IMAGE PROCESSING TECHNIQUES USED IN SOIL MOISTURE ANALYSIS
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TEHNICI DE PROCESARE A IMAGINII UTILIZATE ÎN ANALIZA UMIDITĂȚII SOLULUI

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ABSTRACT
The agricultural sector is one of the most important in the world, having a strategic role in the development of humanity. Image processing methods associated with computational mathematical algorithms are widely used today, having applications in many branches of agriculture, closely related to technologies used in precision farming. To achieve increased crop productivity, a number of conditions need to be met. From these, soil moisture has an important role. This is necessary to be continuously monitored to assure the adequate quantity of water for optimal production. In this context, in the paper is proposed a method for soil humidity analysis. These provide an indirect and qualitative soil moisture evaluation method using aerial image processing, in two phases: image acquisition using a drone and the second phase – image processing using a MATLAB algorithm.

REZUMAT
Sectorul agricol este unul dintre cele mai importante din lume, având un rol strategic în dezvoltarea umanității. Metodele de procesare a imaginilor asociate algoritmilor matematici computaționali sunt utilizate astăzi pe scară largă, având aplicații în multe ramuri ale agriculturii, strâns legate de tehnologiile utilizate în agricultura de precizie. Pentru a obține o productivitate crescută a culturilor, trebuie îndeplinite o serie de condiții. Dintre acestea, umiditatea solului are un rol important. Acesta este necesar să fie monitorizat continuu pentru a asigura o cantitate adecvată de apă pentru o producție optimă. În acest context, în lucrare este propusă o metodă de analiză a umidității solului. Acestea oferă o metodă indirectă și calitativă de evaluare a umidității solului utilizând procesarea imaginilor aeriene, în două faze: achiziția de imagini utilizând un sistem de tip dronă și a doua fază - prelucrarea imaginilor utilizând un algoritm MATLAB.

INTRODUCTION
The agricultural sector is one of the most important in the world, having a strategic role in the development of humanity. The need to increase crop productivity, soil quality issues or crop monitoring, have led to the use of modern farming techniques.

Image processing methods associated with computational mathematical algorithms are widely used today, having applications in many branches of agriculture, closely related to technologies used in precision farming. They can be used in the agricultural field for: diseases and pests detection, classification of different crops, shape analysis, fruit volume, soil quality analysis, crop productivity analysis, soil moisture analysis, etc. Thus, a series of studies and researches on the application of image processing techniques in precision agriculture are presented in the literature.

There are several developed computer vision based methods for percentage estimation of weed, crop and soil present in an image showing a region of interest of the crop field. They divided image processing in three stages: segmentation of vegetation against non-vegetation, crop row elimination and weed extraction. "For each stage, different and interchangeable methods are proposed, each one using a series of input parameters the value of which can be changed for further refining the processing. A genetic algorithm was then used to find the best value of parameters and method combination for different sets of images. The whole system was tested on several images from different years and fields, resulting in an average correlation coefficient with real data (bio-mass) of 84%, with up to 96% correlation using the best methods on winter cereal images and of up to 84% on maize images (*Burgos-Artizzu X.P. et al, 2010*).

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Also, it was implemented an algorithm for disease spot segmentation using image processing techniques in plant leaf. Considering that disease spots are different in colour but not in intensity, compared with plant leaf colour, the authors used colour analysis of the RGB image to identify the affected plants. For image smoothing was used a median filter and finally threshold was calculated by applying Otsu's method on colour component to detect the disease spot *(Chaudhary P. et al, 2012).*

Some authors considered that nitrogen content of the soil is one of the most important factors which affect yields of crops. In the paper "*Estimation of nitrogen content in leaves using image processing*" they developed software which use a method to find nitrogen content in leaves based on image processing technique. The used technique consists in the capture of maize leaf image and preprocess it, for removing the noise of source image. After that, the colour and texture characters of maize leave are extracted and using the RGB and the HSV model the colour characteristics are analyzed (*Sunagar V.B. et al, 2014*).

To achieve increased crop productivity, a number of conditions need to be met. From these, soil moisture has an important role and it needs to be continuously monitored. Therefore, the irrigation system management must be improved. Methods for determining soil moisture are classified in the literature as direct and indirect methods. Direct methods require the collection of a high number of soil samples to be analyzed in the laboratory by destructive methods. Indirect methods use an instrument placed in the soil to measure some soil property related to soil moisture. In this context, precision farming has developed and implemented a series of automatic systems for monitoring and controlling soil moisture. A number of modern soil humidity monitoring techniques are presented in the literature.

A soil moisture measurement technique is based on time-domain reflectometry (TDR) or on the standard thermogravimetric methods. Authors considered that "indirect estimations via Earth Observation (EO) images include the triangle method, which shows that Land Surface Temperature (*LST*) is prevalently controlled by surface and root zone humidity in bare and vegetated soils respectively" (*Maltese A., et al, 2010*).

Other indirect methods for obtaining integrated estimates of soil moisture content over larger regions are based on the correlation between propagation characteristics of low frequency radio surface waves and surface soil moisture (Huebner C. et al, 2011). Some authors considered latent heat measurements of soil, reflectance-based methods, microwave measurements and synergistic approaches, as the main techniques used since long, for providing soil moisture estimates over regional and global scales *(Prajapati R. et al, 2018)*.

The method for soil humidity analysis proposed in this paper provide an indirect and qualitative soil moisture evaluation methods using aerial image processing, in two phases: image acquisition using a drone system and the second phase – image processing using a MATLAB algorithm.

MATERIALS AND METHODS

As a case study we observed, using a quadcopter, a large field located nearby Cluj – Napoca city and obtained several pictures which were processed in MATLAB software, Image Processing Toolbox. In Fig.1 is presented the analyzed area.

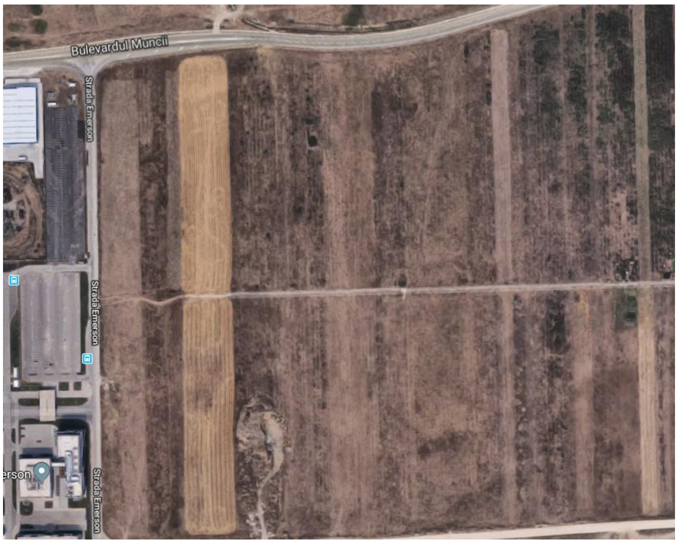

Fig. 1 - The aerial view of the analyzed area in the case study

The equipment we used is a *HUBSAN H501M X4* drone which has features such as *Return to Home, Follow Me*, *Waypoint*. It has superior motors so the drone is powerful and with a flight time of up to 20 minutes. The GPS allows the drone to enter the *failsafe mode,* meaning it automatically returns to the starting point if the signal is lost. The remote, or joystick, has a smart phone grip system. In order to use the smart phone, we needed to install the *X-Hubsan free app*. The media recording was done directly on the drone, using a microSD card.

Fig. 2 - The drone HUBSAN H501M X4

The technical specifications of the drone are the following:

- Weight (including battery and propellers): 0.41 kg
- Max Flight Time: 21 minutes (0 m/s - wind)
- Max Hovering Time: 18 minutes (0 m/s - wind)
- Overall flight time: 20 minutes (in normal flight, 15% remaining battery level)
- Max Flight Distance: 0.29 km (0 m/s - wind)
- Operating Temperature: 0° - 40° C
- GPS Mode: Active

The camera specifications are the following:

- Sensor: Effective pixels: 2.1 Mp
- Still Photography Modes: Single shot
- Video Recording Modes: 720p
- Max Video Bit rate: 60 Mbps
- Photo extension: JPEG
- Video format: MP4 (MPEG-4 AVC/H.264)
- The remote controller specifications are the following:
- Frequency: 2.4GHz
- Channels: 11
- Max Transmission Distance: FCC Compliant: 300m (Unobstructed, free of interference)

The Wi-fi Control specifications are the following:

- Frequency: Wi-fi
- Max Transmission Distance (Without Relay): 50 m (Unobstructed, free of interference)
- Max Transmission Distance (With Relay): 300 m (Unobstructed, free of interference)

Using the equipment presented above we have obtained several images of the area from different angles. After a brief analysis we have chosen for the processing part, the most relevant image to describe the plot of land.

Fig. 3 – The original image used in the processing part

Image processing algorithm

Starting from an original picture, captured by the drone camera, we applied MATLAB codes in order to determine the intensity of the image. Each picture element of an image, or each pixel is represented by a specific number in the three dimensional coordinate system. The pixel is the smallest element of a digital image and the bit depth in digital image defines the number of bits allocated to a pixel. If an image is composed only of white and black pixels is a 1-bit image. Each pixel is assigned 1 bit, which can be 0 or 1 (black or white).

RGB colour is actually a combination of three 8-bit images, one for Red, Green and Blue. The RGB image is an 8-bit image on a 24-bit channel or 24-bit image capable of rendering $(2^8) \times (2^8) \times (2^8)$ colours, that means 16.7 million colours. That is why, starting from the original image in RGB, we determined the intensities of pixels and compared it to the black and white image pixel's intensities.

In order to achieve credible results, we followed an algorithm with the necessary steps to obtain interpretable surface plots, generated by the MATLAB software. The algorithm presented in Fig. 4 is using shortcuts as RGB for the Red Green Blue, colour image and BW for the Black and White image.

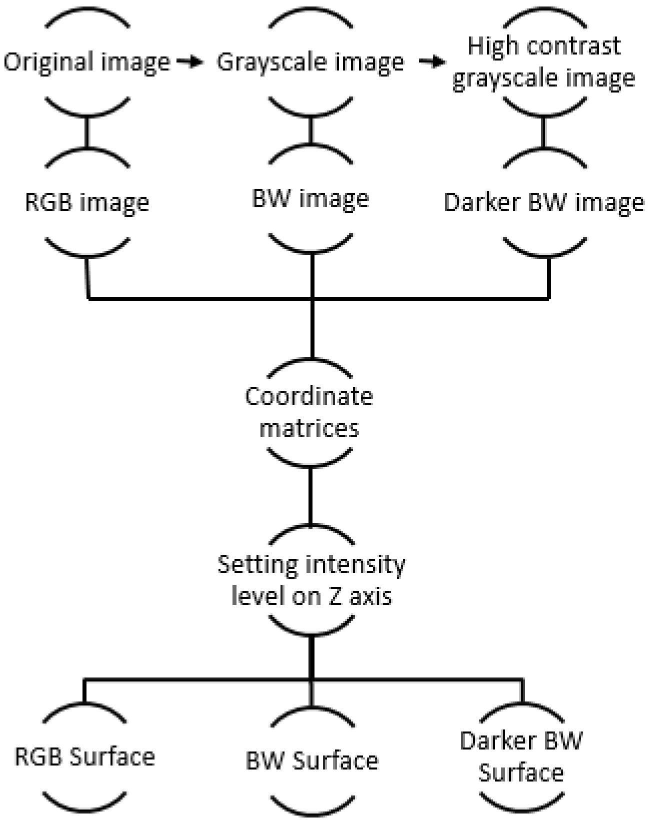

Fig. 4 – Image processing algorithm
RGB – Red Green Blue; BW – Black White;

The image processing algorithm is based on the MATLAB program functions that can determine the number of pixels of an image in two-dimensional or three-dimensional coordinates and their arrangement in matrices.

When determining the colour intensity of an image, it starts first by determining the pixel intensity (on an RGB spectrum) and placing it on a matrix, then on a three-dimensional graph. When determining the intensity of a black-and-white image, the two-dimensional coordinate system can be used successfully, but in order to have a verdict we used the three-dimensional coordinate system for all types of images.

RESULTS

After processing the original image, two black and white or grayscale images were obtained. The two images can be seen in Fig. 5, but also the third image which has a slightly darker grayscale in order to easily observe the intensity. The images have been analysed from the point of view of the pixel distribution and their intensity at different points of the images.

1 2 3

Fig. 5 – Transforming RGB image into BW picture with different grayscale

1 – original image; 2 – Black and White image; 3 – Darker Black and White image

Applying the algorithm in MATLAB Software, we obtained a surface plot with three axes, X, Y, Z, all of them showing the number of pixels on length (X axis), width (Y axis) and height (Z axis). In Fig. 6, the graphical representation of the number of pixels in the original RGB image can be seen.

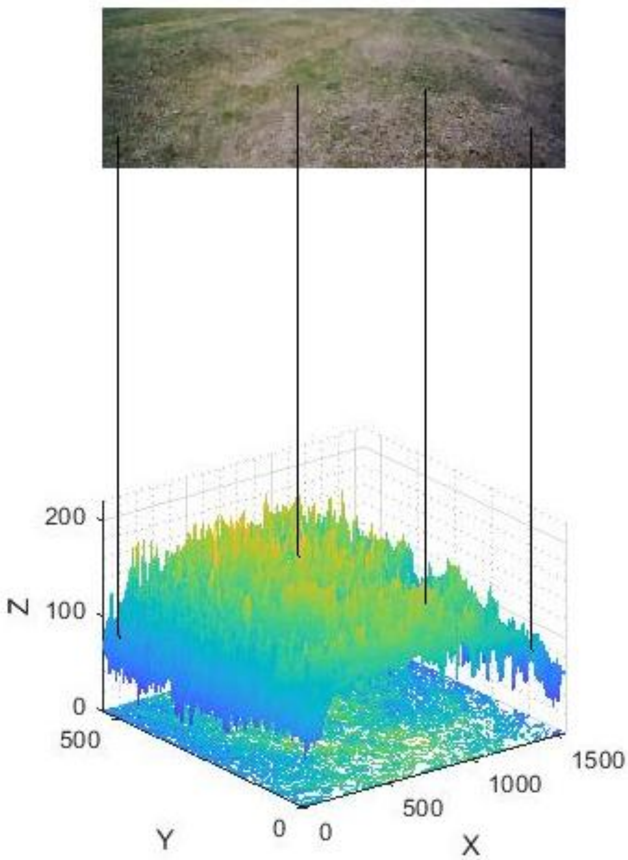

Fig. 6 – The pixel's intensity in the original, RGB image

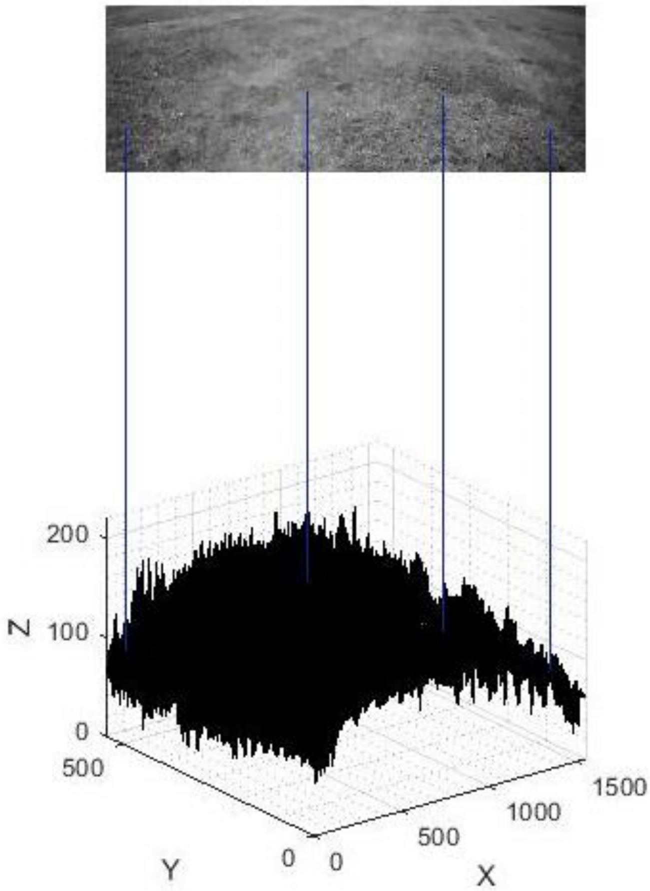

Fig. 7 – The pixel's intensity in the BW image

It can be observed that the number of pixels on Z axis is higher as the colour in the image is brighter, thus a maximum number of 180 pixels is assigned to the green part of the field. The pixel values vary from 0 to 180. Minimum values are located in the darkest parts of the image. On both sides of the image, left and right, the intensity is lower, so we can conclude considering the intense green colour that the grass is fully grown. On the bottom of the image the soil is dry and that can be explained by the higher intensity of pixels on the X axis.

We can translate the number of pixels at higher intensity to the level at which the observed culture has grown and also to the soil humidity.

Fig.7 shows the graphical representation of the number of pixels in the BW image. Black and white are non – colours which form the grayscale in an image. Comparing to the RGB image, a BW image shows less details but has a better pixel distribution and a better contour.

As you can observe in Fig 7, the green parts of the RGB image are darker on the grayscale, in the BW image, and overall the intensity is lower. The maximum number of pixels on Z axis is 178, in the area where there is no grass or slightly increased grass.

In the darkest parts of the image, the left side and the right side, the number of pixels decreases almost to zero. The bottom of the image is a light grey, almost white, so there are more 1 pixels, in the binary code, than 0 pixels, so the intensity is higher and that can be seen on the X axis values. The advantage of the Black and White image is that the contour of the land parcel with grass is more visible.

Starting from the BW image, we increased the contrast so the contour is even more visible. Fig. 8 shows the graphical representation of the number of pixels in the darker BW image.

We chose to change the contrast of the BW image in order to see how the number of pixels on the Z axis varies from a simple BW image. A decrease in the maximum pixel intensity to 176 can be observed, so a contrast-enhanced BW image can produce easier to see results at first glance.

In this contrast-enhanced image, the contours of the grass parcels are better defined than in the other two images because the dark grey becomes even darker and the light grey becomes lighter, almost white.

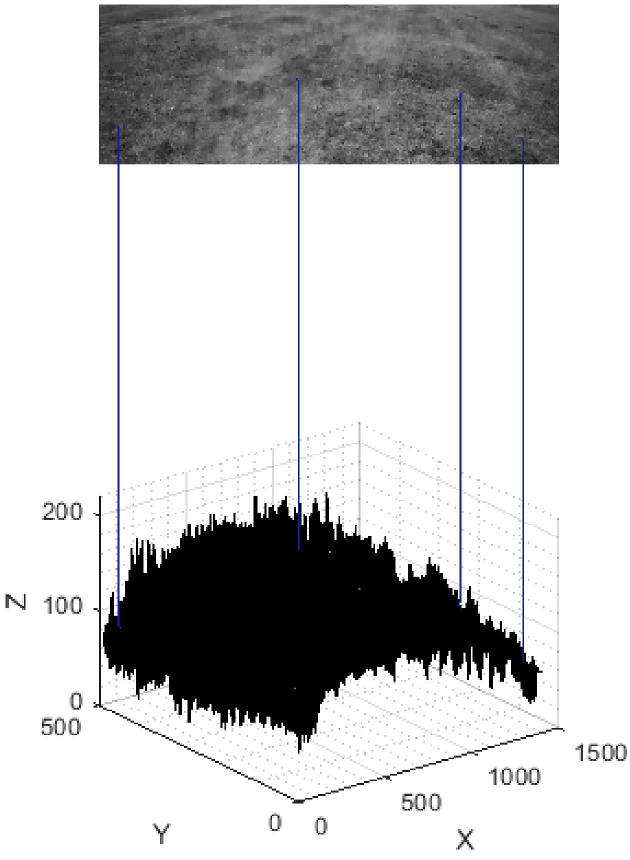

Fig. 8 – The pixel's intensity in the darker BW image

CONCLUSIONS

The agricultural sector has had a strategic role in human development since ancient times. This, along with the development of technology, has led to the need to increase agricultural output. The development of the agricultural sector has accelerated once with the implementation of modern technologies and transition to precision agriculture.

In this context, modern methods for soil quality assessment and crop monitoring have also been developed and implemented, using digital techniques and aerial imaging techniques. At a first stage, modern technologies, such as GIS/GPS, were used in the mapping of farmland. The next stage of development was the transition from classical, direct crop monitoring methods to soil quality assessment, which involves soil sampling from several points, i.e. land movement, as well as a series of destructive methods sample analysis, indirect methods involving image processing techniques.

Modern techniques used in the present can be divided into two stages: the acquisition of satellite images or using aerial devices such as drones and their processing using digital imaging techniques. The continuous assessment of soil quality in terms of humidity is an operation that can ensure both optimal production and preservation of soil properties. Using quadcopters to capture images and transmitting information in real time is a current technique for observing land quality.

Images were obtained using the quadcopter, which were subsequently processed in MATLAB software. The image processing stage can be considered the most important, because it has the ability to generate graphs depending on the image type, RGB or black and white. It was also found that in a darker black and white image, the contours of the objects can be observed more easily, in this case, the contour of the area where the soil is hydrated.

The detailed research in this article demonstrated the possibility of assessing soil moisture through image processing. In this way, applying the proposed algorithm, soil humidity maps can be developed, which is useful in the qualitative monitoring of agricultural land. Image processing provided quantifiable information on the extent of crop development. This technique can be extended in the field of agriculture by: assessing the productivity variation for different crops, determining soil quality from the point of view of the PH, determining the degree of uniformity of the different crops.

From the point of view of the applicability of the presented research, it can serve a wide range of users such as farmers, state administrative agricultural units, regional agencies, agricultural intervention agencies (A.P.I.A.).

The maps that can be created would be an information archive on the evolution of agricultural soil quality and the associated productivity variation.

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