



APPLICATION TO DETERMINE THE NORMALIZED DIFFERENTIAL VEGETATION INDEX OF CROPS USING A DRONE

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ABSTRACT

This work presents an application's design based on Matlab for the relative biomass measurement through the NDVI (Normalized Differential Vegetation Index) using a drone or unmanned aircraft. This application allows farmers to view the crops' topsoil state in real-time to determine corrective or improvement actions. The NDVI calculation response is evaluated through the percentage referenced in the number of pixels with specific image characteristics, which must be a value greater than or equal to 0.2 of NDVI. The results are compared with commercial software. As a result, it's shown the pixel saturation correction stage through the reflectance correction system allows to obtain 10% of pixels lower than the NDVI threshold, at the same time improves the vegetation cover state visualization since by eliminating in this stage, several areas of the culture show overexposure (low color contrast) in the NDVI values.

Keywords: biomass, spectral camera, Matlab, unmanned aircraft, NDVI.

1. INTRODUCTION

In general, a vegetation index can be defined as a parameter calculated from the reflectivity values at different wavelengths. It aims to extract the information related to vegetation, minimizing the influence of disturbances such as those due to the ground and atmospheric conditions (Huete *et al.*, 2018). Among the most widespread vegetation indices that make use of spectral bands are: NDVI (use of NIR and red bands), GNDVI (use of BIR and green bands), RVI (use of NIR and red bands), GVI (use of NIR and green) NGRI (use of green and red bands) and RG (use of red and green bands) (Thenkabail *et al.*, 2018).

The NDVI vegetation index is known as the Normalized Differential Vegetation Index (Rouse *et al.*, 1974), which is introduced to separate vegetation from the brightness produced by the soil (Diaz, 2015). It also uses the energy absorption and reflection properties that plants have in the electromagnetic spectrum in various parts related to photosynthetic activity and plant leaf structure. For example, in the visible spectrum part (red), the leaves pigments absorb most of the energy it receives. Simultaneously, it is reflected in the NIR (Near Infrared) because the cellular leaves composition is water. However, when vegetation presents some stress type either by pests or droughts, the amount of water on the leaf walls decreases considerably; so reflectivity decreases in the NIR. The absorption in the red increases in a similar way; this behavior allows differentiating healthy vegetation from that which presents undesired characteristics within the crop. These characteristics make the NDVI generate an image that shows the relative biomass or crop greenness through digital image processing, achieving the monitoring of the analyzed plant cover conditions.

Nowadays, the NDVI is frequently calculated using images obtained by satellites (Yengoh *et al.*, 2015), producing results that may be affected by atmospheric conditions (gases) at the time of taking the images (Rengarajan & Schott, 2018). A booming solution is

developing systems that use unmanned aircraft (UAV), whose processes generate measurements more precisely, unaffected by environmental conditions, and with higher spatial resolution images than those obtained from satellite way, allowing to reduce the uncertainty in the results.

This project proposes a practical development exercise using a drone with a spectral camera to obtain images and the design of an application through Matlab that allows the vegetable cover analyzed monitoring through the relative biomass using the NDVI. The application and the assembly carried out to make it easy to monitor the overflowed areas and visualize the topsoil state (relative biomass) through the NDVI calculation. Compared with satellite images and processed with specialized software (ArcGIS), these results lead to obtaining differences in relative biomass of up to 12.1%.

2. MATERIALS AND METHODS

2.1 Hardware

The proposed system for monitoring the topsoil is shown in Figure-1. This system is made up of a drone with a 2k resolution RGB camera, a MAPIR spectral camera (located on the drone) with 12 Million pixels with spectral bands: near-infrared ($\lambda = 850$ nm), red ($\lambda = 660$ nm), and green ($\lambda = 550$ nm), GPS and reflectance calibration system.



Figure-1. The proposed system for the NDVI; a) spectral camera, b) drone with RGB and GPS camera, and c) reflectance calibration system.



2.2 Data Acquisition

The images to be analyzed in the designed application are obtained through controlled overflights and optimal weather conditions. The overflight height is practically constant to avoid variations in the results obtained (30 ± 2) meters.

Before vegetation covers overflights, a group of images is obtained from the reflectance calibration system. This system contains four known reflectance values (these values are obtained using a spectrometer), which, compared with the values obtained during overflights, avoid the over-exposed pixel inclusion. In this way, the system guarantees that the reflected light corresponds to the plant or crop information, and calibrated images are obtained to perform the NDVI calculation later.

The following mathematical function defines the NDVI vegetation index:

$$NDVI = \frac{\varphi_{NIR} - \varphi_{RED}}{\varphi_{NIR} + \varphi_{RED}}$$

Where φ_{NIR} is the spectral band corresponding to the near infrared ($\lambda = 850$ nm) and φ_{RED} is the spectral band of red ($\lambda = 660$ nm). Once the images are calibrated, the pixel-by-pixel NDVI calculation is carried out through the mentioned equation. The resulting pixel values are between -1 and +1, and as mentioned by different authors, including (Bhandari *et al.*, 2012), low NDVI values (less than or equal to 0.2) correspond to arid areas of rock, sand or snow, while high values, that is, greater than 0.2 represent, shrubs, grasslands, temperate and tropical forests, among others. When the ground is uncovered, it is usually associated with a value of 0. It is important to clarify that the results obtained from the NDVI through images obtained with drones are not affected by weather conditions, such as gases or clouds.

To avoid soil disturbance in areas where vegetation is sparse, Huete's NDVI modification called SAVI (Soil Adjusted Vegetation Index) is carried out (Huete, 1988). It is defined as:

$$SAVI = \frac{(\varphi_{NIR} - \varphi_{RED})(1 + L)}{(\varphi_{NIR} + \varphi_{RED} + L)}$$

Where L ranges between 0 and 1. For this work, a value of $L = 0.5$ was taken because this value is recommended (Huete *et al.*, 2018) for values of intermediate vegetation density.

2.3 Application Development

The application to visualize the topsoil state makes use of Matlab's digital image processing toolbox. The diagram used for its development is shown in the diagram represented in Figure-2.

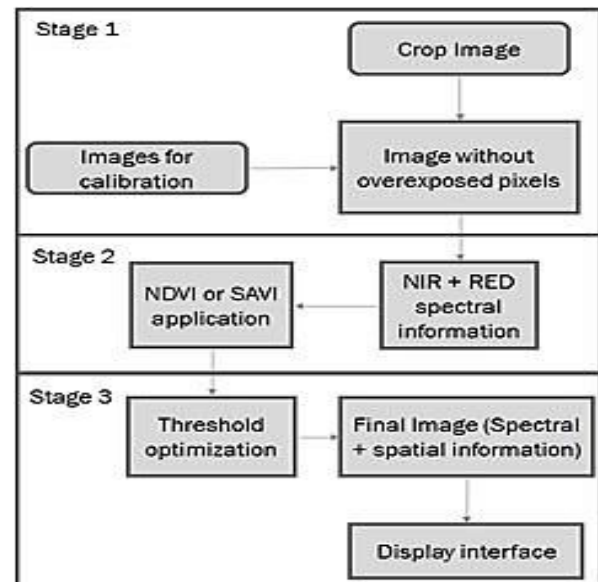


Figure-2. Operation stages of the application for the NDVI determination.

2.3.1 Image correction (Stage 1)

In the first stage, the drone's images through the spectral camera are taken to the computer to be processed. In each overflight of the field to be analyzed, it is essential to obtain the images from the reflectance calibration system to avoid overexposed pixels that can alter the information. The overflights are recommended to be between 3 and 10 meters high to obtain more reliable results. In this stage, the pixel values of each image to be analyzed are compared with the reflectance values of the known calibration system to exclude overexposed pixels that may alter the final spectral information.

2.3.2 NDVI Calculation (Stage 2)

The spectral information (NIR, red, and green) is extracted from the images to be analyzed at this stage. This information is extracted through programming routines, thus generating three new images, of which only two (near-infrared and red) are necessary for the NDVI calculation (See Figure-3).

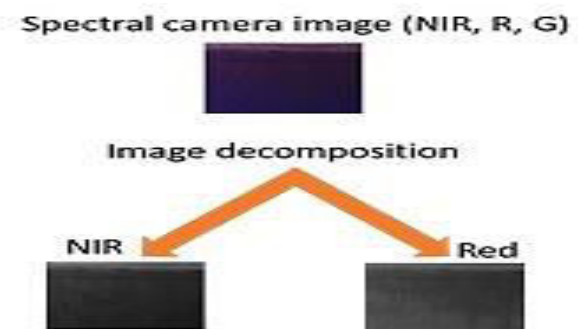


Figure-3. Spectral extraction information: Upper image: original photo of the spectral camera with the NIR, R, G channels. Lower image: image decomposition in the NIR and R channels.



The NDVI calculation vegetation index is obtained by applying the mathematical relationship described in section 2.2. For this purpose, the operation is pixel by pixel; that is, the connection is established with the information present in each image pixel that occupies the same position. The mathematical operation result is a new image of the same size as the originals but whose pixel values range between -1 and 1, associated with the biomass or crop analyzed state. Figure-4 shows an NDVI calculation example for an image represented by a size of 3x3 pixels. It is worth mentioning that the original size of each image is 4000x3000 pixels.

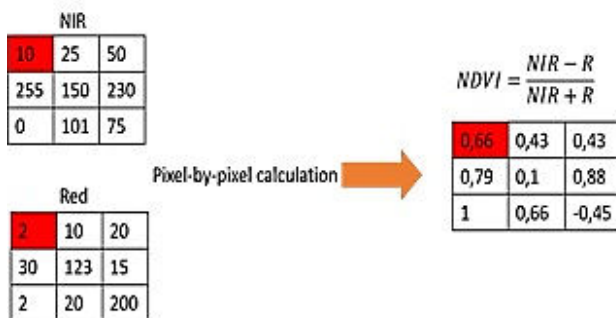


Figure-4. Pixel by pixel calculation of NDVI for a 3x3 size image.

2.3.3 Final image and interface (Stage 3)

The information obtained in the previous stage only gives spectral or quantitative data on the biomass state (values between -1 and 1). This information can be spatially visualized and thus be able to perform a qualitative analysis to establish the vegetative areas that require more attention from the farmer. The final image created in this stage contains the spatial and spectral information (NDVI results). It is obtained by visualization of an adequate color space, with scales that vary from intense red to an intense green that represent the estimated values that it can take the NDVI (-1 and 1), representing the spatial location state of the analyzed topsoil (See Figure-5).

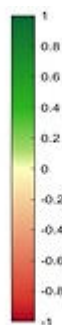


Figure-5. Color scale designed for NDVI spatial visualization.

The designed interface allows the user to enter the images obtained from the overflight and, as a final

result, shows the NDVI spatial location information so that the farmer can quickly and easily monitor the biomass's status.

3. RESULTS AND DISCUSSIONS

From the NDVI equation described in section 2.2, it is analyzed that if the radiation percentage of reflection corresponding to red (φ_{RED}) is small when compared with the reflection in the NIR channel (φ_{NIR}), the NDVI takes a value high (or greater than zero), which corresponds to the topsoil in a possibly healthy state. However, if the reflection of the two spectra are very similar or if $\varphi_{NIR} < \varphi_{RED}$ the NDVI values are close to zero or -1, consequently, it indicates that the topsoil is not at its most optimal level. The images in Figure-6 show the algorithm implementation results created and allow observing the spatial and spectral information of the NDVI calculations in a single image for a specific crop. This figure also observed that the topsoil that is far from an area of roads or highways has a more intense green, with NDVI values close to 1. In contrast, the topsoil bordering the road presents a color that goes from white to red, representing values below 0.2 on the NDVI scale, which indicates that this area of the biomass does not give the same development as the more remote areas. When comparing these results with an image of the same size but in an RGB color space, it is observed that areas surrounding the road have less humidity. Therefore, the topsoil is more susceptible to increases in temperature, resulting in dry areas with water stress. The percentage of pixels with an NDVI value above 0.2 was approximately 86%, representing a margin to intervene in the crop and improve production.

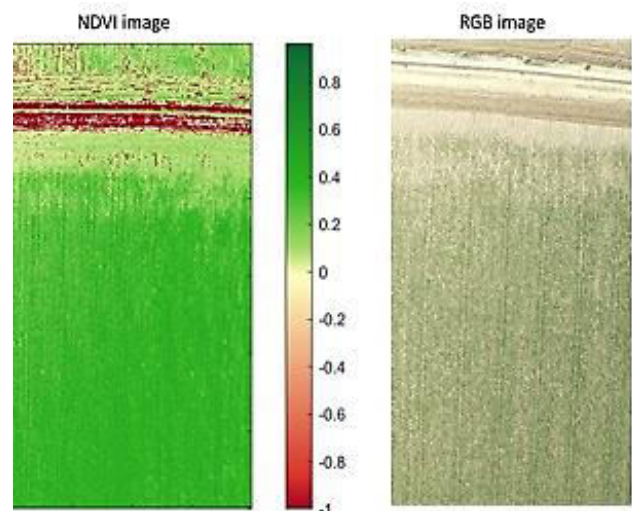


Figure-6. NDVI image result. Left: Image with spatial and spectral information from the NDVI. Right: Image obtained in RGB space.

The images are obtained with different cameras left. Spectral chamber, right RGB camera. The greener areas in the left image represent an NDVI value close to



+1, and it is established that the topsoil has appropriately developed. The white, yellow, and red areas represent values below 0.2, indicating that there are dry areas or that there may be signs of diseases that lead to crop deterioration. The results returned by the Matlab-based application (see application interface Figure-7) are compared with commercial programs such as ArcGIS, whose results are described below.

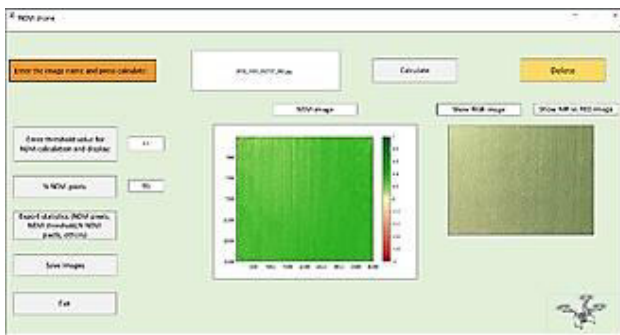


Figure-7. Application interface designed in Matlab through the GUIDE toolbox.

The interface in Figure-7 allows viewing the spectral and overflight spatial information (Image NDVI button). Also, view RGB and NIR images vs. Red, set pixel count thresholds for NDVI values, show the percentage of pixels that exceed the selected NDVI threshold, export statistics, and save future evaluation images.

For the different tests or overflights to crops, the relative biomass value is the sum of all the pixels whose NDVI value is greater than or equal to 0.2. This threshold represents relative biomass in good condition (Bhandari *et al.*, 2012). Figure-8 illustrates the results obtained for 70 images of crop # 1. It shows that the number of blue pixels (NDVI for designed application) and red pixels (NDVI obtained with ArcGIS) present a similar distribution, yielding a total difference of 8.1%.

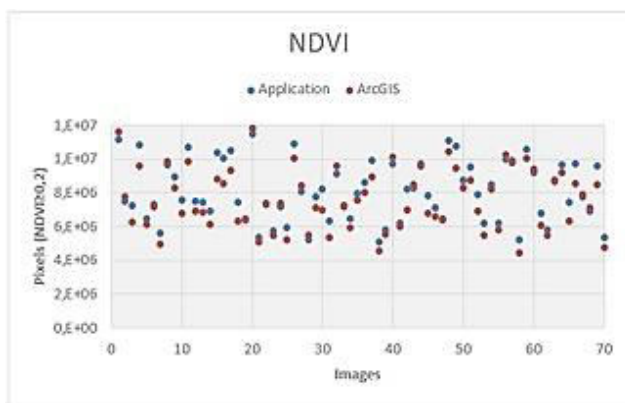


Figure-8. Comparison NDVI culture results 1. Application designed NDVI blue dots, ArcGIS software NDVI red dots.

Similarly, as in crop 1, 70 images are analyzed for each of crops 2 and 3. The difference in biomass

obtained percentage is 9.6% and 12.1% for crops 2 and 3, respectively (Figures 9 and 10 show the result between the two systems used to calculate the NDVI).

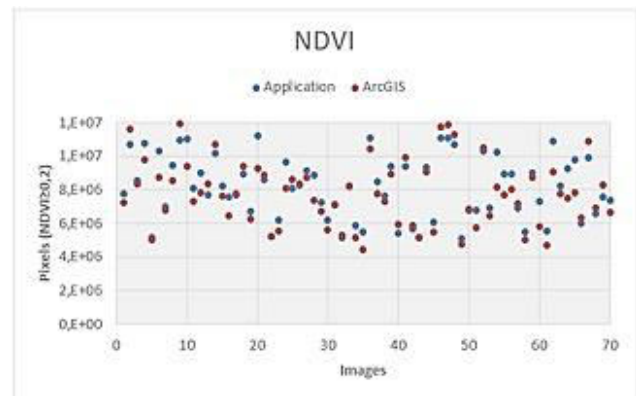


Figure-9. Comparison NDVI crop results 2. Application designed NDVI blue dots, ArcGIS software NDVI red dots.

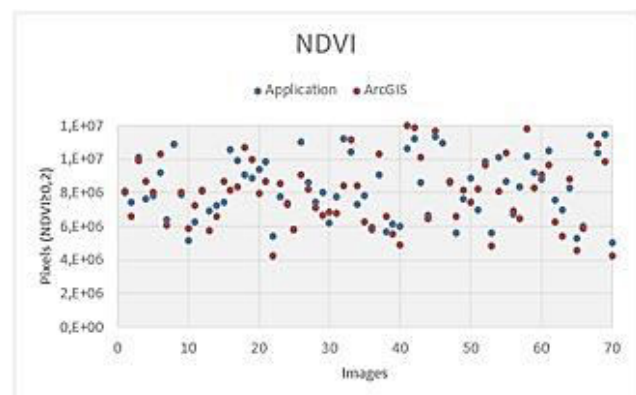


Figure-10. Comparison of NDVI culture results 3. Application designed NDVI blue dots, ArcGIS software NDVI red dots.

When globally comparing the NDVI results in the three tools obtained by the two tools, the percentage difference was 9.9% regarding the commercial software. The leading cause of these results is that an image correction process is carried out for the designed application (see section 2.3.1) that allows the elimination of saturated or overexposed pixels. By eliminating this processing stage, the number of pixels that exceed the NDVI threshold of 0.2 by up to 10% reduces the spatial contrast visualization of the image. Compared with satellite images with a decametric resolution, a discrepancy is expected in the results. The results may be biased due to the images' resolution compared to high-resolution images obtained from UAVs (Khaliq *et al.*, 2019).

4. CONCLUSIONS

According to the results obtained using the Matlab-based tool, it is evident that the image correction process where overexposed pixels are eliminated improves the NDVI results compared to other commercial tools,



improving the identification of relative biomass by up to 12.1% for the analyzed crops.

The spatial identification of the spectral information, such as the mathematical NDVI operation calculation, together with the appropriate color spaces, allows the visualization of areas quickly. In these areas, the relative biomass needs more attention by the farmer, becoming a necessary tool for precision agriculture becoming increasingly important and relevant nowadays.

The proposed hardware (spectral camera + RGB camera + calibration for pixel overexposure) allows obtaining good NDVI results compared with satellite images. The image resolution from the satellite is lower than the one from the hardware. Simultaneously, it avoids the inclusion of inappropriate information such as gases or clouds because the UAV height flights prevent the inclusion of such information.

As a hardware disadvantage and software implemented, the computational cost required by the pixel-by-pixel analysis of images with a size of the order of 12 million pixels that are made through Matlab is anticipated. Not only for the NDVI calculation but also for creating the final image that requires spectral and spatial information with appropriate color maps.

REFERENCES

- Bhandari A., Kumar A. and Singh G. 2012. Feature Extraction using Normalized Difference Vegetation Index (NDVI): A Case Study of Jabalpur City. 2nd International Conference on Communication, Computing & Security [ICCCS-2012]. 6, pp. 612-621.
- Diaz J. 2015. Estudio de Índices de vegetación a partir de imágenes aéreas tomadas desde UAS/RPAS y aplicaciones de estos a la agricultura de precisión. (Trabajo de grado maestría). Universidad Complutense de Madrid, España.
- Gandhi G. M., Parthiban S., Thummalu N. and Christy A. 2015. Ndvi: Vegetation change detection using remote sensing and gis—A case study of Vellore District. *Procedia Computer Science*. 57, 1199-1210.
- Haboudane D., Miller J., Pattey E., Zarco P. and Strachan I. 2003. Hyperspectral vegetation indices and novel algorithms for predicting green LAI of crop canopies: Modeling and validation in the context of precision agriculture. *Remote Sensing of Environment*. 90, pp. 337-352.
- Huete A., Lyon J. and Thenkabail P. 2018. Advances in Hyperspectral Remote Sensing of Vegetation and Agricultural Crops. En *Fundamentals, sensor systems, spectral libraries, and data mining for vegetation* (pp.3-40). U.S: CRC Press.
- Huete A. R. 1988. A Soil-Adjusted Vegetation Index (SAVI) remote sensing of Environment. 25: 295-309.
- Khaliq A., Comba L., Biglia A., Aimonino D., Chiaberge M. and Gay P. 2019. Comparison of Satellite and UAV-Based Multispectral Imagery for Vineyard Variability Assessment. *Remote sensing*. 11, pp. 1-17.
- Rengarajan R. and Schott J. R. 2018. Evaluation of Sensor and Environmental Factors Impacting the Use of Multiple Sensor Data for Time-Series Applications. *Remote Sens*.
- Rouse J., Haas R., Schell J. and Deering D. 1974. Monitoring vegetation systems in the Great Plains with ERTS. Third Earth Resources Technology Satellite-1 Symposium. Volume 1: Technical Presentations, section A. 1: 309-317.
- Sobrino J. 2001. Interacción de la radiación con la superficie. En *Teledetección* (pp. 91-130). España: Universitat de València.
- Thenkabail P., Lyon J and Huete A. 2018. Derivative Hyperspectral Vegetation Indices in Characterizing Forest Biophysical and Biochemical Quantities. En *Hyperspectral Indices and Image Classifications for Agriculture and Vegetation* (pp. 28-57). 2018: CRC Press.
- Xiuliang J., Zhenhai L., Haikuan F., Zhibin R. and Shaokun L. 2019. Deep neural network algorithm for estimating maize biomass based on simulated Sentinel 2A vegetation indices and leaf area index. *The Crop Journal*. 8, pp. 87-97.
- Yengoh G., Dent D., Olsson L., Tengberg A. and Tucker C. 2015. The Potential for Assessment of Land Degradation by Remote Sensing. Use of the Normalized Difference Vegetation Index (NDVI) to Assess Land Degradation at Multiple Scales Current Status, Future Trends, and Practical Considerations. pp. 9-13.