

An Introduction to Small Unmanned Aircraft Systems (sUAS)

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Introduction

Small unmanned aircraft systems (sUASs), have become increasingly popular in agricultural and environmental monitoring and management. Commonly referred to as drones, these craft are used to help monitor plant health, collect valuable farm asset information, assess crop damage, identify weak production areas in fields, and scout irrigation issues. Information collected in drone images has proven useful in both farm management and precision agriculture applications by providing a fast, easily accessible, and relatively affordable system for decision-making.

This change in input information systems has been aided by increasingly advanced sensors and broader applications. Drones are helping to remove the guesswork in modern farming and allows growers to maximize both yields and efficiency. This farm management approach is based on observing, measuring, and then ground truthing before taking action based on (near) real-time crop and livestock data. Many companies suggest that these systems are successful in creating a positive return on investment. The purpose of this fact sheet is to explain the types of sUASs, how they work, and the information they provide.

Terms to recognize:

UAS: unmanned aircraft system

FAA: Federal Aviation Administration

VLOS: visual line of sight

NIR: near infrared

NDVI: normalized difference vegetation index

Remote Sensing: the science of obtaining information about objects/ areas from a distance

Choosing a Drone

When determining what type of drone to purchase, it is important to ask several questions including: what information needs to be collected from the drone, how much area needs to be covered, operator's skill level, as well as cost. There are several types of drones available commercially, each with advantages and disadvantages, depending on one's needs.

A Division of Agriculture fact sheet can familiarize users with the many features to consider when purchasing a drone <https://www.uaex.edu/publications/pdf/FSA-6151.pdf>.

Potential on-farm applications

Drones have proven to be a vital asset for farm management and growers' bottom dollar. The list of applications is continuing to grow. The information being collected from drones is being used most commonly to aid in:

- Crop monitoring
- Soil assessment
- Plant Emergence and Population

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Types of Drones

Fixed wing drones:

Benefits:

- long range flight capacity and time
- great for covering a lot of area
- good performance in varying weather conditions

Disadvantages:

- can be challenging to keep in line of sight (FAA regulation)
- affected by weather conditions, especially strong wind



Fixed wing drone. Source: <https://delair.aero/press/delair-unveils-ux11-ag-new-uav-optimized-for-large-scale-surveying-in-agriculture-forestry/>

Multirotor drones:

Benefits:

- easy launch and recovery
- great for close-in scouting or other detailed survey tasks
- fast set up and disassembly
- stationary image collection



Multirotor Drone. Source: www.sentera.com

Disadvantages:

- short battery life, so shorter flights
- may not handle unfavorable weather conditions well

Hybrid or Combination drones:

Benefits:

- easy launch and recovery
- fixed wing hybrids offer long endurance flight time

Disadvantages:

- complex operation
- limited commercial options available

FAA Regulations

All drones must be registered with the Federal Aviation Administration (FAA). Part 107 governs all rules and regulations associated with drones weighing up to 55 lbs. Approved flight operations related to agriculture include:

- Research and development
- Educational/academic use
- Crop monitoring/inspection
- Aerial photography
- Wildlife nesting area evaluations

Additional regulations in part 137 are required in order to deliver inputs, such as applying pesticides or spreading nutrients with drones. The FAA website has a complete list of rules, regulations, and applications https://www.faa.gov/uas/getting_started/.

Licensing

Pilots using their drones for commercial use (Any kind of paid reimbursement or for non-recreational use off their own property) are required to have an Unmanned Aircraft Systems (UAS) part 107 license.

A drone pilot does not necessarily have to be the person flying the drone, but they should observe all flight operations. This is called Pilot in Command (PIC).

For more information on licensing, please check out this UAEX factsheet: <https://www.uaex.edu/publications/pdf/FSA-6150.pdf>.

How do sUAS work?

Energy from the sun bombards the earth's surface as a spectrum of electromagnetic radiation (Figure A) that is either absorbed or reflected. Drones carry sensors that collect the reflected and/or emitted energy

from the crop below. Most agriculture sensors utilize only a small region of the electromagnetic spectrum primarily within and bordering the spectrum's visible portion. The visible region of the spectrum is from about 400nm to about 700nm wavelengths. The green color associated with plant vigor has a wavelength that is near 500nm. Sensors are also able to use wavelengths outside of the visible region to help analyze field characteristics.

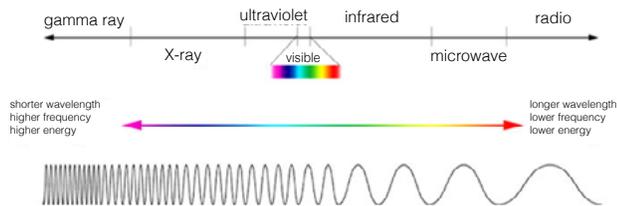


Figure A. Electromagnetic Spectrum. Source: NASA, www.nasa.gov

What can we learn from colors in an image?

Red Green Blue (RGB), or standard color imagery, is most closely related to what the human eye can see. RGB has limitations when compared to its counterparts in remote sensing. RGB imagery requires that crops be significantly stressed to see visual differences in an image. Near Infrared Imagery (NIR) utilizes wavelengths outside of the visible spectrum (approximately 720nm). Research has shown that NIR images are much more effective in showing crop performance, weed detection, and defining management zones compared to standard RGB imagery alone.

Plants capture visible light in order to drive photosynthesis. NIR energy does not carry enough energy to drive photosynthesis, but it does carry a lot of heat. Over time, plants have evolved to reflect NIR light. This reflection mechanism breaks down as the leaf dies or undergoes stress.

False color images in agriculture use NIR, red, and green wavelengths in an image rather than the typical RGB visible to humans. Doing so provides a simple and potentially useful image for crop assessment and diagnostics for further inquiry.

Common Sensors

Sensors in most affordable use-cases for agriculture are passive, which means they are effectively an advanced camera. A typical camera creates an image with RGB wavelengths from the electromagnetic spectrum. While we don't see near-infrared, ultra-blue, or thermal infrared light, sensors can capture this information in image pixels in addition to RGB light. The data can then be used to analyze different aspects of the landscape through spectral indices. Spectral indices are created by differences between the reflectance

values of various wavelengths to assess vegetation.

A normalized difference vegetation index (NDVI) is a common agriculture index that leverages a crop's red and NIR reflectance values. Figure B is an example of an NDVI image of a rice field. The NDVI provides values between -1 and +1. A strong NDVI signal means a high density of plants or leaf greenness whereas weak NDVI indicates potential problem areas in the field.

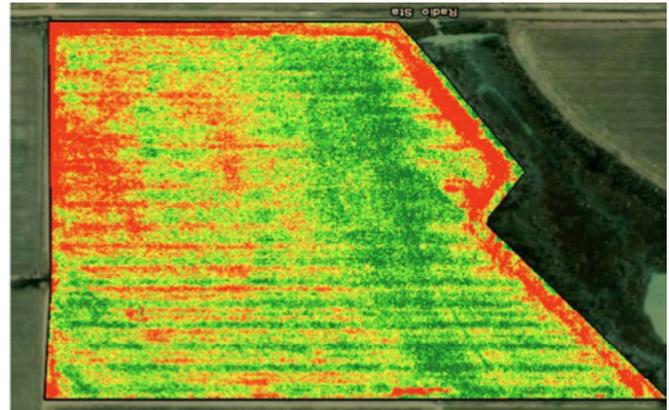


Figure B. NDVI Image of a Corn Field. Source: Nutrien Ag Solutions <https://www.nutrienagsolutions.com/>

Other remote sensors that have uses in agriculture include Visual Atmospheric Resistance Index (VARI) which accounts for the presence of blue light in the atmosphere to increase accuracy of measurements and Soil-Adjusted Vegetation Index (SAVI) is used to minimize soil brightness to further emphasize data from vegetation. Additionally, Green Difference Vegetation Index (GDVI) can be used which helps account for the variation of chlorophyll content in plants.

These examples illustrate sensors that passively collect energy originating from sunlight that has reflected from crops. Aside from vegetation, sensors have uses in irrigation. A popular measurement utilized is Normalized Difference Water Index (NDWI), which falls within the visible to infrared wavelength range. Figure C shows the percent reflectance associated with each wavelength in the electromagnetic-

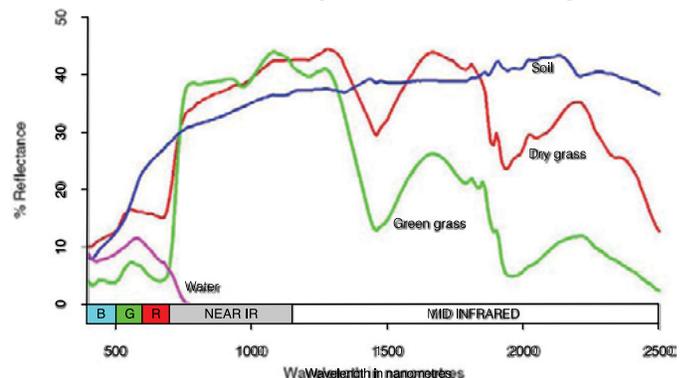


Figure C. Spectral Reflectance by Wavelength. Source: Biomass and the Remote Sensing of Biomass <https://www.intechopen.com/books/biomass-and-remote-sensing-of-biomass/introduction-to-remote-sensing-of-biomass>

ic spectrum for different objects in the environment. This provides the foundation for using drones with image sensors to assist with agricultural management.

Challenges facing vegetation indices

A hurdle facing producers is increasing unpredictability with weather and other environmental factors. This directly impacts the ability to take measurements throughout the growing season as these aforementioned factors impair a plant's reflectance properties. NDVI and other discussed indices are of great value in these instances as they provide deeper insight for producers to help manage risks and identify problem areas earlier in the season. Additionally, seasonal imaging comparisons of vegetation indices create challenges for growers because image quality must be normalized and locations of image pixels must be validated for accuracy.

Conclusion

Drones have continually proved their effectiveness and importance in the agriculture industry. Every year, more growers and companies alike are adopting these technologies to aid in their management and recommendations. Different systems have been developed to suit various purposes and have proved to have many applications in production agriculture. Sensors utilizing a variety of ranges within the electromagnetic spectrum have been developed, most commonly in

agriculture are sensors capable of collecting data to calculate an NDVI for plant health evaluation due to their cost effectiveness. Price ranges for systems vary as they are constantly evolving to become more user friendly while offering more data capabilities.

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