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# Unmanned aerial vehicle (UAV) for precision agriculture

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By Dr. Yafit Cohen



## ABSTRACT

Addressing in-field variability is a major challenge in modern agriculture, as it is considered to be a key component in attempting to enhance the yield/resources-inputs ratio. In general, assimilating Precision Agriculture (PA) principles to address in-field variability

involves four components: (1) data collection, (2) data analysis, (3) development of designated spatial decision support systems (SDSS) or the creation of prescription maps, and (4) based on the products of the three preceding components, variable rate resource application. Currently, data collection technologies and variable rate application (VRA) technologies are the most advanced and are widely used. Unmanned Aerial Systems (UAS) are being promoted as a promising platform for data collection for precision agriculture. This paper discusses their unique characteristics, and compares them with satellite platforms.

## INTRODUCTION

Addressing in-field variability is a major challenge in modern agriculture, as it is considered to be a key component in attempts to enhance the yield/resources-inputs ratio. In general, assimilating Precision Agriculture (PA) principles to address in-field variability involves four components: (1) data collection, mostly by the use of sensing technologies, (2) data analysis, to create in-field variability maps, (3) development of designated spatial decision support systems (SDSS) or the creation of prescription maps, and (4) variable rate resource application based on the products of the three preceding components. Currently, data collection technologies and variable rate application (VRA) technologies are the most advanced and are widely used (Zhang and Kovacs, 2012). Operational success of VRA requires accurate maps of crop growth, crop nutrient deficiencies, weeds, insect infestations, and other crop and soil conditions. Valuable data/maps are agricultural-task dependent, as different map qualities are required for different



tasks. Other than data analysis, there are various factors that affect the value of the data to the farmer, including time resolution, spatial resolution, and specificity. Specificity relates to the question: do the data contain specific attributes related to specific deficiencies, such as of nitrogen and water, or specific attributes related to the presence of specific weeds, pests, or diseases?

## SATELLITE AND UAV PLATFORMS

Satellite images collected during the growing season have been used over the last 30 years to monitor crop growth, crop stress, and to predict crop yield. Israeli farmers use satellite images mainly to explore the variability in their fields and orchards, to locate anomalies, and to direct field monitoring. The use of manned airborne platforms is limited in Israel as in other countries by high operational complexity, costs, and lengthy delivery of products. Unmanned Aerial Systems (UAS), are being promoted as an alternative platform for data collection. The ultra-high spatial resolution (centimeters), relatively low operational costs, and the near real-time image acquisition attracts numerous companies and farmers to consider these platforms ideal tools for mapping and monitoring in PA. Most UAVs to that end are equipped with very small cameras providing images in the visible range. The availability of UAVs equipped with small multi-spectral (MS) cameras in the visible and near infrared range (VIS-NIR) is rapidly increasing. Significant attention has been paid to the collection, calibration, geo-registration and mosaicking of data collected from small UAVs. In a way, because of their ultra-high spatial resolution and

their near real-time production, the UAV images bring the field to the farmer and may be used as a tool to simulate a field survey. Farmers have realized these advantages and either buy their own system and acquire images whenever they need, or order imaging campaigns from a commercial company. Over the last 3 years, Israeli companies have advised local farmers as well as farmers around the world with field imaging services employing UAVs. An example of a UAV image above a vineyard is presented in Figure 1. Both canopy width (density) variability and soil variability are well evident in the image. There are rows or parts of rows with very narrow canopy, as in the northern part of the vineyard, indicating a kind of stress. Patches of lighter soil are evident along the vineyard, apparently as a result of surface water runoff and erosion. The high resolution of the UAV image enables a good separation



Figure 1. A UAV image above a grapevine showing variability in both crop and soil. The image is a combination of 3 bands: Near-infrared, red and green. The imaging campaign was ordered by the Carmel Winery (Zikhron Ya'aqov, Israel; <http://www.carmelwines.co.il/en/>) and conducted by Agricam (<http://www.agricam-ag.com/>).

of the narrow-canopy rows from the soil. When transformed to Normalized Difference Vegetation Index (NDVI) units (Figure 2), the variability in crop density is more prominent and reveals the existence of weeds in-between vineyard rows. Comparison between the UAV and free-of charge Sentinel2 satellite images (10m spatial resolution; Figure 2), both converted to NDVI, reveals remarkable differences.

It should be emphasized, though, that the remarkable differences between the two images is derived from the narrow-row shape of the vineyard and the coarse resolution of the Sentinel2 images. Milder differences might occur between the UAV image and the 2-10m-spatial-resolution-satellite image with field crops or even with table grapes at full crop cover. An example can be seen at: <http://agridrone.co/evidence-satellite-ndvi/>.

As mentioned above, satellite images in the VIS-NIR range are usu-

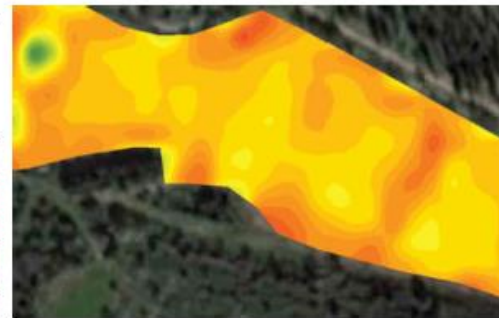
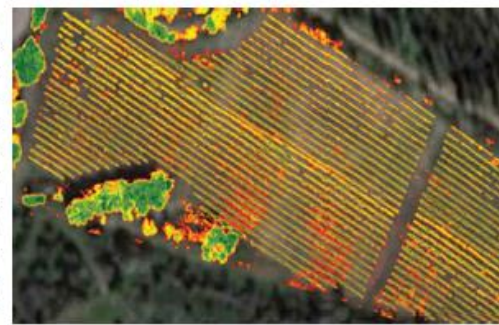


Figure 2. NDVI map of the vineyard derived from a UAV multispectral image (above) and from a Sentinel2 multispectral image (below), both showing variability in crop density. Green: high crop density, Yellow: medium crop density and Red: low crop density.

Both NDVI maps were produced by Agricam Ltd. for Carmel Winery.

ally used for general in-field variability mapping for rational field monitoring, to detect problems and as an aid for VR application. Also, most of the UAV images for agricultural purposes provide merely a general picture of crop and soil variability. Yet, having spatial resolution of centimeters and even of millimeters, the UAV images potentially can provide data with high specificity for some agricultural tasks. For example, weed species and their accurate locations can be detected in UAV images by the unaided eye. Also, with an expert eye, damage resulting from water deficiencies or specific insects or diseases can be detected and diagnosed. Much effort is invested at present to develop algorithms that can interpret UAV images into semantically meaningful information and translate them into specific prescription maps for various agricultural tasks. Research and development teams in academia





→ and private industry have indicated that there is much potential in machine-learning techniques to develop reliable algorithms (e.g. Hung et al., 2014). For that to succeed, enriched databases of images linked with on-the-ground data need to be generated.

#### UAV AND PRECISION AGRICULTURE AT THE A.R.O.

On-going research at the Institute of Agricultural Engineering of the A.R.O. is focusing on enhancing the ability to map water-status variability in crop fields by aerial thermal imaging for irrigation management (Cohen et al. 2016). Manned aerial platforms have been used for the thermal imaging trials. During the spring of 2016, a trial was performed to conduct thermal imaging by UAV using our thermal imaging system, one that weighs little

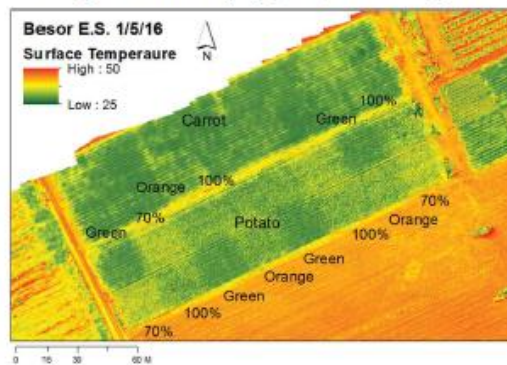


Figure 3. A UAV thermal mosaic of an experimental potato plot at the Besor Experiment Station, under various irrigation treatments. The image was acquired by Aeromap, Ltd. (<http://www.aeromap1.com/>). A similar thermal imaging campaign was conducted by P.A.M., Ltd. (<http://pam-can.com/>)



Figure 3. A UAV in the visible range of an experimental potato plot at the Besor Experiment Station, under different irrigation treatments. The image was acquired by P.A.M., Ltd. (<http://pam-can.com/>)

more than 1.5 kg. Our thermal imaging is composed of a 700g SC655 thermal camera (FLIR® Systems, Inc.), a controller, and a power supply unit. The camera has an accuracy of  $\pm 2^{\circ}$  Celsius, as is required for accurate estimation of crop water status. Figure 3 presents a thermal mosaic of experimental sub-plots of potato under different irrigation treatments with four replicates. The thermal mosaic had high temperature and geographic accuracies. Irrigation treatments were 100% and 70% of commercial amounts and 2 irrigation treatments that had 70% of commercial amounts at the beginning of the season and then, when water stress was detected by thermal images, irrigation was modified to 110% (orange) and 100% (green) of commercial amounts. The mild differences between irrigation treatments were well depicted by the UAV thermal-mosaic. For comparison, in a regular image acquired by a UAV, much fewer differences were observed (Figure 4).

It is important to mention that the imaging trial, covering 8 hectares, lasted 1-2 hours and included 3 sets of 20-minute flights, with power-supply batteries switched between flights. This experience emphasizes the limitations of the UAV-imaging capabilities. Thermal imaging services by UAVs are suggested to farmers by commercial companies. Yet, most of the available thermal cameras designated for UAVs do not have the adequate resolution needed for irrigation decision making.

There are various kinds of UAVs. They can be distinguished by their size, their payload size, the range they can travel and their endurance time in the air (see for example: <https://www.e-education.psu.edu/geog892/node/5>). Most UAVs that are used for imaging of agricultural fields are small, have a relatively light payload (up to 1 kg) and a short endurance time (up to 1 hour). On one hand, this is why most of the UAV-imaging services suggested to farmers concentrate on images in the visible range. On the other hand, this limitation inspired the development of small cameras in the near-infrared and the far-infrared (thermal) ranges that would fit small and inexpensive UAVs. In some cases, the physical size of the cameras compromises their performance and caution should be taken when using them. Recently, the A.R.O. purchased "Sniper", an unmanned helicopter with a fuel engine that can carry up to 2.5 kg and with 1.5 hours flight time (<http://www.alphaunmannedsystems.com/>). This system will be used to enhance our capabilities in various research areas, including precision agriculture and phenotyping. □

#### ACKNOWLEDGMENT

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#### FURTHER READING

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Yafit Cohen is a senior research scientist at the Institute of Agricultural Engineering of the A.R.O. She possesses a B.A. and Ph.D. in geography from Bar-Ilan University, with specialization in Geographical Information Systems and Remote Sensing. She served as a post-doctoral fellow at the Technion, Haifa, Israel during 2002 and specialized in remote sensing for land-use recognition and mapping. Since 2003, she is a research scientist at the Institute of Agricultural Engineering of the A.R.O. She is also an adjunct faculty member at the Faculty of Agriculture, Hebrew University of Jerusalem, Rehovot, Israel, where she teaches Geographic Information System (GIS). Her main scientific interests are remote-sensing for precision-agriculture practices, especially for irrigation and fertilization; and spatio-temporal analysis of insect distribution in agricultural environments, such as the medfly and the red-palm-weevil.

Over the past 15 years, she has served as a member of a number of scientific committees, has served as a guest editor of a special issue of the journal *Biosystems Engineering*, and serves today as a member of the editorial board of the journal *Remote Sensing*. Expertise: Precision agriculture, thermal and hyper-spectral imaging, GIS, spatial decision support systems for integrated pest management, automatic monitoring of insects.