Science Societies

Drones for fruit producers

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Photo courtesy of Adobe Stock/Budimir Jevtic.

Fruit orchards require site-specific or even individual-tree-specific management throughout the growing season. Remote sensing via drones, or unmanned aerial vehicles (UAVs), is becoming more common among growers and is useful for real-time crop monitoring, weed detection, tree classification, water stress assessment, disease detection, yield and fruit quality estimation, and various pest and nutrient management strategies.

Vegetation reflects certain types of light depending on its nutritional and health status. Drones, or unmanned aerial vehicles (UAVs), equipped with precision sensors and cameras can detect even slightest differences in the amount of reflectance for light of various wavelengths. For example, multispectral sensors detect reflectance for up to five discrete spectral bands of light (red, near-infrared, red edge, green, and blue). The ability to detect the different types of light reflected by crops allows farmers to identify specific nutrient deficiencies and even detect diseases before they become severe enough to be visible to the naked eye. Human eyes are sensitive only to wavelengths between 400 and 700 nm, known as the visible light spectrum. Thus, humans can recognize a variety of colors from violet to red. Wavelengths, however, can be shorter (ultraviolet) and longer (infrared) than those our eyes can perceive. Even though these types of light are invisible to the naked eye, these wavebands can often be indicative of certain plant characteristics. For example, photosynthetically active vegetation absorbs most of the red light to which it's exposed to while reflecting most

of the near-infrared light. On the other hand, dead or stressed vegetation reflects more red light and less near-infrared light.



Recently, UAVs have been used to implement variable-rate application tasks such as selective ultra-low-volume chemical applications although compared with capturing remote-sensing information, applications with UAVs are still technologically challenging. Photo courtesy of Pixabay/viya0414c.

In addition, drones equipped with precision global positioning systems (GPS) and thermal cameras have proven useful for phenotyping (assessment of expressed traits driven by genetic makeup and the environment), crop health mapping, heat and water stress analysis, leak scouting, and input (fertilizer, irrigation, and pesticide) management. Data gathered by drones can be downloaded and analyzed by various software programs designed to help farmers make informed decisions about their crops. Fruit orchards require site-specific or even individual-tree-specific management throughout the growing season (Zhang et al., **2021**). Remote sensing is becoming more common among growers and is useful for real-time crop monitoring, weed detection, tree classification, water stress assessment, disease detection, yield and fruit quality estimation, and various pest and nutrient management strategies.

UAV Advantages in Fruit Production

The UAVs provide the following advantages over the traditional nursery/orchard scouting:

- Rapid data collection with high quality, range, and resolution, depending on specific need

- Capability to create and combine 3D canopy height and orthophoto information (allows for distortion-free measurements)
- Capability to capture multi-angular data (enables better discrimination between vegetation types)
- Capacity to operate multiple sensors at the same time (opportunity for capturing a wide range of data with a single flight)

Use of UAVs in Orchards

Examples of UAVs used by orchard managers include:

Pollination

Pollination ensures a bountiful fruit harvest. Some growers are using drones to pollinate almond, cherry, and apple orchards. Ground can be covered much faster with UAVs, pollinating in just one hour what it might take bees two weeks to accomplish. The UAV-assisted pollination may become very useful for orchards due to continuous decline of the bee population in the past decades. Utilizing UAVs is one way to provide a long-term solution to fewer bees, coupled with the short pollination window in the spring by ensuring rapid and thorough pollination of orchards. The UAVs are especially helpful during the cold spring spells during which the bees are not active. Depending on environmental conditions, which affect the effectiveness of bees, the UAV-aided pollination has been shown to improve the pollination set by 25 to 60% in cherries and almonds and to increase fruit set in cherries, apples, and almonds by 40, 53, and 94%, respectively (Herrick, **2018**).

Fertilization

Fertilization is essential for optimizing yields. Before fertilizers are applied, a UAV can be flown to collect crop reflectance data, processed as vegetative indices such as the

normalized difference vegetation index (NDVI). The NDVI is indicative of the crop nutrient status and is widely utilized to prescribe fertilizer application based on the crop nutrient requirements. Rather than applying fertilizer as an average of the field, variable-rate application of fertilizer can be done where nutrients are applied according to the plant needs and taking spatial variability into consideration. This helps to reduce the fertilizer cost, especially at times of skyrocketing prices. An increasing number of growers are utilizing UAVs to map their fields and orchards and for crop monitoring (Holsten, **2019**).

Irrigation

Agricultural crop production greatly depends on water availability. The soil moisture status and its fluctuations during the season can significantly affect the tree growth and is dictating the need for irrigation. With their ability for thermal imagery, UAVs could be efficiently utilized in estimating soil moisture in various parts of the orchard and pinpointing areas with lower and higher water stress. The crop water stress index (CWSI) derived from the UAV data is a useful indicator of water status for irrigation management in orchards. Optimizing irrigation applications in space and time can result in substantial water savings. Variable-rate irrigation with UAVs has been successful in orchards, resulting in water use reductions without impairing fruit yield, and improving fruit quality. The UAVs can be also utilized to monitor irrigation efficiency and survey the irrigation lines. The UAVs with thermal sensors can be used to seek out water leaks. Detection and prevention of water loss due to water pooling and/or leaking during irrigation events greatly improves water use efficiency. For larger farms, UAVs can be used to schedule irrigation and keep track of what parts of the orchard are being watered at any time, enabling growers to use water resources more effectively (DSLRpros, **2022**).

Disease Control



The world's population is expected to increase 40% by 2050, requiring a doubling of fruit and other agricultural production to keep up with the continuously increasing demand. At the same time, however, the already decreasing number of field workers is expected to decrease to half of today's level. Photo courtesy of Adobe Stock/industrieblick.

Apple scab is a fungal infection causes dark scabby lesions on the apple leaves and skin. Although it doesn't make the apples taste bad, it makes them difficult to market. Identifying scab early can help orchard managers to minimize the disease spread to nearby trees and apply fungicides to prevent a widespread outbreak. When UAVs are outfitted with an infrared camera, they can be used for precision detection of differences in colors and temperatures to locate apple scab disease. Predictive models can be used to determine the best time to spray fungicides to minimize damage (Rohr, 2013). Recently, UAVs have been used to implement variable-rate application tasks such as selective ultra-low-volume chemical applications although compared with capturing remote-sensing information, applications with UAVs are still technologically challenging.

Yield Prediction

Precision agriculture enables producers to use mid-season information to determine status of the crop for precise management. In the fruit industry, drones are being used to predict yield. An accurate assessment of the blossom and estimation of the harvest allows growers to be more productive, environmentally friendly, and sustainable. Accurate yield forecasting can be very beneficial to growers in terms of planning labor,

logistics, storage, marketing, and distribution to ensure that there is sufficient supply for the consumers. The current manual-sampling-based yield estimation is time consuming, labor intensive, and inaccurate. Cameras mounted to UAVs have an ability to distinguish between ripe fruit and the leafy tree canopy; and the UAV-derived imagery can also be utilized to accurately estimate the number of harvestable fruits per tree (University of Cambridge, **2019**).

Harvesting

The world's population is expected to increase 40% by 2050, requiring a doubling of fruit and other agricultural production to keep up with the continuously increasing demand. At the same time, however, the already decreasing number of field workers is expected to decrease to half of today's level. The travel restrictions imposed on the migrant workers due to COVID-19 is a major concern. The solution to orchard managers facing the labor shortage and associated high labor costs are UAV-based platforms such as flying autonomous robots (FAR). Typically, the maturity of fruit is determined by scouting and visual examination. The system uses AI perception algorithms to detect the trees and vision algorithms to locate the fruit within the tree canopy and classify the fruit size and maturity. After selecting the ripe fruit, the UAV works out the most efficient way to approach the fruit while remaining stable as its picking arms grasps the fruit (Crumley, **2022**).

UAV Limitations in Fruit Production

Limitations to use of UAVs and adoption among fruit producers:

- High costs to acquire a drone and/or to hire a UAV operating company. This technology is still difficult for producers to adopt because of the cost involved, especially for larger acreage orchards.

- Lack of technical knowledge to operate UAVs and to collect, process, and analyze the high volumes of data obtained from a drone. A working partnership with a specialized technician is imperative to make meaningful decisions based on the collected data.

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