Selecting Small UAS Equipment for Agricultural Applications

Types of Small Unmanned Aerial Vehicles (UAV)

Multi-Rotor

Multi-Rotor is any aircraft with more than two rotors. Unlike helicopters multi-rotors use a fixed-pitch blade instead of variable pitch. Advantage to have a multi-rotor is more stability and power. Multi Rotors are typically easier to fly and have a lower risk of crashing. Another benefit of multi-rotors is, it does not require assistance for taking off or landing because of their design.

Figure 1 Multi-rotor

Examples of Multi-Rotors UAVs

DJI Phantom UAVs are low priced quad copters. They are relatively easy to assemble and operate. Phantoms come with a RBG sensors, but can be upgraded to multi-spectral sensors cable of providing vegetative indexes, such as the normalized difference vegetative index (NDVI). Phantom UAVs have flights of times of approximately 25 minutes, and can provide images of 15-20 acres per flight. The lowest priced price for Phantom is $500 and can be up to $1400.

The DJI Mavic Pro is a compact foldable Quadcopter with advanced features starting at $999. This multi-rotor UAS includes four vision sensors that prevent it from flying into other objects. The Mavic can be controlled up to four miles away. I comes with a four-band sensor so images can be used to create vegetative indexes.

Figure 3 DJI MAvic

Matrice Series currently has two different options the Matrice 100 and Matrice 600. The Matrice 100 with its dual battery compartments gives up to 35min of flight time and Matrice 600 gives 25min to 40min depending on the payload. Both Matrice series can have almost any type of camera; thermal, multispectral, lidar, and hyperspectral. DJI partnered with Precision Hawk to create the smarter farming package which includes Matrice 100 or Matrice 600, one-year subscription to DataMapper(includes 2D and 3D map processing), one RBG sensor, one Multispectral sensor, and extra batteries depending on model selected. The price for the smarter farming package $8,300.

Figure 2 DJI Matrice

Agras MG-1 is a crop spraying multi-rotor. It is designed for precision variable rate application of liquid pesticides, fertilizers, and herbicides. It can cover seven to ten acres per hour or one acre every ten minutes. The Agras MG-1 has an interchangeable nozzle system for different patterns or widths. The package includes all software needed to run the multi-rotor and price is $15,000.

Figure 4 Agras MG-1

Fixed Wing

A fixed wing is an aircraft that generates its lift by a stationary wing. Aircraft that use a fixed wing have much longer flight time then multi-rotors. Fixed wing aircraft cannot take off vertically so they must be launched or use a runway. With fixed wing aircraft not as much power is required to stay inflight because the lift is generated by the wing compared to multi-rotor aircraft where the blades generate lift.

Figure 5 eBee

eBee Series is a flying wing UAS that can cover up to 512 acres per flight in a single automated flight. It is 43in wide and can carry a payload of 2.4 pounds. It has detachable wings for storage and transportation. eBee is hand launched so no other components are required for launch. eBee has different camera options based on the application. The options are RBG, multispectral, and NIR. Most expensive model is $25,000.

The Trimble UX5 is a large flying wing, with a wing span of 39.4in. There are two available sensor options for the Trimble UX5: RGB sensor or the Trimble UX5 HP (hyperspectral sensor). The Trimble UX5 has a max flight time of 50min, this allows for larger flight plans. Trimble UX5 requires a catapult to launch the aircraft to begin flight. The Trimble UX5 is great for large areas of land or large fields. Trimble price ranges from $42,000 to $50,000. The Trimble UX5 at a height of 100ft it gets a resolution of 1.6cm per pixel and at 500ft it gets 5cm per pixel. Trimble also has a great calculator that will tell you the flight time resolution and number of pictures. http://uas.trimble.com/calculator

Figure 6 RF-70

The RF-70 is a 70" flying delta constructed of a 2.0 dense foam, this aircraft provides a durability that surpasses most others. Less weight in turn also means longer flight times, slower stall speeds for shorter landing distances and gentle touch downs. The RF-70 can carry payloads of up to 5 pounds while still offering approximately 1 hour of flight time. The payload is designed to use various cameras.

A 70" wingspan means the RF-70 is capable of flying where other smaller UAVs are not able, particularly in wind above 30 mph, meaning you can get complete your missions when it is often times matters the most. When disassembled, the RF-70 becomes two separate wings and the fuselage, resulting in an extremely portable aircraft for ease of transportation.

Figure 7 Lancaster 5

Lancaster 5 is standard fixed wing UAS with many interchangeable camera options from RGB, thermal/infrared, multispectral, lidar, and hyperspectral. Lancaster can survey up to 300 acres per flight with 45 min of flight time. It is hand launched and has to belly land. The Lancaster is not open platform, so you must pay subscription to use PrecisionHawks software. A Complete package with Lancaster 5 and software is priced $12,000 to $25,000 depending on camera selected.

Uses for UAV Type

Uses and comparison chart Multi-Rotor Fixed Wing

UAS	*Price*	*Application*	*Available Sensors*	*Acres Per Hour*	*Flight Time*	*Speed*
Agras MG-1	$15,000	Spraying		10	20min	17mph
Matrice Series	$4,800-$8,000	RT, Map	RGB, TIR, MS, LD, HS, NIR, NDVI	160-400	35 minutes	20 mph
Phantom Series	$700-$1400	RT, Map	RGB, MS, NDVI	60-325	25 minutes	12 mph
Altavian Galaxy	$15,000	RT, Map	RGB, TIR, MS, NIR	200-350	25 minutes	13 mph
eBee	$25,000	Map	RGB, MS, NIR, TIR	600	50 minutes	40 mph
Trimble	$42,000	Map	NIR, RGB, MS	720	50 minutes	45 mph
Roboflight	$8,000	Map	NIR, RGB, MS	600	50 minutes	30 mph
Lancaster 5	$25,000	Map	TIF, MS, LD, HS, RBG, NDVI	600	45min	40 mph
Altavian Nova	$15,000-$30,000	Map	RGB, TIF, MS, NIR	730	90min	35 mph

Key:

Application

RT – Real-time Image; Map - Mapping Fields; Spraying – pesticide Application

Sensors

RGB – Visual; TIR - Thermal Infrared; MS – Multispectral; LD – Lidar; HS - Hyperspectral, NIR - Near Infrared; NDVI - Normalized Difference Vegetation Index

Acres Per Hour

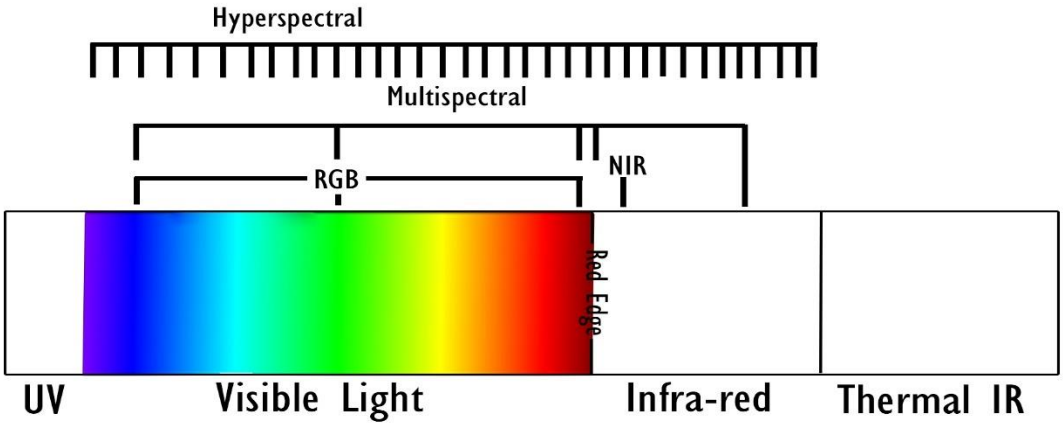
The number of acres per hour can greatly depend on the height of the flight. If you are flying higher you will get a much lower resolution like 19.5cm per pixel and if flying lower covering a smaller area can get up to 0.5cm per pixel.

Advantages and Disadvantages of each type of UAV

Multi-Rotor		Fixed-wing	
Advantages	***Disadvantages***	***Advantages***	***Disadvantages***
Any Camera	Short flight time	Cover much larger area	Requires takeoff space
Ease of use	Small area	Longer flight time	More stable flight
Ability to hover	Slower Speed	Simpler structure	Assistance for takeoff
Vertical takeoff and landing	Greater complexity	Greater payload	Much larger in size (wingspan)
Less expensive	Smaller Payload	Multiple sensors	More expensive

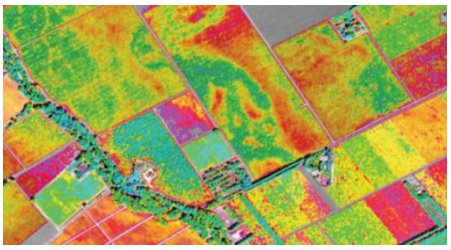
Cameras and Sensors

Overview: All sensors take pictures of a certain wavelength in the electromagnetic spectrum. Some cameras take multiple or many wavelengths. The more wavelengths the sensor reads the more expensive the camera.



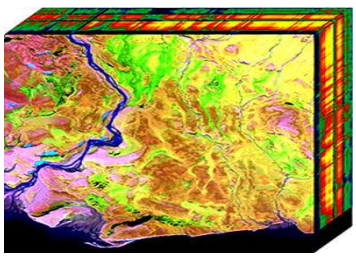
RGB sensors are the least expensive of all the cameras but also provide the least amount of information and uses. They only capture visible light (red, green, and blue). Applications for RGB sensors include agriculture, inspection, and terrain modeling.

Multispectral sensors allow specific ranges of the electromagnetic spectrum to be captured. They normally capture 4-7 bands. This includes RGB, red edge, and NIR. Many times the blue channel is replaced by near infrared and is used for vegetation which is highly reflective. Application is primarily used for agriculture. Multispectral sensors give a clearer picture and more field data. Examples: RedEdge, Swquoia, Sentera, Tetracan, ADC Micro

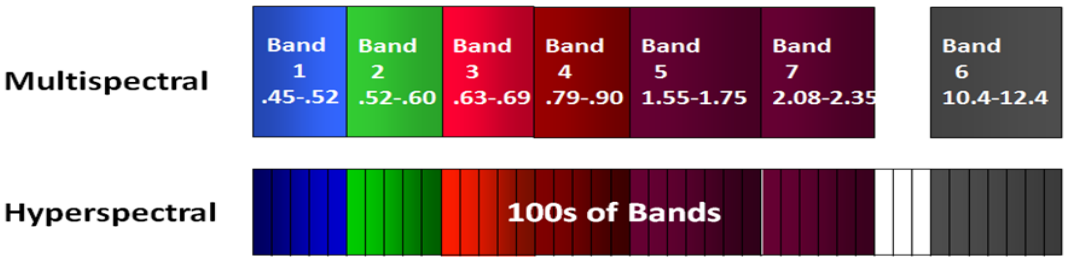


http://www.xyht.com/enviroag/satellite-imagery-precision-agriculture/

Hyperspectral: Collects and processes lots of information from the electromagnetic spectrum. Its goal is to obtain the spectrum for each pixel in the image to find objects and identifying materials. Usually are most expense type of camera because the most wavelengths. It can capture 100s of wavelengths from the visible light spectrum and NIR.
Examples: OCI-UAV, Rikola Ltd

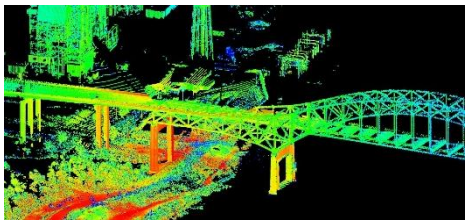


https://en.wikipedia.org/wiki/Hyperspectral_imaging

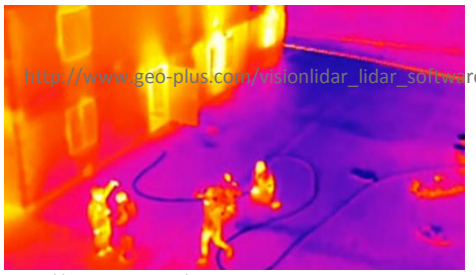


http://altigator.com/wp-content/uploads/Multispectral-vs-Hyperspectral1.png

LiDAR is used for high resolution mapping as it provides accurate distances and measurements. It is also known as airborne laser swath mapping (ALSM). It primary uses are for geomatics, archaeology, geography, geology, seismology, and forestry. It also used in agriculture for highly accurate elevation maps to aid in water drainage planning.
Examples: Velodyne LiDAR



Thermal or Infrared cameras convert infrared radiation to visible spectrum. Thermal IR has many uses but is also one of the most expensive sensors. Applications include building diagnostics, inspections, security and rescue, firefighting, agriculture, and livestock.
Examples: Xenmuse XT, SWIR 640



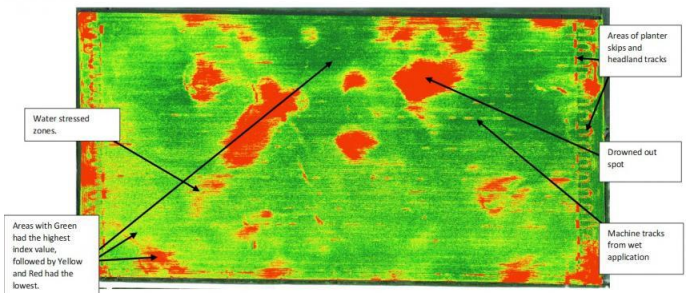
http://www.geo-plus.com/visionlidar_lidar_software/

http://www.dji.com/zenmuse-xt

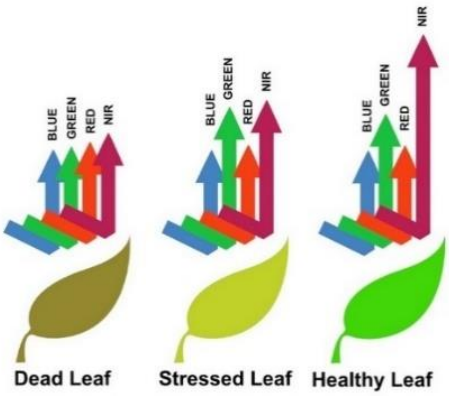
NIR (near infrared) is wavelength close to the visible region of the electromagnetic spectrum. This band is where vegetation data exists. NIR is rarely used on its own and usually combined with NDVI to remove the red edge.
Example: Sony a6000

https://www.geospatialworld.net/news-posts/smartplanes-custom-ricoh-gr-nir-camera-for-agriculture-applications/

NDVI is a ratio of near infrared reflectivity minus red reflectivity over NIR plus VIS. It is a combination of many different cameras layered together to show normalized difference vegetation index. Its applications are only for agriculture or other plants.
Example: Sentera, Canon Powershot SX280HS



http://crops.extension.iastate.edu/cropnews/2016/05/choosing-right-imagery-best-management-practices-color-nir-and-ndvi-imagery



http://agribotix.com/blog/2014/06/10/misconceptions-about-uav-collected-ndvi-imagery-and-the-agribotix-experience-in-ground-truthing-these-images-for-agriculture/

UAV Operation Software

Pix4Dmapper Pro: An image stitching software that will allows users to create orthomosaics, digital surface models, and 3D Point clouds. Its starting price is $350 a month. Features included unlimited cloud and desktop processing, volume measurements, Index maps (NDVI) and 3D models.

Drone2Map for ArcGIS: Drone2map is a stitching software that is compatible with any sensor. It can create orthomosaics and 3D meshes. An ArcGIS online subscription is required to use Drone2Map. It allows the user to import directly into ArcGIS for data analysis.

ESRI ArcGIS Pro: Lets you edit 2D and 3D maps from Drone2Map. Construct detailed models of condition in your field to identify the optimal locations for individual crops. Giving data analysis like crop coverage, plant health, and soil information.

DataMapper: Is a complete stitching software that includes 2D, 3D, and contour map output files. Then after it creates the selected map it suggests analysis processes like plant height, field uniformity, soil adjusted vegetation index, canopy cover, volume measurements and many more. Starting at $49 a month, it includes 50GB of cloud storage local or offline image processor.

ENVI: Is an automated workflow that guides you through advanced image analysis tasks to easily deliver expert level results. Processes images into 3D point cloud and orthomosaics. ENVI is fully integrated with ESRI's ArcGIS software. It also includes many analysis tools like hotspot analysis and ENVI FX.

https://www.ag.ndsu.edu/agmachinery/uas

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