Unmanned Aerial Vehicle Remote sensing: Application in Precision Agriculture

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Introduction

Precision Agriculture (PA) could be described as site specific crop management practices at precise location, at the exact rate and at exact time to improve efficiency of agricultural inputs for increased and sustained crop productions. The efficient development of local and site-specific practices profoundly depend on the use of remote sensing technology for gathering and processing spatial data from sensors mounted in satellite or aerial platforms. This technology has been widely applied in agricultural studies including crop conditions (Houborg *et al.*, 2009), soil properties (Lo´pez-Granados *et al.*, 2005), water content (Meron *et al.*, 2010) and weed distribution (de Castro *et al.*, 2012), among others. Satellites and aircraft platforms are conventionally used to acquire local to global remote sensing data with limited applicability in precision agriculture due to inadequate spatial and temporal resolutions and strong interference of weather conditions (Herwitz *et al.*, 2004).

Unmanned Aerial Vehicle (UAV)

Unmanned Aerial Vehicle is basically one of the Remote Sensing Platforms are evolving as an important, reasonable, component of precision farming and crop development. It allows observer and/or sensor to be above the target/phenomena of interest. UAV is an autonomous aerial vehicle which is piloted remotely and uses aerodynamic forces for lifting and can carry various types of payloads.

It is important to point out that there is slight difference between drone and UAV. Drone stands for Dynamic Remotely Operated Navigation Equipment which has zero intelligence. No communication during fly and the results such as photographs or images are typically not obtained until it is returned to the base. On the other hand, UAV have some ability of performing 'automatic intelligence' in the form of communication capacity with its controller and to return payload data like images of different spectral resolutions, together with its different state of information (Austin, 2010). There are several advantages of UAV over satellite as shown in the following table.

Satellites	UAVs
Low spatial resolution of image & High Cost	Reduced altitude of their flight, High spatial Resolution & Low cost
Predefined orbit and time bound	Fill the data gap between satellites and ground surveying
High cost of operation	Low-cost operation, Can fly in riskier and more treacherous areas
Sensor is fixed i.e. unchangeable	Sensor can be changed

Source: http://www.unep.org

Components of UAV system

- Ground control station
- Inertial measurement unit (IMU)/Flight controllers / GPS integration
- Multirotor (eg. Quad roter) revolving blades
- Battery storage
- Gimbals for sensor payload mounts

Applications of UAV in Agriculture

UAV can disclose patterns that render everything from variation in soil, differences in stressed and healthy crop plants to pest and fungal invasions. It can be used to accurately trace irrigation systems to find leaks and assess efficiency; parts of broken equipment in fields can be delivered. Crop survey can be conducted to create a time-series animated imageries for better management of crops. Broadly they can be used for assessment of crop phenotype, height, density, and yield and for detection of weed, crop disease, nutrient deficiencies, double planting, and soil erosion. UAV remote sensing can also be used for application of chemicals, crop insurance estimation, and Inventory management.

Crop phenotypic assessment: Small UAVs with appropriate sensors have several benefits in terms of better field access, high spatial resolution data, rapid and simultaneous data acquisition when required, self-automated fly for better crop growth monitoring in a given growing season and low operational costs (Hunt *et al.*, 2008; Nebiker *et al.*, 2008; Araus and Cairns, 2014). UAV delivers higher operational flexibility and easy access to the field plots in difficult areas (e.g. hilly and mountainous) which is challenging and can be time consuming.

Aerial multispectral images were acquired at maximum growth vigor (early mid-pod set) and modified green normalized difference vegetation index (GNDVI, green as visible band) were computed and correlated with yield (plot-to-plot comparison) with correlation coefficient of 0.79 ($p = 0.01$)(Sankaran *et al.* 2015).

Crop Yield Monitoring: A rapid yield estimation method for characterization of crop phenotype can be developed using evolving UAV technology through periodic high resolution spectral imaging as required during the growing season. UAV-based multispectral imaging could not only be capable of estimating yield potential for breeding studies but potentially can be used by growers for predicting yield and thus, market value of their crop. Breeding study of winter wheat in WSU has successfully correlated the GNDVI image estimates of winter wheat to actual plot yield, with correlation coefficient of 0.60–0.71(Khot *et al.*, 2014) using the periodic multispectral aerial images.

Plant growth parameters: Various plant growth parameters like emergence (Sankaran et al., 2014), vigor and leaf area index (Hunt et al., 2010), and biomass can be estimated and evaluated through UAV-based sensing. GNDVI estimates computed from UAV-based multispectral images were correlated with leaf area index (LAI) of winter wheat having variable nitrogen application treatments (Hunt et al., 2008, 2010) and showed R2 of 0.85 ($p<0.001$). A study by Sankaran et al. (2014) used aerial multispectral images of field plots and estimated GNDVI to correlate with ground-truth emergence of winter wheat and a good correlation R2 of 0.86 ($p<0.0001$) was obtained. The technique was valuable to classify winter wheat varieties that showed good emergence after planting combined with good winter hardiness, which are important traits in the U.S. Pacific Northwest wheat production regions.

Other applications: UAV sensing technology can practically be useful for variety of other applications such as weed assessment in the field, soil erosion, double planting, nitrogen assessment, and crop density assessment. Applicability of this technology for evaluating various plant traits is summarized in Table 1(Sankaran et al. 2015). Moreover, evaluation using aerial imaging can also be possible for soil compaction, salinity, deficiencies or toxicities of soil minerals, herbicide tolerance or injury, and damage from disease or insect pest.

Table 1: Summary of UAV-sensing based plant traits estimation in prior studies

Phenotypic trait	Standard method	UAV-based sensing method
Plant height	Measuring scale	LIDAR system. Technology is in developmental scale, although UAV-based systems are available. Important to know the elevation of the terrain. 3D construction could be another possibility.
Plant biomass Plant emergence	Visual rating; destructive sampling; Plant count	Visible-near infrared imaging to measure canopy coverage.
Plant senescence	Visual rating	Visible to near-infrared imaging to measure plant greenness.
Plant flowering	Visual observation	Visible imaging to estimate number of flowers.
Water stress; stomatal conductance; Heat stress, salinity stress	Visual rating, soil moisture measurements, porometer	Visible, near and thermal infrared imaging to measure canopy temperature and water absorption bands. Plant growth can also be related to abiotic stress.
Nutrition	Foliar and/or petiole nutrient analyses	Visible-near infrared imaging to estimate leaf nitrogen, and potentially other nutrients.
Leaf area index	Destructive sampling, plant canopy analyzer	Visible-near infrared imaging to estimate plant biomass and coverage. May get saturated with LAI.
Disease susceptibility	Visual disease rating	Visible-near infrared imaging for assessing plant health/damage. Similar techniques can be applicable for toxicity studies.

[a] Non-UAV studies. The techniques can be integrated with low-altitude UAV-based sensing.

Challenges in using UAV in agriculture

There are two vital factors for fruitful application of UAV remote sensing technologies in farmer's field. The first factor is the UAV characteristics (stability, safety, control, reliability, positioning, autonomy, sensor mount, and controller) and the second significant factor is the sensor characteristics (spatial and spectral resolution, weight, calibration, and field of view). In addition the operation of UAV is restricted by size or weight of the sensor payload, its altitude and flight time (Ma *et al.*, 2013; Deery *et al.*, 2014). Though, these aspects are rapidly improving.

Constraints with UAV

- UAV require more flights to cover large areas due to their reduced flight time. For example, a single flight covering approximately 2 ha can yield around 150–200 images.
- UAV imagery is frequently taken in a random manner with overlaps and cross-over points.
- Images collected from UAV often have large rotational and angular variations.

Conclusion

Over the past decade there have been an increasing number of examples of UAV application in environmental monitoring and Precision Agriculture (PA). Still, it has got important limitations related to involvement of high initial costs, platform reliability, sensor characteristics, availability of standardized methodology for processing of huge volumes of UAV imageries and strict aviation regulations. However, from precision agriculture and environmental monitoring point of view, UAV remote sensing will be highly helpful and appreciable with the progress of UAV technology with new sensor designs, lower costs, improved techniques of image processing and a larger number of experimental studies. Furthermore, research scientists could be more involved with the farming sector through a better implementation of UAV in PA if the relaxation of regulations in UAV aviation may happen in near future.

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