II	2143	3150	1007	2749	47.0
III	2143	2850	707	53633	33.0
IV	1897	2700	803	7540	42.3
V	1897	2700	803	23736	42.3

With the help of this method, the profit rate has increased to 42.33%, which is a difference of 9.3% compared to the class III, 45 plants/sqm.
If the rapeseed culture had been maintained on the surfaces IV and V the profit rate would have had negative values in case 2, so it would not have been rented. In case 1, the profit rate is even higher than the third (Figure 8).

Figure 8. Economic efficiency Case 1 and Case 2

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CONCLUSIONS

In this paper, we presented a procedure that was developed to determine the density of plants and to obtain the re-sowing plan using an UAV. It has been verified successfully by the analysis of both indoor and outdoor measurements thatdifferent classes of densities can be determined using an orthophoto plancorrelated with in situ measurements.
An UAV can be used successfully to make a diagnosis of the land with the purpose of determining the affected area and making a decision about whether to re-seed or not.
In the present case it was possible to divide the land according to the obtained plans, so that the affected area was re-seeded with peas, which is a spring culture.
This modern method involves the use of drones in taking pictures and determining the density of plants based on the pixel classification. By using this method, the profit rate for the area of 38.95 ha increased to 42.33%.
The plans delivered to the farmer were used for the compilation of the APIA (Agricultural Payments and Intervention Agency) file, and to schedule the working data in the field, for reusing the calamity areas.
The use of UAVs provides time- and cost-saving data for further processing and allows forflexible and weather-independent data collection. (Gnädinger F. & Schmidhalter U., 2017)

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