

IMAGING ANALYSIS IN AGRICULTURAL LAND SURFACE CHARACTERIZATION - CASE STUDY ON WHEAT STUBBLE

Ciprian BUZNA¹, Marinel Nicolae HORABLAGA^{1,2}, Florin SALA^{1,2,*}

¹Agricultural Research and Development Station Lovrin, Lovrin, 307250, Romania

²University of Life Sciences "King Mihai I" from Timisoara, Timisoara, Calea Aradului, 300645, Romania

*Corresponding author: florin_sala@usvt.ro

Abstract. The study used imaging analysis (UAV images) to analyze and characterize an agricultural land area resulting from the harvest of the wheat crop. The researches were carried out in the framework of ARDS Lovrin, agricultural year 2021-2022. The agricultural land was worked with a disk, and the vegetable remains (straw, stubble) were partially incorporated into the soil. The images were taken with the drone (DJI Phantom 4) at variable heights, between $H = 0.5$ m and $H = 50$ m from the ground level (19 series of images from variable heights). The analysis of the images resulted in values in the RGB color system. Normalized values (rgb) and NDI and INT indices were calculated. The color parameter R (red) varied between $R = 77.36 - 89.14 \pm 0.71$, the color parameter G (green) varied between $G = 71.29 - 81.99 \pm 0.60$, and the color parameter B (blue) varied between $B = 71.42 - 79.29 \pm 0.47$. The values of the calculated indices varied between $NDI = 0.040 - 0.048 \pm 0.0007$, respectively $INT = 73.357 - 83.217 \pm 0.582$. Correlations of varying levels of intensity were recorded between color parameters, calculated indices and image retrieval height. High variability was recorded in the case of the NDI index ($CV = 7.3156$), and low value in the case of the normalized value g ($CV = 0.4443$). Polynomial equations described the variation of some color parameters in relation to the image retrieval height ($p < 0.001$). The variation of the NDI index in relation to the image acquisition height was described by a spline model, under statistical safety conditions ($\bar{\epsilon} = 8.57E - 05$). Associated with the image retrieval height, the NDI index presented four ranges of values, respectively uniform values on the 0.5 - 1 m height interval, and on the 25 - 50 m height interval; variation of 0.001 units on the height interval 2 - 8 m, and high variability on the height interval 9 - 20 m.

Keywords: aerial images, agricultural land, imaging analysis, UAV, wheat stubble

INTRODUCTION

Imaging analysis presents multiple advantages in the study, description and characterization of terrestrial areas (Weiss et al., 2020; Xiong et al., 2022; Qian et al., 2023). Imaging analysis based on satellite, aerial, UAV, or terrestrial images has been used for studies of natural areas, protected areas, urban areas, agricultural areas, agricultural crops, agricultural experiments with different variables (Bégué et al., 2020; Herbei and Sala, 2020; Popescu et al., 2020; Sala et al., 2020; Weiss et al., 2020; Choudhary et al., 2023).

The new approaches in agriculture, which aim at the interdependence between crop science and computer vision, propose different solutions (e.g. Agriculture - Vision) to solve a series of identified aspects regarding the acquisition of images, their quality, analysis and interpretation of images, etc., in order to providing scientifically and practically valid solutions (Chiu et al., 2020).

High accuracy classification of images was considered very important for land mapping, and classification in relation to different classification elements. Deorankar and Rohankar (2020) addressed such topics regarding the classification of some lands in relation to the quality and health of the soil, and analyzed a series of factors that can influence the accuracy of the classification.

AL-Taani et al. (2021) used techniques based on remote sensing and GIS to evaluate the spatio-temporal dynamics of land use and the degree of coverage. The authors of the study identified agricultural land surfaces and the proportion with which they are suitable for agriculture under natural rainfall regime (0.2%) and under irrigation regime (1.4%). Also, the authors of the study, based on the obtained results, associated the suitability of the land for agriculture in relation to soil fertility and water regime.

Drones are increasingly used in agriculture, both in research approaches and for agricultural practice, as a result of the specific advantages that technology based on UAV images brings (Constantinescu et al., 2018; Olson and Anderson, 2021; Qiu et al., 2022; Rejeb et al., 2022). Techniques based on UAV images were used to classify some genotypes of grassy cereals, to estimate the content of chlorophyll and fresh biomass, under statistical safety conditions (Constantinescu et al., 2018). Chen et al. (2020) used UAV images in studies on the classification and use of some agricultural lands, and for the evaluation and management of agricultural productions with a precision rate of about 90% (high value for the study conditions).

The present study used imaging analysis (UAV images) to analyze and characterize a surface of agricultural land, after the harvest of the wheat crop and the incorporation of plant residues into the soil by working with the disc.

MATERIAL AND METHODS

The study took place within ARDS Lovrin, on a plot of land, after harvesting the wheat crop. Plant residues were incorporated into the soil, by working with the disk.

The digital images were taken with the drone (DJI Phantom 4) at different heights from the ground level. Series of 19 images were taken at different heights from the ground level, between 0.5 - 50 m high.

The digital images (jpeg format) were processed to select a central area on each image (crop images, 1005 × 2245 pixels) for the purpose of a unitary analysis. Some examples of images, from the UAV digital image series, are presented in figure 1.



Figure 1. Examples of UAV images used, taken at different heights from ground level

The series of images were analyzed (Rasband, 1997) and the values of the color parameters in the RGB system (R, G, B color parameters) were obtained. Based on equations (1), (2), and (3), the normalized rgb values were calculated (Lee and Lee, 2013).

$$r = \frac{R}{R + G + B} \quad (1)$$

$$g = \frac{G}{R + G + B} \quad (2)$$

$$b = \frac{B}{R + G + B} \quad (3)$$

Based on equation (4) the NDI index was calculated (Mao et al., 2003), and based on equation (5) the INT index was calculated (Ahmad and Reid, 1996).

$$NDI = \frac{(r - g)}{(r + g + 0.01)} \quad (4)$$

$$INT = \frac{R + G + B}{3} \quad (5)$$

The data obtained from the analysis of the images (RGB parameters), the normalized values (rgb), and the values of the calculated indices (NDI, INT) were analyzed and processed mathematically and statistically, in the first place to evaluate the safety of the data and the presence of variance in the data series.

In relation to the purpose of the study, different statistical analyzes were made to evaluate the variability of the considered parameters, the degree of interdependence, and their variation in relation to the height of the image retrieval (Hammer et al., 2001; Wolfram Alpha, 2020).

RESULTS AND DISCUSSIONS

From the analysis of the images, taken at different heights, between 0.5 - 50 m, the values of the color parameters in the RGB system were obtained. The normalized values (r,g,b) were calculated based on relations (1), (2), (3), and the values of the NDI and INT indices were calculated based on relations (4), (5). The values resulting from the analysis of the images and from the calculations are presented in table 1.

In the study conditions to describe the surface of agricultural land with wheat stubble, land worked with the disc for the incorporation of plant residues, the color parameter R (red) varied between $R = 77.36 - 89.14 \pm 0.71$, the color parameter G (green) damaged between $G = 71.29 - 81.99 \pm 0.60$, and the color parameter B (blue) varied between $B = 71.42 - 79.29 \pm 0.47$. The values of the calculated indices varied between $NDI = 0.040 - 0.048 \pm 0.0007$, respectively $INT = 73.357 - 83.217 \pm 0.582$. The statistical analysis of the data series (Anova test, Alpha = 0.001) confirmed the presence of variance and the statistical reliability of the results, table 2.

Table 1. The values of the color parameters and the calculated indexes

Trial	H	R	G	B	r	g	b	NDI	INT
Ich-50	50	84.93	77.09	75.37	0.3578	0.3247	0.3175	0.048	79.130
Ich-45	45	86.52	78.51	76.08	0.3588	0.3256	0.3155	0.048	80.370
Ich-40	40	87.00	78.95	76.84	0.3583	0.3252	0.3165	0.048	80.930
Ich-35	35	86.04	78.01	75.91	0.3586	0.3251	0.3163	0.048	79.987
Ich-30	30	88.20	79.95	77.46	0.3591	0.3255	0.3154	0.048	81.870
Ich-25	25	85.92	77.94	75.65	0.3587	0.3254	0.3159	0.048	79.837
Ich-20	20	84.68	76.94	75.04	0.3578	0.3251	0.3171	0.047	78.887
Ich-15	15	87.02	79.55	76.89	0.3574	0.3267	0.3158	0.044	81.153
Ich-10	10	85.95	78.80	76.78	0.3559	0.3263	0.3179	0.043	80.510
Ich-9	9	87.01	79.97	77.07	0.3565	0.3277	0.3158	0.042	81.350
Ich-8	8	89.14	81.99	78.52	0.3571	0.3284	0.3145	0.041	83.217
Ich-7	7	83.32	76.62	73.98	0.3562	0.3275	0.3163	0.041	77.973
Ich-6	6	83.51	76.78	74.18	0.3562	0.3275	0.3164	0.041	78.157
Ich-5	5	83.70	77.11	75.33	0.3545	0.3265	0.3190	0.040	78.713
Ich-4	4	79.42	73.09	72.24	0.3534	0.3252	0.3214	0.041	74.917
Ich-3	3	77.36	71.29	71.42	0.3515	0.3239	0.3245	0.040	73.357
Ich-2	2	79.96	73.56	73.80	0.3518	0.3236	0.3247	0.041	75.773
Ich-1	1	87.48	80.08	79.29	0.3544	0.3244	0.3212	0.044	82.283
Ich-0.5	0.5	85.09	77.78	77.82	0.3535	0.3232	0.3233	0.044	80.230
SE		± 0.71	± 0.60	± 0.47	± 0.0005	± 0.0003	± 0.0007	± 0.001	± 0.582

Table 2. Anova test

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	238886.5	7	34126.65	10114.67	1.9E-190	3.71643
Within Groups	485.8525	144	3.373976			
Total	239372.4	151				

Alpha = 0.001

The correlation analysis led to the values presented in table 3. A very strong correlation was found between G and R ($r = 0.986$), between B and R ($r = 0.914$), between B and G ($r = 0.925$), between the corrected values b and r ($r = -0.912$), between INT and R ($r = 0.990$), between INT and G ($r = 0.992$), and between INT and B ($r = 0.957$). Strong correlation was recorded between NDI and H ($r = 0.861$).

Moderate correlations were recorded between the corrected value r and H ($r = 0.771$), between the corrected value r and R ($r = 0.749$), the corrected value b and R ($r = -0.730$), between b and G ($r = -0.706$), between b and g ($r = -0.733$) and between NDI and the corrected value r ($r = 0.764$). Correlations of lower intensity were also recorded between the different analyzed parameters.

Table 3. Correlation table

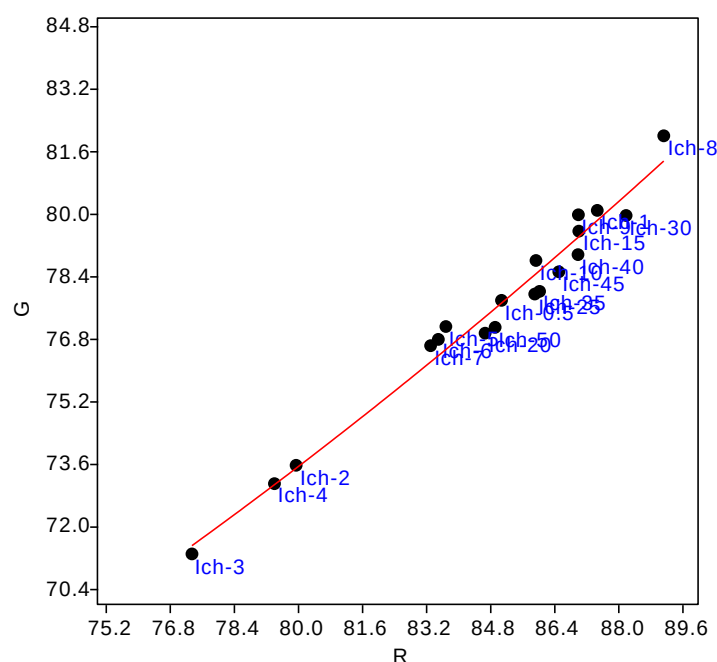
	H	R	G	B	r	g	b	NDI	INT
H									
R	0.392								
G	0.260	0.986							
B	0.143	0.914	0.925						
r	0.771	0.749	0.664	0.437					
g	-0.081	0.399	0.488	0.175	0.391				
b	-0.536	-0.730	-0.706	-0.399	-0.912	-0.733			
NDI	0.861	0.520	0.372	0.361	0.764	-0.289	-0.436		
INT	0.287	0.990	0.992	0.957	0.650	0.377	-0.647	0.436	

The variability of the parameters considered in the description of the agricultural land presented different levels, according to the values of the coefficient of variation. High variability was recorded in the case of the NDI index (CV = 7.3156), and low value in the case of the normalized value g (CV = 0.4443). Color parameters (RGB) presented values of the coefficient of variation CV = 3.6445 in the case of the R parameter, CV = 3.3806 in the case of the G parameter and CV = 2.6783 in the case of the B parameter. In the case of normalized values, CV = 0.6678 in the case of r, CV = 0.4443 in the case of b, and CV = 1.0173 in the case of b. In the case of the calculated indices, CV = 7.3156 in the case of the NDI index, respectively CV = 3.1938 in the case of the INT index.

The variation of the parameter G in relation to R was described by equation (6), under conditions of $R^2 = 0.973$, $p < 0.001$, with the graphic distribution in figure 2.

$$G = 0.00804 x^2 - 0.5028 x + 62.3 \quad (6)$$

where: x – the R color parameter

**Figure 2. Distribution of the values of the color parameter G in relation to the parameter R**

The variation of the normalized r values according to the image capture height (H, m) was described by equation (7), under conditions of $R^2=0.822$, $p < 0.001$, $F=36.939$, with the graphic distribution in figure 3.

$$r = -5.854E - 06x^2 + 0.0003862 x + 0.3528 \quad (7)$$

where: x – image capture height (H, m)

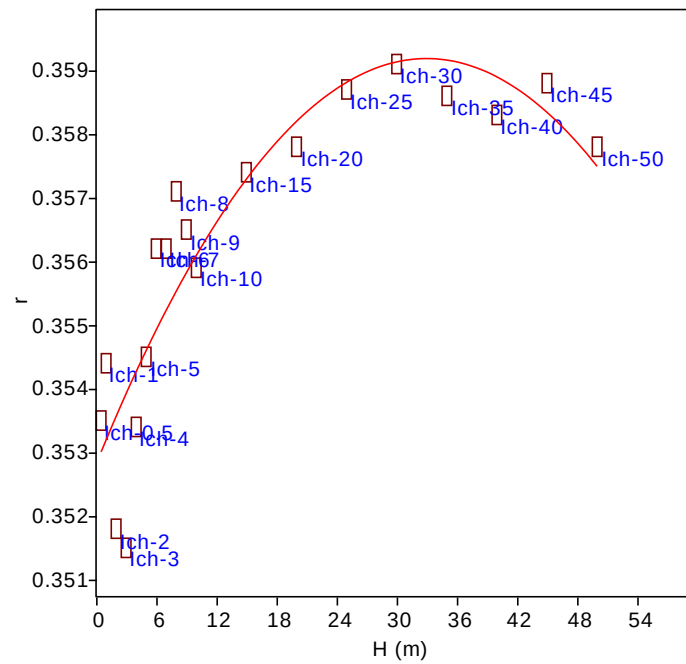


Figure 3. Graphic distribution of r values in relation to H

The variation of the NDI index values in relation to the image acquisition height was faithfully described by a spline model, with the statistical values of the model presented in table 3. The graphic distribution is presented in figure 4.

Table 4. Statistical values related to the spline model in the description of the variation in the NDI

Trials		NDI statistical parameters			
No	x_i	y_i	y_{Si}	e_i	$I_{i/1}$
Ich-50	50	0.048	0.048	0.0000	1.0000
Ich-45	45	0.048	0.048	0.0000	1.0000
Ich-40	40	0.048	0.048	0.0000	1.0000
Ich-35	35	0.048	0.048	0.0000	1.0000
Ich-30	30	0.048	0.048	0.0001	1.0001
Ich-25	25	0.048	0.048	0.0002	1.0002
Ich-20	20	0.047	0.047	-0.0010	0.9781
Ich-15	15	0.044	0.044	0.0020	0.9185
Ich-10	10	0.043	0.043	-0.0057	0.8908
Ich-9	9	0.042	0.042	0.0004	0.8754
Ich-8	8	0.041	0.041	0.0080	0.8610
Ich-7	7	0.041	0.041	-0.0014	0.8530
Ich-6	6	0.041	0.041	-0.0080	0.8473
Ich-5	5	0.040	0.040	0.0100	0.8416
Ich-4	4	0.041	0.040	-0.0160	0.8405
Ich-3	3	0.040	0.041	0.0130	0.8441
Ich-2	2	0.041	0.042	0.0126	0.8649
Ich-1	1	0.044	0.043	-0.0166	0.9015
Ich-0.5	0.50	0.044	0.044	0.0041	0.9204

$\bar{\varepsilon} = 8.57E - 05$

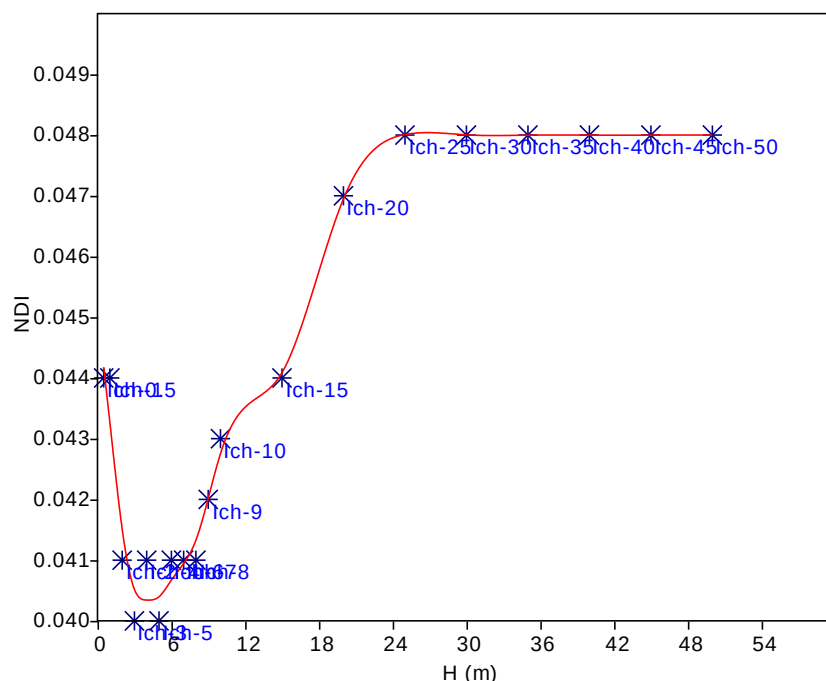


Figure 4. Graphical representation of the spline model in the description of the NDI variation in relation to H

The values of the RGB color parameters expressed the properties of the agricultural land surface in which the plant residues resulting from the wheat crop were partially incorporated. In the case of the color parameters R and G, the coefficient of variation presented close values (CV = 3.6445 for R, CV = 3.3806 for G) and lower values in the case of parameter B (CV = 2.6783).

Greater differences in the coefficient of variation (CV) were recorded in the case of normalized values (CV = 0.6678 in the case of r, CV = 0.4443 in the case of b, and CV = 1.0173 in the case of b). With regard to the calculated indices (NDI, INT), the coefficient of variation showed values of CV = 7.3156 in the case of the NDI index, respectively CV = 3.1938 in the case of the INT index.

The recorded correlations expressed the interdependence between the color parameters, the normalized values and the calculated indices, depending on the image capture height.

The variation of some parameters resulting from imaging analysis, in the characterization of a wheat crop, was communicated by Sala et al. (2020). The authors of the study observed the variation of color parameters in different color representation systems (RGB, HSB, HSL, etc.) in relation to the time and the angle at which the images were taken. From the recorded results, the authors identified the time and the angle of taking the images with minimal influence on the analyzed parameters, they calculated and proposed correction factors in the analysis of the images taken at crops under similar conditions.

Al-Naji et al. (2021) studied the surface of an agricultural land (clay soil) by analyzing images obtained in different conditions of capture height and lighting, in order to estimate irrigation requirements.

Tobiszewski and Vakh (2023) communicated the usefulness of RGB parameters, results from images obtained with a smartphone camera, in the analysis and characterization of the soil, of uniting plants and agricultural crops.

Other color representation systems (e.g. CIE L*a*b*) were also used for the analysis and characterization of lands and soils, in relation to different influencing factors (Moritsuka et al., 2019).

The analysis of the values of the spline model, as well as from the graphic analysis (figure 4), the NDI values registered four areas of variation, in relation to the height of the image retrieval. First of all, there was a decrease in the values from the height of Ich 0.5, Ich 1. In the interval of taking the images Ich 2 - Ich 8, the NDI index presented close values. Then, there was an increase in NDI values from Ich 9 to Ich 20, and on the interval Ich 25 Ich 50, the NDI values presented a linear, horizontal distribution, with similar values.

CONCLUSIONS

Imaging analysis based on UAV images, taken at heights between 0.5 - 50 m, facilitated the description of the agricultural land surface considered in the study.

Color parameters in the RGB system, normalized values (rgb) and calculated indices (NDI and INT), resulting from the analysis of digital images and through calculations, expressed the land surface differently, through variability in relation to height and interdependence relationships.

Polynomial models described the variation of the color parameter G in relation to the parameter R, respectively of the normalized value r in relation to the image capture height, under statistical safety conditions ($p < 0.001$).

The spline type model describes the variation of the NDI index in relation to the image retrieval height, under statistical safety conditions ($\bar{\varepsilon} = 8.57E - 05$). Linear distribution of the spline model values resulted in the 25-50 m range of image acquisition, and high variability in image acquisition conditions in the 0.5-20 m range.

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