USING UAVs/DRONES AND VEGETATION INDICES IN THE VISIBLE SPECTRUM TO MONITORING AGRICULTURAL LANDS

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ABSTRACT

Unmanned Aerial Vehicles UAVs or Drones have made great progress in the field of aerial surveys to study vegetation and farmland. The research focuses on developing smart systems for managing agricultural fields, thus facilitating decision-making, increasing agricultural productivity, improving profitability and protecting the environment. The paper highlights the ability of drones to distinguish agricultural land intended for cultivation and classified as deserted or cultivated or in the germination stage. For the first time in the Nineveh governorate, a Phantom 4 DJI UAV images were used, in addition to using the spatialized Pix4Dfielde program to process these images. Four types of the standard agricultural indices that rely on the visible spectrum have been used (Visible Atmospherically Resistant Index (VARI), Triangular Greenness Index (TGI), Synthetic Normalized Differences Vegetation Index (S-NDVI) and Visible Difference Vegetation Index (VDVI)) to test UAVs images and to categorize different types of agricultural land. The results showed that when using the S-NDVI and VDVI indicators, the values 0.16 and 0.14 appeared respectively in certain areas, which indicates the presence and integrity of vegetation cover, unlike other regions, whose indicators showed 0.010 and -0.004, respectively, which indicate that the plant has a bad condition or its absence at all. All results finding in this research reflect and confirm the validity of using UAVs images for agricultural field management and development.

Keywords: smart agriculture, remote sensing, aerial agricultural survey, spectral reflectance.

استعمال الطائرات بدون طيار ومؤشرات الاغطية النباتية في الطيف المرئي لمراقبة الأراضي الزراعية

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المستخلص

حققت الطائرات بدون طيار تقدمًا كبيرًا في المسوحات الجوية لدراسة الغطاء النباتي والأراضي الزراعية. يهدف هذا البحث بشكل رئيسي إلى تطوير أنظمة ذكية لإدارة الحقول الزراعية، وبالتالي تسهيل عملية صنع القرار، وزيادة الإنتاجية الزراعية، وتحسين الربحية. في هذا البحث، تم تسليط الضوء على قدرات الطائرات بدون طيار لتمييز الأراضي الزراعية المخصصة للزراعة وتصنيفها على أنها مهجورة أو مزروعة أو في مرحلة الإنبات ووفقًا للمراحل المختلفة للدورة الزراعية. لأول مرة في محافظة نينوى، تم استخدام صور طائرة مسيرة نوع DJI Phantom 4، بالإضافة إلى استخدام برنامج Pix4Dfields لمعالجة هذه الصور. تم استخدام أربعة أنواع من المؤشرات الزراعية القياسية التي تعتمد على الطيف المرئي فقط وهي (مؤشر مقاومة الغلاف الجوي المرئي (VARI)، ومؤشر الخضرة الثلاثي (TGI)، ومؤشر الغطاء النباتي للاختلافات الطبيعية-الصناعي (S-NDVI) ودليل الفروق المرئية (VDVI)) لاختبار صور الطائرات بدون طيار وتصنيف أنواع مختلفة من الأراضي الزراعية. أظهرت النتائج أنه عند استخدام مؤشري S-NDVI و VDVI، ظهرت القيمتان 0.16 و 0.14 على التوالي في مناطق معينة، مما يدل على وجود الغطاء النباتي وسلامته، على عكس المناطق الأخرى التي أظهرت مؤشراتها 0.010 و -0.004 على التوالي، والتي تشير إلى أن حالة النبات سيئة أو عدم وجوده اصلا. وتعكس جميع النتائج التي توصل اليها البحث وتؤكد امكانية استخدام صور الطائرات بدون طيار لإدارة وتطوير المجال الزراعي.

الكلمات المفتاحية: الزراعة الذكية، الاستشعار عن بعد، المسح الزراعي الجوي، الانعكاسية الطيفية.

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INTRODUCTION

There is a growing interest in precision agriculture and the development of smart agricultural resource management systems to increase agricultural productivity, improve profitability and protect the environment. Data collection, field variability mapping, decision-making and management practices are the early stages of smart agriculture (18). Unmanned Aerial Vehicle (UAV) is a sophisticated, cost-effective data collection tool. UAV or Drone plays an important role in agriculture after their technological development and the ability to carry various sensors onboard, whether they are regular cameras or multi-spectral sensors or thermal sensors (13). With the technological development of these sensors, drones have made significant progress in aerial surveys of vegetation and agricultural land, including crop and soil monitoring, natural resource management, irrigation and fertilization Methods as well as detection of plant disease (17). UAVs provide very high spatial resolution images that are very useful for controlling agricultural production expectations and evaluating yields. Although satellite imagery is widely used in agricultural fields, it differs in its spatial accuracy and according to the type of satellite and sensors used. Which means that it can cover an area of one kilometer per pixel in the image, hundreds of meters or, at best, tens of meters. This lack of precision has limited applications for small-scale agricultural owners (9). Although satellite images can now be obtained free of charge (11), such as the satellite launched by the European Space Agency Sentinel, which provides excellent spectral bands specifically designed for vegetation studies with a spatial accuracy of 10 m per pixel, they are not considered to be effective for monitoring small agricultural fields. Additionally, there are other restrictions on the use of satellites, such as the distance between the satellite and the earth, meaning that the water vapor, the ozone layer, and the clouds impact the emission signal that enters the sensor. This negatively affects the quality of the data despite the possibility of using a special program to correct it (6). Smallholder farmers often grow different types of crops over a small area in order to create a very heterogeneous vegetation mosaic, which complicates the distinction between types of crops in satellite images (5). UAV images are therefore the solution and have very high capabilities that serve small field owners, as they provide us with images with a spatial resolution of up to a few centimeters per pixel and depending on the technical characteristics of the different sensors that these aircraft can carry. In addition, drones provide a solution to the problem of clouds and other weather effects caused by the high altitude on the data quality as they fly at very low altitudes of 100 meters or less. However, the main downside of the UAVs is the very limited spatial coverage resulting from short flight times due to their limited capacity to carry large batteries (14). The research focus on developing smart systems for managing agricultural resources, thus facilitating decision-making, increasing agricultural productivity, improving profitability and protecting the environment. The research demonstrate the abilities of drones to distinguish and classify the vegetation cover of small agricultural lands. The main elements of the work system based on agricultural remote sensing using drones have been described, in addition to a review of the possibilities and use of one of the global programs that were devoted to image processing and analysis provided by such aircraft and demonstrating its great potential in the classification of agricultural products. Four of the standard agricultural indices that rely on the visible spectrum have been used (VARI, TGI, S-NDVI and VDVI) to categorize different types of agricultural land.

MATERIAIS AND METHODS

Study area and devices used

Pictures have been taken at the archeological area of Nineveh, located in the center of Mosul (Fig. 1) near the University of Mosul, which contains small fields planted with several different types of seasonal agricultural crops, is considered an archeological area where urban construction is prohibited and is bordered by residential areas on all four sides. Several different areas were surveyed on several drone operation, after obtaining official approvals and accompanying the security forces to cover the field experiment. The DJI

Phantom 4 pro drones have been used in Fig. 2 (19), and were launched at an altitude of approximately 100 meters, which provided us with images with a spatial resolution of approximately 10 cm. In order to upload and process drone images, the program Pix4Dfields was used (15). Where the program includes the possibility of geographical modification, in addition to the possibility of making special interference with the production of mosaics for the area surveyed. The program also includes the possibility of using mathematical equations for the application of indices to discriminate between different cultivated lands and crops.

Fig. 1: The study area, Nineveh Archeological Area, in the center of Mosul.

Fig. 2. DJI Phantom 4 Pro, The Drones used in this research

UAVs data acquisition and processing

Every traditional Drone air survey needs a number of main phases that we shall sum up in this paragraph (Show Fig. 3) (7). The first stage is the planning stage, where this stage reflects the key preparation for the entire process, including deciding the devices available for the survey and choosing the optimal flight time and date. The second step consists of the images taken process, which includes the preparation and orientation of the camera, its calibration, its location on the drone. After capturing the images, the stage of gathering these images begins, which is known as "The Mosaic Process," where we take advantage of the interference process that we mentioned in the previous stage in order to have a single visualization. All images taken from one location are included in one single visualization. In the final stage, the approach of extracting the information we need from the completed scene and the application of digital processing and photogrammetry processes to find measurements in engineering. For instance, areas and boundaries, characteristics extraction, 3D modelling or digital and surface model extraction (12). In Fig. 3, the general workflows are shown and the details of the case study are followed in the following sections.

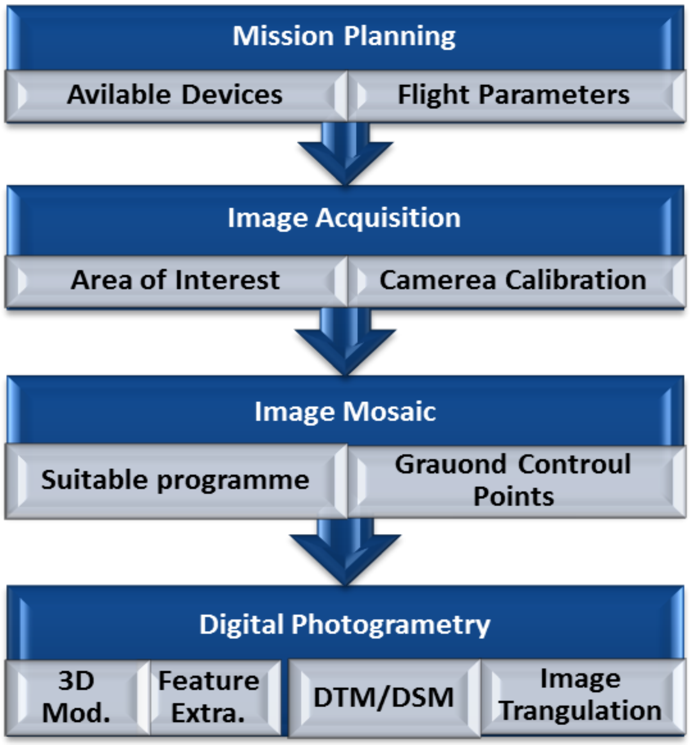

Fig. 3. Typical acquisition and processing pipeline for Drone images

An aerial survey was performed on four separate locations throughout the surveyed area. A total of (257) photo were taken using four lines in one of the locations. Fig. 4 shows an example of serial images captured using a UAVs camera.

Fig. 4. Serial images captured using the UAV

Fig. 5 shows the use of thePix4Dfields specialized program for the processing of captured images, as the program performs a process of geographical correction based on the information stored in the images. The figure also shows the direction of the flight and the number of airlines covered by the four-line survey process. The survey covered an area of less than 15 thousand square meters. To the left side of Fig. 5, the program shows the timing of the start and end of the survey and the duration of the survey, which is 11 minutes, in addition to the date of the survey, which is 14/11/2018

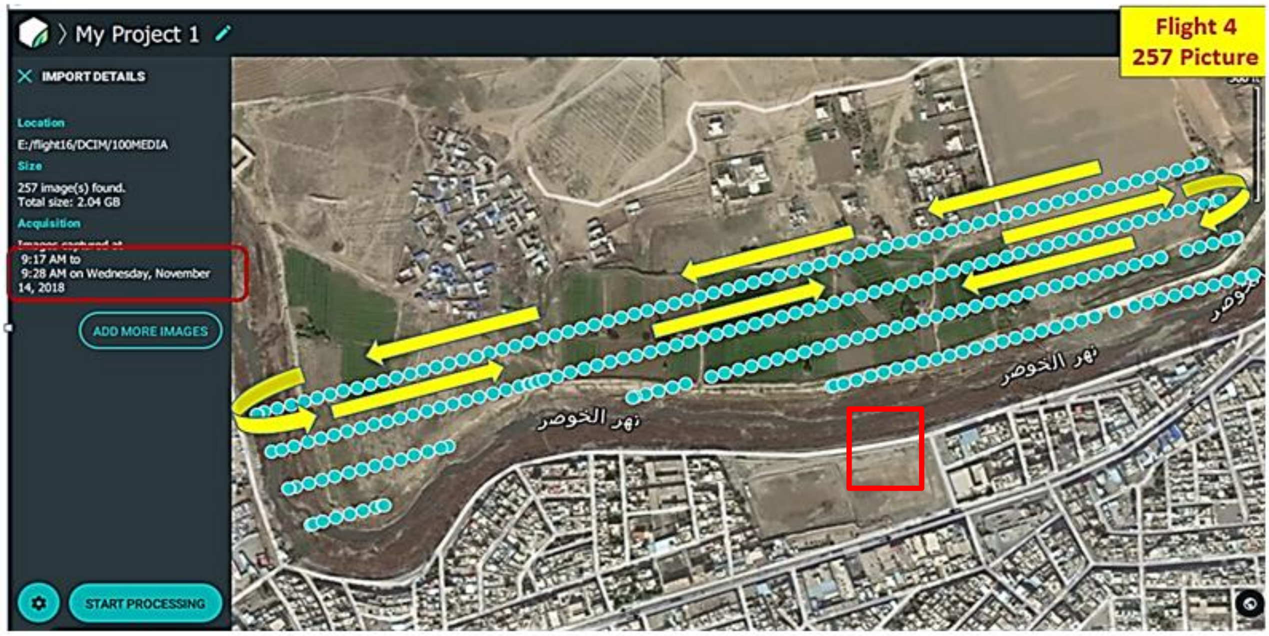

Fig. 5. Processing for the collection images using a mosaic mechanism, projected onto its true geographical coordinates. The figure also clarifies the direction of routes and numbers of flight lines

Fig. 6 shows the area covered by the scanning process after the completion of the process and gathering the images, i.e., the mosaics of the area. So that we have an up-to-date aerial photo with high spatial resolution, where can be realize accurate details when zooming in to any part of the surveying area. Fig. 7. shows the high spatial resolution of the UAV images for a given agricultural field. A certain part of the study area was deducted and enlarged, using Pxi4Dfeild software, which involves of a variety of small-hold agriculture fields. The cut portion contains different planting stages and using as a tested region,

Fig. 6. Shows the survey area after gathering all the images, and doing the mosaic operation. The area enclosed by the rectangle will be tested

Fig. 7. A certain part of the study area contains different planting stages

RESUITS AND DISCUSSION

1- Agriculture land classification using Pix4Dfields software

Remote sensing techniques was used to study the relationship between the spectral reflectivity and the vegetative index and to determine the variation in vegetation cover (1). In order to determine the possibilities of taking advantage of drone images in the field of smart agriculture and in the field of agricultural land management and development, the specifications of the Pix4Dfields program for the classify of agricultural land have been used, and two classification options provides by this program have been tested, according to the following details:

First: Using agricultural indices

Many indices were used as a means of measuring and analyzing changes happening in the vegetation cover. One of the most important geotechnical techniques is Normalized Differences Vegetation Index (NDVI) (3), but it using the infrared band. As we only have RGB camera, provides images within the visible spectrum and there are no multispectral camera available, RGB agricultural indices have been used for this analysis to take advantage from the UAV images as follows:

1/ A Visible Atmospherically Resistant Index (VARI) were used as evidence of the agriculture cover intensity (RGB index for leaf coverage) according to Equa. (1) (8):

VARI=min (max (-(GREEN-RED) / (GREEN+RED-BLUE))) ------ (1)

2/ A Triangular Greenness Index (TGI), were used to measure the chlorophyll sensitivity according to Equa. (2) (16):

TGI= (GREEN-(0.39*RED)-(0.61* BLUE))/(normalized to the maximum value of RED, GREEN, and BLUE bands)--------(2)

Fig. 8 provides a comparison of the application of two agricultural indices to a single field within the study area. As is evident from the figure, it is possible to determine the very obvious and overwhelming red color in the VARI index image, which states that the land has no leaf cover. Whereas the red color tinged with yellow in the TGI index image indicates that there is a percentage of chlorophyll, which implies that the field is cultivated, but it is at the beginning of the crop germination. Throw these indices, the farmer or the supervising manager can monitor and track the stages of growth and can detect diseases that have occurred in this field in addition to identifying the parts that need to be irrigated, and therefore all these things will make the farmer control his field, which will increase the rate of production and yield.

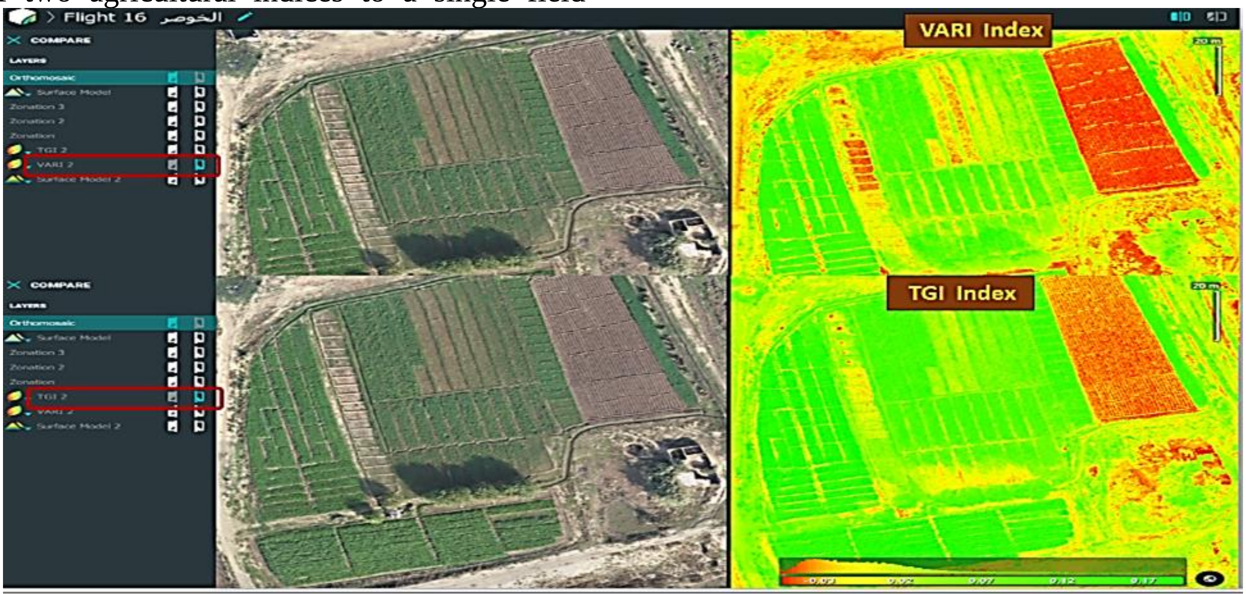

Fig. 8. A comparison between the VARI and TGI agricultural indices used for a certain part

Second: Using classification methods:

The use of supervised and non-supervised classification methods with specific vegetation indices provides efficient results in distinguishing land and agricultural cover (4). Agricultural fields can be classified into several different classes using Pix4Dfields software, where the researcher can select and enter the number of classes he expect and according to the number of agricultural fields that can be deduced from the drone images. Fig. 9 shows the select of seven classes. After the digital processing procedure, the program shows the limits of the proposed classes in different colors. The program also provides us with a number representing the area of each category. In addition, it provides the ability to add the actual real areas of each field to be modified and identified precisely when measured in the field.

2- Agriculture land classification using Band software

In order to ensure and evaluate that the UAV images provide correct vegetation information, other RGB vegetation indices, such as Synthetic NDVI and Visible Difference Vegetation Index, which are not provided by the Pix4Dfields software, were used in detail as follows:

1/ Synthetic NDVI (S-NDVI) is an index that attempts to predict NDVI values using red and green bands only. Therefore It can be applied to images collected from any RGB camera. Like NDVI, its values also range from-1 to + 1, with higher values indicating the presence of more healthy plants. It is also referred to as the Green Red Vegetation Index (GRVI) (10). Equa. (3) demonstrate how to calculate the S-NDVI:

S-NDVI = (G - R) / (G + R) ------------------ (3)

2/ The Visible Difference Vegetation Index (VDVI) can also be calculated using only the visible portion of the electromagnetic spectrum. Several experiments have shown that VDVI is better at extracting vegetation information and predicting NDVI than other RGB-only indices (20). Equa. (4) shows how to compute the VDVI index:

VDVI = ((2*G) - R - B) / ((2 * G) + R + B) -- (4)

The two indices S-NDVI and VDVI have been calculated using BAND software (2). The average reflectivity values were determined for five locations as a check point in the surveyed areas as shown in Fig. 10. The rectangles shown in the figure are only intended to indicate the positions where the average spectral reflectivity intensity of the three colors (R, G, B) has been measured for soil or agricultural plants on which the agricultural field classification depends. These five locations or five fields have been taken as an example of the possibility of classification and considered as the basis for verify the concept of the theory of work, and the idea can be generalized to the whole drone survey area, which contains dozens of small agricultural fields. The five locations included: the first is a high reflective location that is not cultivated area and almost had white points, the second is a ready-to-cultivate area, the third is a medium-growth site, the fourth is newly planted, and the last location represents mature and complete plants. Using the Band software, RGB values are found. Then this software creates a reflection rate based on calibration with the brightest areas chosen as a training area in the scene, which is in here, is location 1.

Fig. 11 confirmed that the first location had a very high reflectivity rate of 99.9 percent, as it was the criterion (reference) on which the system depended, while the second and fourth locations had a low reflectivity, which reflected the soil areas in it. As for the third and fifth location, due to the strong growth of the plants, the reflection rate was the lowest. After providing reflectivity values without the use of Pix4Dfields, the vegetation indices of S-NDVI and VDVI were obtained based on the average reflectivity percentage as shown in Table 1. Fig. 12 below shows the effects of applying the S-NDVI and VDVI equations to calculate the vegetation index for specific regions where the values range from (-1 to +1). The higher and closer the values to (+1), this is evidence of plant safety and vice versa. The first location tends to have the least plant value due to its non-agricultural land, while the third and fifth locations have very high values, indicating that the plant has good growth and health. As for the second and fourth locations, they have less positive values due to the appearance of the soil.

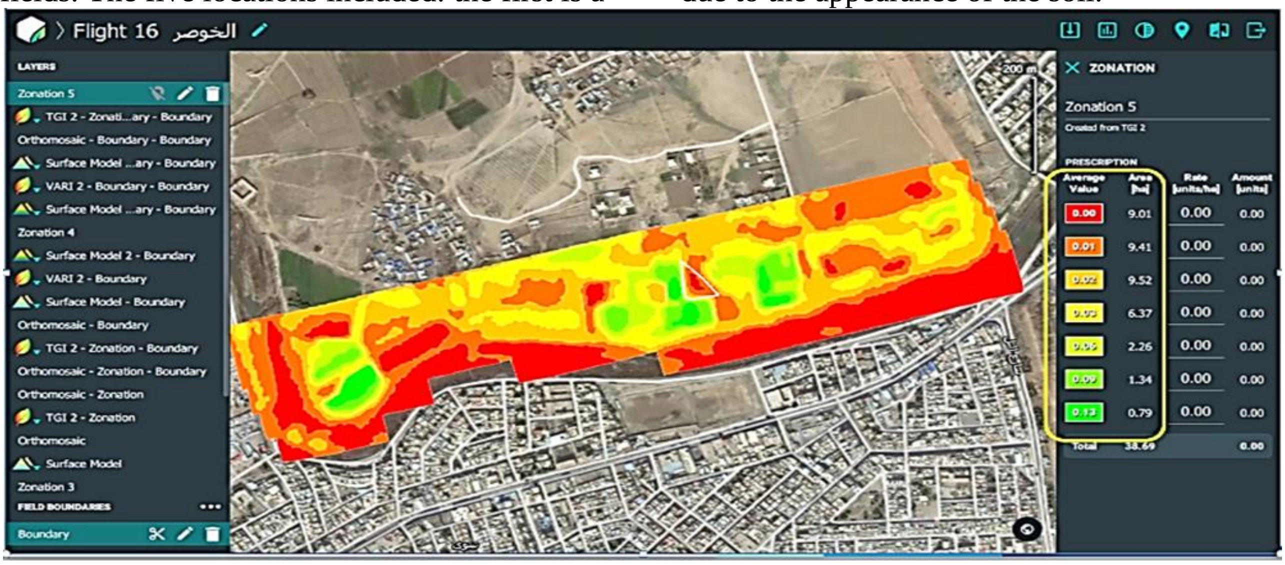

Fig. 9. Semiautomatic classification, 7 different classes of agricultural fields

Fig. 10. Five testing locations in the surveyed areas

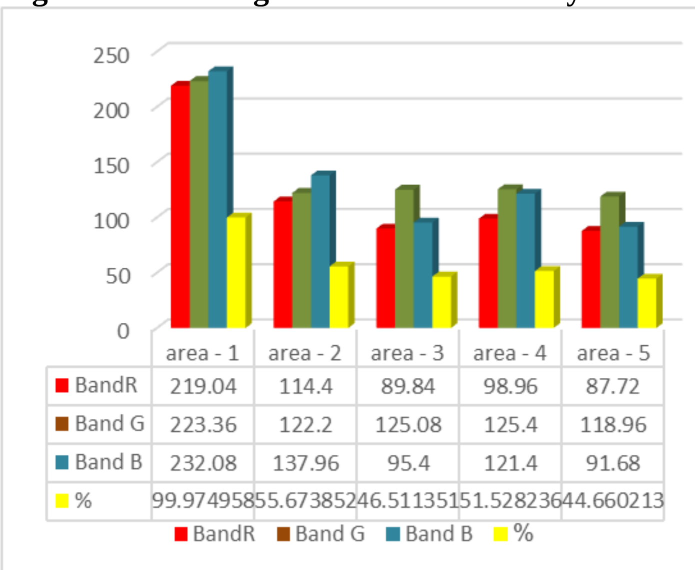

Fig. 11. The reflectivity rate for the five locations

Table 1. The S-NDVI and VDVI indices

	Average of R Band	Average of G Band	Average of B Band	Reflectivity%	S-NDVI	VDVI
Location. 1	219.04	223.36	232.08	99.97496	0.010414	-0.00466
Location. 2	114.4	122.2	137.96	55.67385	0.03274	-0.01624
Location. 3	89.84	125.08	95.4	46.51135	0.163307	0.148727
Location. 4	98.96	125.4	121.4	51.52824	0.11803	0.06593
Location. 5	87.72	118.96	91.68	44.66021	0.150329	0.140169

These results reflect and confirm the validity of the classification of evidence used in the Pix4Dfields software, which in turn shows the high significance and usefulness of using UAV images for agricultural field monitoring, management and development.

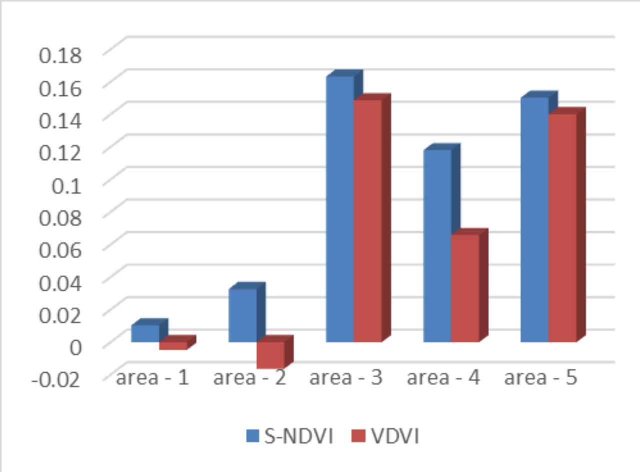

Fig. 12. A chart showing the values of the two indices (S-NDVI) and (VDVI) when applied on the five locations selected.

CONCLUSION

For the first time in the city of Mosul in Iraq, a realistic field experiment was carried out using a UAVs/Drone to classify lands or agricultural areas. Where an area containing multiple fields planted with multiple crops was surveyed. The research showed the ability of such technology and the importance of using it to discriminate between different fields and agricultural crops. Where two types of classification processes were used: RGB agriculture index classification and semi-automatic classification, based upon class selection. Four of the standard agricultural indices that rely on the visible spectrum have been used (VARI, TGI, S-NDVI and VDVI) to categorize different types of agricultural land. The results showed that when using the S-NDVI and VDVI indicators, the values 0.16 and 0.14 appeared respectively in certain areas, which indicates the presence and integrity of vegetation cover, unlike other regions, whose indicators showed 0.010 and -0.004, respectively, which indicate that the plant has a bad condition or its absence at all. The use of agricultural indices helped also to determine the degree of crop growth, whether it is at the level of germination, whole plant or harvested plant, as well as it is possible to determine the health degree of plants, whether they are sick or healthy, and fields that need watering can be identified. As for the non-directed classification, by using the Pix4Dfields software, it can define the areas of the fields, their dimensions and define their boundaries, and thus help determine the amount of production for each field using smart agriculture by UAVs. In addition, as more and more data are available from the various multi-spectral sensors carried on drones, choosing the right indices will remain important. The indicators presented here provide a simple solution to the indicator-based selection process. Therefore, the art of using UAVs' agricultural techniques has proven to be very efficient, and the official's authorities are advised to support farmers to use such techniques.

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