Journal of Agriculture and Environment for International Development - JAEID 2017, 111 (2): 383 - 407
DOI: 10.12895/jaeid.20172.690

A comparision between satellite based and drone based remote sensing technology to achieve sustainable development: a review

Babankumar Bansod[1 *], Rangoli Singh[2], Ritula Thakur[2], Gaurav Singhal[1]

[1] *Council of Scientific and Industrial Research (CSIR), Central Scientific Instruments Organisation (CSIO), Agrionics Department, Chandigarh, India*
[2] *National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh, India*

**Corresponding author: babankumarbansod12345@gmail.com*

Submitted on 2017, 28 September; accepted on 2017, 15 November. Section: Reviews

Abstract: Precision agriculture is a way to manage the crop yield resources like water, fertilizers, soil, seeds in order to increase production, quality, gain and reduce squander products so that the existing system become eco-friendly. The main target of precision agriculture is to match resources andexecution according to the crop and climate to ameliorate the effects of praxis. Global Positioning System, Geographic Information System, Remote sensing technologies and various sensors are used in precision farming for identifying the variability in field and using different methods to deal with them. Satellite based remote sensing is used to study the variability in crop andground but suffer from various disadvantages such as prohibited use, high price, less revisiting time, poor resolution due to great height, Unmanned Aerial Vehicle (UAV) is other alternative option for application in precision farming. UAV overcomes the drawback of the ground based system, i.e. inaccessibility to remote and very dense regions. Hovering at a peak of 500 meter - 1000 meter is good enough to offer various advantages in image acquisition such as high spatial and temporal resolution, full flexibility, low cost. Recent studies of application of UAV in precision farming indicate advanced designing of UAV, enhancement in georeferencing andt he mosaicking of image, analysis and extraction of information required for supplying a true end product to farmers. This paper also discusses the various platforms of UAV used in farming applications, its technical constraints, reliability, privacy rights and safety.

Keywords: Hyperspectral Image, Precision farming, Remote Sensing, UAV, Vegetation Indices.

Introduction

Sustainability is the key source of future enhancement. It's the duty of today's generation to protect and nourish the environment for the betterment of today and tomorrow generation. Agriculture outputs have adverse impact on circumambient environment, particularly in conditions of water quality. One distinctive feature of this field is that it provides biological products which are sensitive to both environmental and managerial practices (Swain *et al.*, 2007). So it is really vital for the farmer to identify where variations exist in their arena so as to establish their practices accordingly. As a result any technique which can promote sustainability or increase the agricultural output while minimizing its impact on the environment will be beneficial to society. Variable rate technologies, grain yield scanner in combination with Global Positioning System are made to dispense with this matter (Stafford, 2000; Price 2004; Robertson *et al.*, 2007). Such techniques fall under the term called precision agriculture.

Precision farming in simple words can be explained as the linkup of technology with traditional agriculture practices. This term suggest that agricultural practices can be carried out with a right amount of input at the right place at the right time in the right quantity. Precision agriculture is the means of attaining sustainability along with food security. Pre cision farming is a manner to optimize the probable harmful impact of patterns in order to furnish a safer environment to humans. According to the projection done by united nation Department of economic and social affairs, the world population is estimated to be 9.7 billion in 2050. It requires a huge amount of food to feed such a large number of mouths and precision farming is the only way to achieve this target. Precision farming or satellite farming or site-specific crop management uses technologies like high precision positioning system called global positioning system, geographical information system, wireless sensor network, variable rate technology and integrated electronic communication. Precision agriculture is the way to manage the crop yield resources like water, fertilizers, soil, seeds in order to increase production, quality, gain and reduce squander products so that the existing system become eco-friendly. The main target of the precision agriculture is to match resources and execution according to the crop and climate to ameliorate the effects of praxis.

The progress in remote sensing technologies and its increasing role in precision farming has led to growth of many agricultural equipment. Right now variable rate technology is the most practiced and advanced technology of precision farming. The working success of variable rate technology requires precise knowledge of map of nutrients, weeds, fertilizers, crop deficiency and quality of soil (Moran *et al.*, 1997). Farmers use this data to compare with the nutrient requirement of crop with spatial variations of playing area (Cookand Bramley, 1998; Robertson *et al.*, 2007). But this takes a continuous visit of field in order to have prompt actions against crop deficiency. To acquire variability datasets for large farmlands is very unmanageable and pricey (Quilter, 1997). Today the advancement in sensing technologies i.e. ground based and remotely based has made the acquisition of subject level data very cheap. Therefore, the map defining the crop and soil variations through image acquired by sensors employed on satellite, airborne and ground based equipment become the all-important portion of variable rate technology. The pictures acquired by satellite and aerial platforms were used for soil monitoring, crop classification, insects and weed identification, crop and water stress and prediction of crop production (Stafford, 2000; Warren and Metternicht, 2005), but their role has been limited due to poor revisiting time and spatial solution(Moran *et al.*, 1997; Stafford, 2000). Furthermore the role of manned aerial platform was limited because of its functional complexity and high cost (Moran *et al.*, 1997; Zhang *et al.*, 2006; Berni *et al.*, 2009a; Rango *et al.*, 2009), but the low altitude remote sensing system paid a new path to acquiring earth images at from a low elevation. Unmanned Aerial Vehicle (UAV) is a new concept in precision agriculture, which is being encouraged for this determination. The purpose of this review paper is to provide an insight of UAV *a*ndits application in precision agriculture by exploring their limitations, current practices *a*ndfurther advancements.

Remote Sensing and **precision farming**

Application of remote sensing in precision agriculture is dominated by platform used for data gathering, multispectral or hypersectral sensor, i.e. counts and width of spectral bands, spatial *a*ndtemporal resolutions of sensors, and number of bits used by the sensor, variable mapping and decision making system. Remote sensing is used in all this stage of precision agriculture.

The application of remote sensing in agriculture is based along the concept of interaction of electromagnetic radiation with plants and crops material. It assesses the quantity of light reflected from soil and crop; simply do not react to the amount of transmitted and absorbed light. The role of remote sensing in agriculture has been applied since 1950s (Colewell, 1956). Agricultural Adjustment Administration of the United States has used aerial imagery for monitoring of crop field in 1930s (Monmonier, 2002). The essential points of interest of remote detecting in exactness cultivating are the early identification of contagious and weed contaminations before they wind up plainly noticeable to the human eye (Lorenzen and Jensen, 1989; Malthus and Maderia, 1993).

The basic remote sensing platforms are satellite, unmanned and manned aircraft, and balloons. Optical sensors, near infrared sensors and Radio Detection and Ranging (RADAR) are some of the examples of sensors employed on platforms of remote sensing for application in precision agriculture. The images collected by these platforms programs are applied in estimating the biomass leaf area index, water stress, weed and insect identification, crop production and therefore helpful in crop monitoring, protection and management. Till now remote sensing is used in many precision farming applications like monitoring and mapping of soil (De Tar *et al.*, 2008; Gomez *et al.*, 2008), weed identification (FLan *et al.*, 2009), water stress management (Lelong *et al.*, 1998; Erickson *et al.*, 2004), pest management of crop(e.g., Lan *et al.*, 2009). Many products like wheat, rice, cotton were examined with the guide of remote detecting strategies (Seelan *et al.*, 2003; Zhao *et al.*, 2007). The images used for the investigation of crops are basically airborne multispectral or hypersectral and multispectral satellite images. Presently the role of synthetic aperture radar (SAR) was applied in application of precision farming, but their applications are restricted because of high cost, time and, operational complexity (McNairn and Brisco, 2004).

The satellite used for remote sensing application in agriculture was taken up in the early 1970s (Bauer and Cipra, 1973; Doraiswamy *et al.*, 2003; Jewel, 1989) with the launching of LANDSAT 1(Table 1). Many trends were recognizable in improvement in techniques of satellite remote sensing. Firstly, there has been an improvement in spatial resolution from 80 meters with LANDSAT to sub meter in Worldview. Secondly the revisiting time is decreased to one day with Wolrldview satellite. At last count of spectral bands was increased from four of LANDSAT to eight bands of Worldview which increase the role of satellite based remote sensing in precision agriculture. For the most part the image taken by satellite was used for estimation of biomass (Yang *et al.*, 2000) and crop output (Doraiswamy *et al.*, 2003) with the help of Normalized Difference vegetation index (NDVI) (Rouse *et al.*, 1973). There were many limitations associated with satellite based remote sensing like weather conditions, atmospheric corrections in the image, geo rectification of images with reference to earth coordinates, converting digital images into a true reflectance image (Moran *et al.*, 1997; Yao *et al.*, 2010).

The image provided by satellite is of low spatial and temporal resolutions as compared to UAV image. High resolution images provided by UAV were used in many studies for examination of crop health including Leaf Area Index. Leaf Area Index (LAI) influences the two properties of crop, i.e. Evaporation and photosynthesis, which are hooked on solar radiation (Warren and Metternicht, 2005). The studies of various crop canopies require the estimations of LAI. LAI is the main parameter that can connect remote remote sensing to crop health and environment conditions (Wu *et al.*, 2007; Lopez-Lozano *et al.*, 2009). Other applications of remote sensing include soil monitoring(Sullivan *et al.*, 2005), water stress management (Zarco-Tejada *et al.*, 2012), weed infestation (Gomez-Casero *et al.*, 2010), chlorophyll and nitrogen content of leaf, crop height, species *a*ndgrowth (Donoghue *et al.*, 2006; Enclona *et al.*, 2004; Pena-Barragan *et al.*, 2008; Castillejo- Gonzalez *et al.*, 2009). Many of the above mentioned data were determined by estimating various vegetation indices like Normalized Difference Vegetation Index (NDVI), Enhanced Normalized Difference Vegetation Index, Modified Soil Adjusted Vegetation Index (MSAVI), and the GNDVI (Green Normalized Difference Vegetation Index)(Hunt, 2005; Fang, 2016; Swain *et al.*, 2007; Lelong *et al.*, 2008).

Table 1 – Satellite based remote sensing platforms used for precision farming applications.

Satellite	Launching Year	Participants	Spectral Resolution	Spatial Resolution	Revisiting Time	Quantization	Swath Width
LANDSAT 1	23, July 1972	• NASA • Department of the Interior (DOI) U.S. Geological Survey (USGS) • Manufacturer: General Electric's (GE's) Space Division in Valley Forge, Pennsylvania	Four bands (Green, Red, 2 Infrared)	56 x 79 m	18 days	6 bit	185 km
AVHRR	19, October 1978	• NOAA's Polar Orbiting Environmental Satellites	Four bands (Red, NIR, 2 thermal infrared)	1090 m	1 days	10 bit	2900 km
LANDSAT 5 Thematic mapper	1, March 1984	• NASA • National Oceanic and Atmospheric Administration (NOAA) • Earth Observation Satellite Company (EOSAT) • Department of the Interior (DOI) U.S. Geological Survey (USGS)	7 bands (Blue, Green, Red, NIR, 2 SWIR, Thermal)	30 meter	16 days	8 bit	185 km
SPOT 1	22, February 1986	• Centre National d'études spatiales • Belgian scientific, technical and cultural services(SSTC) • Swedish National Space Board (SNSB).	3 Bands (Green, Red, NIR)	20 meter	26 days	6 bits	60 km
IRS 1 A	17, March 1988	• Indian Space Research Organization	4 Bands (Blue, Green, Red, NIR)	72 meter	22 days	7 bits	148 km
ERS 1	17, June 1991	• European Space Agency	2 bands (Ku band altimeter, IR)	20 meter	35 days	10 bits	102.5 km
JERS 1	11, February 1992	• NASDA (National Space Development Agency) • Ministry of International Trade and Industry Science and Technology Agency	L band radar	18 meter	44 days	3 bits	75 km
LiDAR	1995	• -	VIS (Vertical RMSE)	10 cm	N/A	-	-
RADARSAT	4, November 1995	• Canadian Synthetic Aperture Radar Earth Observation satellites	C band radar	30 cm	3-6 days	4 bit	500 km
IKONOS	24, September 1999	• Digital Globe	Panchromatic, B, G, R, NIR	1-4m	3 days	11 bits	11.3 km
SRTM	11-22, February 2000	• The National Aeronautics and Space Administration (NASA) • National Geospatial-Intelligence Agency (NGA)	X band Radar	30m	N/A	-	225 km
Terr EOS Aster	18, December-r 1999	• NASA • Japan's Ministry of Economy • Trade and Industry (METI) • Japan Space Systems	G, R, Near Infrared and 6 Mid Infrared, 5 Thermal infrared bands	15-19 m	16 days	8 bits	60 km

Source: David J. Mulla, "Twenty Five Years Of Remote Sensing In Precision Agriculture: Key Advances and Remaining Knowledge Gaps", Biosystems Engineering, 114, 2013, 358-371.

Table 1- continued

EO-1 Hyperion	21, November 2000	• NASA	400-2500 nanometre, 10 nanometre bandwidth	30 m	16 days	12 bit	7.5 km
Quick Bird	18, October 2001	• Digital Globe	Panchromatic, B, G, R, NIR	0.61-2.4 km	1-4 days	11 bits	16.8 km
EOS MODIS	4, November 2002	• NASA	36 bands	250-1000 m	1-2 days	12 bits	2330 km
CBERS-2	21, October 2003	• Brazil • China	5 Bands (Blue, Green Red. NIR, Panchromatic)	20 meter	26 days	8 bits	120 km
Rapideye	29, August 2008	• MacDonald Dettwiler, Ltd. (MDA)	5 Bands (Blue, Green Red. NIR, edge Red)	6.5 meter	5.5 days	12 bit	77 km
Geoeye-1	6, September 2008	• Digital Globe	6 bands (Blue, Green Red. NIR1, NIR2 Panchromatic)	1.6 meter	2-8 days	11 bits	15.2 km

There is no doubt that satellite remote sensing is proved to be profitable and beneficial for agriculture application (Godwin *et al.*, 2003; Seelan *et al.*, 2003, Tenkorang and DeBoer, 2007) but nevertheless its use is limited. The restrictions identified for remote sensing cover low spectral and temporal resolution, large revisiting time, difficulty in data extraction and elucidation from image and in cooperating this data in agronomic system for fieldmanagement (Jackson, 1984; Du *et al.*, 2008). Climate condition is in like manner an imperative issue for picture obtaining from satellite remote detecting particularly the rainstorm.

It has levied that high price, lack of flexibility, operational complexity make the function of satellite for remote sensing non practical (Stafford, 2000; Lamb *et al.*, 2008).

Unmanned Aerial Vehicle

The UAV is an aircraft without any human pilot on board. It can be operated either remotely, i.e. controlled by a human operator or completely autonomously i.e. by the help of on-board computer (Unmanned Aircraft System, 2016). It is basically used in that area which is inaccessible and dangerous to human beings (Tice, 1991). In originally UAV is mainly used in military applications, but nowadays it is expanding its wing in agriculture, scientific activities, andrecreation and in many other applications like surveillance, delivering goods, photographs, etc. (Franke, 2015). UAV is used as a modish approach of farming for optimizing efficiency. By utilizing cloud computing UAV gives an extremely strengthfull information handling and managing ability of data. It also provide aerial civil investigation and intelligence collecting abilities with the help of various sensors, including multispectral, Near-infrared and Light Detection and Ranging (LIDAR) (Rise Above, 2016*)*.

Association for Unmanned Vehicle System International (AUVSI) estimated that about 80% of the commercial market of UAV will be covered by agriculture UAV andit will be able to generate around 100,000 jobs in the USA only (Chuchra, 2015).Nowadays geomatics is having a large application in precision agriculture and field inspection because of its basic three-dimensional photography and data interpretation skill (Santhosh *et al.*, 2003; David, 2013).Inspection of crop field from sky give a great opportunity of studying the crop from the different point of view, perceiving few oddity of crop field which is difficult to find out from ground.

The important feature of precision agriculture is water stress management, crop health monitoring, including insects, nutrients, biomass etc. (Lelong *et al.*, 2008). Conventionally satellite and manned aircraft were used for obtaining the distant image of the earth but these images do not provide much information about the spatial *a*ndtemporal response of crop (Nebiker *et al.*, 2008). These problems were overcome by the use of pliable unmanned aircraft like Unmanned Aircraft Vehicle also known Remotely Piloted Aircraft Systems (RPAS) (Nexand Remondino, 2014; Colomina and Molina, 2014). The various application of UAV in agriculture are: crop patrolling, precision farming, weed controlling, soil properties monitoring, ice alleviation and fertiliser utilisation (Everaerts, 2008; Sugiura *et al.*, 2003; Sebastian *et al.*, 2015; BenDor E., 2002; Ehsani *et al.*, 2014; Lucieer *et al.*, 2014).

UAV conception on remote sensing provides a great opportunity for acquiring field data in a very simple and fast way for accomplishing various application of precision farming. Use of UAV is increasing day by day because of its enormous number of benefits for managing resources of farml andespecially for studying health issues of crops (Primicerio *et al.*, 2012). UAV system incorporated with image, range, position sensors are capable of capturing the multispectral image low level resolution and provide a great opportunity in the field of precision farming (Lucieer *et al.*, 2014; Primicerio *et al.*, 2012; Turner *et al.*, 2011; Bendig *et al.*, 2012). UAV gives us the opportunity to perform various quantitative and enthralling opportunity to capture image with good spatial and temporal resolution along with cost effectiveness as compared to other remote sensing platforms (Primicerio *et al.*, 2012). Table 2 present a comparison between UAV with other Remote Sensing platforms.

Table 2 – Comparison of Uav with other Remote sensing platforms.

PLATFORMS	SPATIAL RESOLUTION	FIELD OF VIEW	USABILITY	PAYLOAD	COST OF DATA ACQUISITION
UAV	0.5-10 cm	50-500 m	Very good	Limited	Very low
Helicopters	5-50 cm	0.2-2 km	Pilot mandatory	Limited	Medium
Airborne	0.1-2 m	0.5-5 km	Pilot mandatory	Unlimited	High
Satellite	1-25m	10-50 km	-	-	Very High

Source, Sebastian Candiago , Fabio Remondino , Michaela De Giglio , Marco Dubbini and Mario Gattelli, 2015, "Evaluating Multispectral Images *a*ndVegetation Indices for Precision Farming Applications from UAV Images", *Remote Sens.* , *7*(4), 4026-4047, doi:10.3390/rs70404026.

Japan has been the first country to use UAV in agriculture for applications like chemical spray in 1980 (Nonami, 2007), crop wiping in 1990. Around 1220 units of unmanned helicopters manufactured by YAMAHA were sold and used in Japan in the year 2001(Sato, 2003). About 40% of total lands used for rice paddies i.e. 2.5 million acres were spritz with the help of more than 2000 YAMAHA RMAX pilotless helicopter.

Japan has outstripped USA in making commercial use of UAV in agriculture (Rajvanshi, 2016). In spite of the fact that UAV have a vast embryonic in the field of precision farming, it is still a neonate in many country. Opulence and reliability of a country come from its and so it is necessary to make the agriculture sustainable, high yielding and innovation by the use of advanced tillage technologies which will bring food and vitality reliability in the nation leading to the promotion of new era of green revolution (Rajvanshi, 2016).As it's mentioned already that UAV have huge application in the field of agriculture so next section of the paper describes the various application of UAV in precision agriculture and challenges.

Application of UAV in precision agriculture

The use of UAV in precision farming is ascended from the last decennium because of its low flight cost, good approachability and also it is a pragmatic alternative to satellite and manned aircraft for obtaining high definition image by remote sensing. There are many UAV manufactures available in the market (Table 3) who developed UAV with different specifications and based on dem andof farmers. Some of UAV systems, which have developed till date are: Fixed wing aircraft (Beard *et al.*, 2005; Everaerts, 2008), chopper (Sebastian *et al.*, 2015; BenDor, 2002), multi-copter (Ehsani, 2014; Bryant *et al.*, 2013), motor parachute and glider (Lelong *et al.*, 2008; Sampaio *et al.*, 2014; Bryant *et al.*, 2013), UAV system with perpendicular take off and arrival ability (Primicerio *et al.*, 2012; Spanoudakis *et al.*, 2003; Ugur Ozdemir *et al.*, 2014), congregating ready made parts (Huang *et al.*, 2013) and commercialized UAV (Fornace *et al.*, 2014; Perculija *et al.*, 2015) showing great capabilities in the field of farming and environment. Together with the development of UAV platform, a variety of sensors have also been developed that that can be used with a UAV for collecting data for tillage. To capture image sensors like multispectral camera, thermal camera (Jose *et al.*, 2009), hyper-spectral camera (Caroline *et al.*, 2015), digital camera (Jianwei Yue *et al.*, 2004) and low altitude/ large scale imaging units (Quilter and Anderson, 2001; Tomlins and Lee, 1983) were used. The costs of all the types of sensors have been declining with the improvement and development in manufacturing process and technology. Compact camera is the cheapest method for sensing the near infrared light by removing its infrared filter. Although these camera have no application in sensing the long wavelength infrared light but still they are one of the cheapest method for taking infrared images for Normalized Difference Vegetation Index (NDVI). Normally the image taken by the camera installed on UAV is transmitted wirelessly to the earth station

for image processing with the help of special software and programmes. These images can also be stored in an on-board memory card and used when a UAV is landed. An Inertial Navigation System or GPS and earth station with the gliding planning scheme are essential for geo-referencing these images (Chao *et al.*, 2008; Grenzdörffer *et al.*, 2008; Harwin and Lucieer, 2012; Nagai *et al.*, 2009; Xiang and Tian, 2011b). Laser scanners and synthetic aperture radar are some other sensors used in farming applications (J. Lumme, 2008; Foody, 1998). Many countries researcher have used UAV for monitoring and investigating many crop species and fruit orchard. Other than the Normalized Difference Vegetation Index (NDVI) there are many multib andspectral indices available for use in precision agriculture. These various multib and spectral indices were tested by using (Table 4) UAV system.

In India KISAN project standing for Crop Insurance using Space technology and Geoinformatics were launched by ministry of agriculture in 2015. This project anticipates utilization of satellite and UAV-based image data along with Geoinformatics technology for estimating reliable and accurate data on crop production. This data were used by the government for improvement in crop production and better planning Crop Cutting Experiments (CCEs) required for the crop protection scheme. The government also launched an app prepared by Indian Space Research Organizations to measure the real time data of damage done to crops by hailstorm (Kisan Project, 2016).

UAV (Bulanon *et al.*, 2014) in cooperating with multispectral camera and image processing unit were used to develop a crop monitoring and evaluation scheme to assess the variation in water quantity in the field. This scheme was tested in the Apple orchard situated at the Parma Research *a*ndExtension Centre of the University of Idaho. The evaluation of results is based on Enhanced Normalized Difference Vegetation Index (ENDVI) shows that tree having full drip and trickle have a higher value of ENDVI as compared to having less water input.

UAV were used for crop scouting to detect huanglongbing in Florida (Garcia-Ruiz *et al.*, 2013). This experiment was carried out by using a spectroscopy in the range of 530-900nm and UAV flew at height of 100 m to cover a field of 0.35 ha. The result shows that data collected by UAV images give an accuracy of 67%-85% in detecting huanglongbing proving its reliability in crop scouting.

UAV system for identification of *Silybum marianum* (L.) Gaertn weed were used (Tamouridou *et al.*, 2017). The fixed wing UAV installed with the high-resolution camera used for taking the image of a pixel size of 0.1m. Maximum Likelihood Classifier identifies *Silybum marianum* (L.) Gaertn weed among with *A. sterilis* and other weed present in the crop field.

An unmanned copter based on low height remote sensing were used to acquire high resolution images over a height of 20m on a rice field (Swain et al, 2010). From the acquired data it was found that rice yield and biomass for five different regions were remarkably different at 0.5 and 0.1 level of significance and their value of NDVI is highly correlated to yield and biomass at the regression coefficient of 0.728 *a*nd0.760 respectively. This method is also applicable in determining the chlorophyll content of leaf in respect of NDVI and evaluates the area which requires additional nutrient to increase the yield of a crop.

An experiment was conducted to evaluate the cotton field response towards water stress *a*ndcrop remnant management by attaching thermal infrared sensor on UAV (Sullivan et al, 2007). The image of the sample location situated at the Tennessee Valley Research and Extension Centre located in Belle Mina, Alabama took from a height of 90m with a spatial resolution of 0.5 m. The results proved the TIR emittance or UAV inspection is much accurate in differentiating the canopy response to water stress *a*ndcrop remnant management as compared to stomatal conductance measured on the ground which also time-consuming and labour intensive. UAV were used for acquiring thermal and narrowb andmultispectral image to evaluate natural properties of the sunflower crop like leaf area index, water stress, nitrogen content, the yield of grains, and biomass in terms of NDVI during growing season (Vega *et al.*, 2015). Positive and high correlation confidence of crop indicates increased crop production and biomass with increase in NDVI. The result also indicates that the image taken at the appropriate time enables the farmer to use precision farming techniques by recognising certain problems of crops which lead to enhancement of profit, yield *a*ndenvironments benefits.

Table 4 – Various multib and*spectral indices used in precision farming and tested by UAV.*

Index	Formula	First Time Use	Bands	Uses	References
NDVI	(NIR - R) / (NIR + R)	J.W. Rouse., Jr., R. H. Haas, J. A. Well and D. W. Deering, in 1973 (Rouse et al. , 1973)	NIR, VIS	Leaf Area Index Estimation	Lelong, 2008; Calderón, 2013; Zarco-Tejada, 2012; Berni, 2009; Nebiker, 2008; Sugiura, 2005; Stefanakis, 2013; Arnold, 2013.
Soil Adjusted Vegetation Indices	(1 + L) (NIR - R) / (NIR + R + L)	A. R. Huete (Huete et al., 1988)	NIR, VIS	Leaf Area Index Estimation	Lelong, 2008; Calderón, 2013; Baluja, 2012.
Crop Water Stress Index	(Dt - MIN) / (MAX - MIN)	B. R. Gardner, D. C. Nielsen, C. C. Shock in 1922 (Gardner, Nielsen and Shock et al., 1992)	TIR	Water stress estimation	Calderón, 2013; Baluja, 2012; Gago, 2013.
Photochemical Reflectance Indices	$(R_{531} - R_{570}) / ((R_{531} + R_{570})$	A. J. Richardson C. L. Wigand in 1977 (Richardson , Wiegand et al., 1977)	VIS	Water stress estimation	Calderón, 2013; Zarco-Tejada, 2012; Berni, 2009; Baluja, 2012.
Greenness Index	(R - V) / (R + V)	R.J. Kauth and G.S.Thomas in 1976 (Kauth , Thomas et al., 1976)	VIS	Amount of Chlorophyll	Lelong, 2008; Calderón, 2013; Zarco-Tejada, 2012; Baluja, 2012.
TCARI/OSAVI	$3[(R_{700} - R_{670}) - 0.2(R_{700} - R_{550})^* (R_{700} / R_{670})] /(1 + 0.16) * (R_{800} - R_{670}) / (R_{800} - R_{670} + 0.16)$	F. Bayrat, G.Guyot in 1969 (Bayrat, Guyot et al., 1969)	NIR, VIS	Water stress and Chlorophyll detection	Calderón, 2013; Zarco-Tejada, 2012; Berni, 2009; Baluja, 2012.
Green Normalised Difference Vegetation Indices	(NIR - G) / (NIR + G)	Anatoly A.Gitelson, Yoram J.Kaufman in 1988 (Gitelson, Kaufman et al., 1988)	NIR, VIS	Water stress, Nitrogen Concentration and Leaf Area Index Estimation	Lelong, 2008.

Source: Esther Salamí , Cristina Barrado and Enric Pastor,2014 , UAV Flight Experiments Applied to the Remote Sensing of Vegetated Areas, Remote Sensing, 6, 11051-11081; doi:10.3390/rs61111051

An Unmanned Aerial Vehicle (UAV) for path detection developed by NASA were used to monitor 1500 ha of Kavai Coffee field. This UAS is powered by solar having both colour and multispectral camera (Hurwitz *et al.*, 2004). LAN working with unlicensed radio frequency was used for controlling the camera and downloading of the image at a rate more than 5 Mbps-1 along with WAN used for up linking the control comm andfrom ground station to UAV during the mission. Images from the colour camera were used for evaluating irrigation and fertilizers peculiarities whereas image from the multispectral camera was used successfully for estimating fruit maturity. In spite of cloudy cover, this system was able to record cloud-free images because of its good manoeuvrability

Implementation of cheap customer grade camera for colour infrared on 2 m wide fixed wing UAV having weight 5.8 kg and 63 km/hr speed with respect to ground integrated GPS to measure canopy height (Tajeda *et al.*, 2014). Total 750 and 679 high-resolution images of both study area was taken to generate Geo-referenced and digital surface model with the help of Pix4UAV plotting software. The study was conducted on olive orchard. This system is a replacement of expensive and complex LIDAR system used in farming applications.

Challenges

Use of UAV in farming will have a huge influence on both tillage industry and customers as it is expected to exp andits market to 21.23 billion dollars by 2022 with the compound annual growth rate of 19.99% between 2016 to 2022 (Markets and Markets, 2013), howbeit its implementation in agriculture field faces many challenges than just ministerial issues. This section of the paper discusses challenges and issues of using UAV in farming.

Technology contraints

There is no worldwide acceptable solution for each crop because each crop has different properties so they need to be analysed in a different manner to produce operation-able data. Traditionally garner does not want to learn and adopt advanced farming technologies like UAV so the ultimately specialist is required to operate the advanced technology to generate a solution for garner. These issues lead to increase in technical complexity and running cost. To avoid this problem, it is necessary to make a UAV fully autonomous, i.e. they are able to do the entire task by their own; have the statistical *a*ndgraphical representation of data when they are landed and for this garner just need to press the start button from their cell phone. The UAV will automatically do the entire task, including imaging, data transfer, result generation etc.

As it is very clear from the above discussion that aerial image is very capable of telling the health status of the crop, locating the problems in the fields and with further amendments it will be able to tell which class of affliction is affecting the crop. The imaging system suffers from the problem of test- retest reliability of data that need to be vanquished for developing a reliable and authentic system. Nowadays various image sensor for NDVI, GNDVI, LAI is present to give the insight of crop fields, but to know what exactly is going on at the biological stage in the crop field it is necessary to do a comparison study of present data with previous data. This comparison of data will give positive or negative trend followed by crop, as this data is being compared to produce the trend so they need to be collected in a repeatable way. The collection of data is very much affected by weather, cloud, the amount of sun energy reaching to crop and angle of the sun. Due to this reason, entire data gathering must be done in a reiterate manner under same environment. The different season will produce a different reflectance value so the future system must be designed in such a manner that the data can be calibrated based on old data in a systematic manner to generate calibrated value for further iterations of data.

Another technical constraint of the UAV is its payload *a*ndgliding time. Li-ion battery is used to power UAV because of its light weight, but it does not st andanywhere in front of gasoline power. In multi-copter, as payload increase its gliding time reduces due to its disk loading and requirement of a generation of impelling equal to its mass. However, reduced gliding time can be overcome by the use of fixed wing UAV, but it cannot hang at a place and also faces difficulty in landing.

Safety, privacy and security issues

In today's world anyone can buy UAV for picture making, leisure, package dispatch, mapping, patrolling, etc. Although customized UAV is much more in dem and than that of commercial UAV, they are much more dangerous as they do not follow the norms of electrical power system. This lack of regard can prompt the failure of UAV, hazard to humans and destruction of material. To avoid such type of incident, it is necessary to develop guidelines for flying UAV. Another concern with UAV is privacy and security. If a UAV fall in wrong hand, then it will become a very dangerous threat to security and privacy of citizens.

At the present time, there is no set of rules and regulations which can be followed by UAV during their operation habit. Federal Aviation Agency (FAA) and other organizations are working towards it due to the high uplifting of technology in this field.

Controlling bodies and regulations

The UAV has been used in military applications from many decennium but this is yet to be universally accepted for profit making applications due to the ban placed because of its safety and rules constraints (Clarke, 2014). In every country there is National Aviation Authority that overlooks the rules and regulation of domestic aeronautics.

In a country like India Directorate General of Civil Aviation (DGCA) under the supervision of the Ministry of Aviation implements the rules and regulations for better utilization of UAV in both military and civil environment. In the past year there were lots of deputation and commission for setting right regulation and substructure for the safe operation of the UAV. To ensure proper operation of UAV DGCA is planning to do registration of all civilian drones and issuing permission letter for operating them. The association bought an 8 pages draft regulation in May 2016 inviting various stakeholders to provide their valuable suggestion before the release of the final edition of rules and regulation.

According to this draft, each UAV sold in India must have their distinctive recognition number and each person flying UAV must have permission letter. For flying UAV beneath a stature of 200 ft. authorization from the local authority is required and if stature is over 200 ft. at that point consent from DGCA has required likewise a dem and letter for getting the authorization need to submit before 3 months of the flying date. Only citizen of India or company governed by citizen of India can register their drones or UAV under this rule. Presently DGCA is in the process of auditing the response to its advocacy from its stockholders (Government of India Office of The Director General of Civil Aviation, 2016).

Table 5 - Controlling bodies for aeronautics in different countries.

Country	Authority Name	Website
Afghanistan	Ministry of Transport and Civil Aviation	www.motca.gov.af
Argentina	National Civil Aviation Administration	www.anac.gov.ar
Armenia	General Department of Civil Aviation of Armenia	www.aviation.am
Australia	Civil Aviation Safety Authority	www.casa.gov.au
Austria	Federal Ministry for Transport, Innovation and Technology	www.bmvit.gv.at
Belgium	Federal Public Service Mobility and Transport	www.mobilit.fgov.be/fr/
Brazil	National Civil Aviation Agency of Brazil	www.anac.gov.br
China	Civil Aviation Administration of China	www.caac.gov.cn
Colombia	Special Administrative Unit of Civil Aeronautics	www.aerocivil.gov.co
France	Directorate General for Civil Aviation	www.dgac.fr
Germany	Federal Office for Civil Aviation of Germany	http://www.lba.de/EN/
Hong Kong	Civil Aviation Department	www.cad.gov.hk
Indonesia	Directorate General of Civil Aviation	hubud.dephub.go.id
Iran	Civil Aviation Organisation of Iran	www.cao.ir
Iraq	Directorate General of Civil Aviation of Iraq	www.iraqcaa.com
Italy	National Agency for Civil Aviation	www.enac-italia.it
Japan	Japan Civil Aviation Bureau	www.mlit.go.jp
South Korea	Korea Office of Civil Aviation	koca.go.kr
Mexico	Directorate General of Civil Aviation of Mexico	sct.gob.mx/transporte-y-medicina-preventiva/aeronautica-civil/
Myanmar	Department of Civil Aviation of Myanmar	www.mot.gov.mm/dca/
Switzerland	Federal Office for Civil Aviation	www.bazl.admin.ch/index.html?lang=en
Taiwan	Civil Aeronautics Administration	www.caa.gov.tw
Thailand	The Civil Aviation Authority of Thailand	http://www.caat.or.th/

Future scope of UAV

Use of UAV in precision farming is boosting day by day and in future, it will increase its pace. Definitely, the coming year will bring more advanced UAV technologies in the agriculture field. It is crystal clear that UAV applications in farming are still neonate and it has lots of scope for improvement in terms of technology and other farming application. Future scope of UAV includes improvement in its designing, availability of cheaper and good quality hardware, relaxation in regulation, advanced and easy image and data processing method and particle representation of result for better utilization by a farmer.

The UAV can gather the aerial image, but it does not let the farmer to know about the cause of non-uniformities present in the field, to overcome this, UAV can collaborated with an unmanned ground vehicle and robots for better analysis *a*ndmonitoring of crop fields. Today's advanced information technologies like cloud computing, big data analysis can also be integrated with a UAS for advanced data gathering and evaluation.

Conclusion

In today's world of completion, it is necessary for garner to meet the requirement of the present population while maintaining sustainable development. Precision farming is the key to initiate another green revolution in World. The emerging technology in precision farming is based on Satellite based remote sensing and airborne remote sensing. The use of Satellite based remote sensing proves to suffer from various drawback such as- prohibited use, high price, less revisiting them, poor resolution due to great height; Unmanned Aerial Vehicle (UAV) is other alternative option for application in precision farming. UAV overcomes the drawback of the ground based system, i.e. inaccessibility to remote and very dense regions. Use of UAV in agriculture application like water stress management, biomass detection, weed identification have already proved to be a success, but still, there are lots of issues andchallenges associated with UAV implementation in farming, including the high cost of operation and hardware, strict regulations, safety, security, a complex method of data processing.

It is anticipated that the lower cost of hardware, advanced UAV technology, relaxed policy, and modified and improved image analysis software will increase the acceptance of UAV in agriculture. In summation, the government must consider several steps towards making farmer aware about these technologies so that they can strengthen their capabilities to satisfy the requirement of present and future population.

References

Arnold T., De Biasio M., Fritz A., Leitner R., 2013. UAV-based measurement of vegetation indices for environmental monitoring, In Proceedings of 2013 International Conference on Sensing Technology (ICST), Wellington, New Zealand, 3–5 December 2013; pp. 704–707.

Baluja J., Diago M.P., Balda P., Zorer R., Meggio, F., Morales F., Tardaguila J., 2012. Assessment of vineyard water status variability by thermal andmultispectral imagery using an unmanned aerial vehicle (UAV), Irrig. Sci., Vol. 30(6): 511–522.

Bendig J., Bolten A., and Bareth G., 2012. Introducing a low-cost mini-UAV for thermal- andmultispectral-imaging, Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., Vol. (XXXIX-B1): 345–349.

Berni J. A. J., Zarco-Tejada P. J., Suarez L., Gonzalez-Dugo V., and Fereres E., 2009. Remote sensing of vegetation from UAV platforms using lightweight multispectral andthermal imaging sensors, Retrieved March 12, 2012 from http,//www.ipi.uni-hannover.de/fileadmin/institut/pdf/isprs-Hannover2009/ Jimenez_Berni-155.pdf.

Baret E., Guyot G., and Major D. J., 1989. TSAVI, A vegetation index which minimizes soil brightness effects on LAI andAPAR estimation, In Proceedings of the 12th Canadian Symposium on Remote Sensing, Vancouver, Canada, 1355-1358.

Bauer M. E., and Cipra J. E., 1973. Identification of agricultural crops by computer processing of ERTS MSS data. LARS Technical Reports, Paper 20, http,//docs.lib.purdue.edu/larstech/20. W. Lafayette, IN, Purdue Univ.

Beard Randal W., Derek Kingston, Morgan Quigley, Deryl Snyder, Reed Christiansen, Walt Johnson, Timothy McLain, and Michael Goodrich, 2005. Autonomous vehicle technologies for small fixedwing UAVs, Journal of Aerospace Computing, Information, andCommunication, Vol. 2(1): 92-108.

BenDor E., 2002. Quantitative remote sensing of soil properties. Advances in Agronomy, Vol. 75:173-243.

Bryant R., Susan Moran M., McElroy S. A., Chandra Holificld Thome, K. J., and Tomoaki Miura, 2003. Data continuity of Earth Observing 1 (EO1) Advanced L andI satellite imager (ALI) andLandsat TM andETM+. IEEE Transactions on Geoscience andRemote Sensing, Vol.41(6):1204-1214.

Bulanon Duke, M., Horton Mark, Salvador Paulo Fallahi, and Esmaeil, 2014. Apple Orchard Monitoring Using Aerial Multispectral Imaging. Americn Soceity of Biological andEngineering Soceity, 141913165. doi, 10.13031/aim.20141913165.

Calderón R., Navas-Cortés J., Lucena C., Zarco-Tejada P., 2013. High-resolution airborne hyperspectral andthermal imagery for early detection of Verticillium wilt of olive using fluorescence, temperature and narrow-b and spectral indices. Remote Sens. Environ., Vol.139, 231–245.

Caroline M. Gevaert, Juha Suomalainen, Jing Tang, and Lammert Kooistra, 2015. Generation of Spectral–Temporal Response Surfaces by Combining Multispectral Satellite andHyperspectral UAV Imagery for Precision Agriculture Applications. IEEE Journal of Selected Topics in Applied Earth Observations andRemote Sensing, Vol. 8(6):3140 – 3146.

Castillejo-Gonzalez I. L., Lopez-Granados F., Garcia-Ferrer A., Pena-Barragan J. M., Jurado-Exposito M., Orden M. S., 2009. Object- andpixel-based analysis for mapping crops andtheir agroenvironmental associated measures using QuickBird imagery. Computers and Electronics in Agriculture, Vol.68(2):207–215.

Chao, H., Baumann, M., Jensen, A., Chen, Y., Cao, Y., Ren, W., andMcKee, M., 2008. Bandre configurable Multi UAV based cooperative remote sensing for real time water management anddistributed irrigation control, Paper presented at the IFAC World Congress, Seoul, Korea.

Chuchra Jyotsana, 2016. Drones andRobots, Revolutionizing Farms of the Future, https,//www.geospatialworld.net/article/drones-and- robots-future- agriculture/.

Clarke R., and Bennett Mose L., 2014. The regulation of civilian drones' impacts on public safety. Computer Law andSecurity Review, Vol.30(3):263-285. doi, http,//dx.doi.org/10.1016/j.clsr.2014.03.007

Colewell R. N., 1956. Determining the prevalence of certain cereal crop diseases by means of aerial photography, Hilgardia Vol.26(5):223–286.

Colomina I., and Molina, P., 2014. Unmanned aerial systems for photogrammetry andremote sensing, A review. ISPRS J. Photogramm. Remote Sensing, Vol. 92:79–97.

Cook S. E., and Bramley R. G. V., 1998. Precision agriculture, Opportunities, benefits andpitfalls of site specific crop management in Australia. Australian Journal of Experimental, Agriculture Vol.38: 753–763.

David J.M., 2013. Twenty five years of remote sensing in precision agriculture, Key advances andremaining knowledge gaps. Biosystem. Enineering, Vol. 114: 358–371.

De Tar W. R., Chesson J. H., Penner J. V., andOjala J. C., 2008. Detection of soil properties with airborne hyperspectral measurements of bare fields. Transactions of the ASABE, Vol. 51: 463–470.

Du Q., Chang N. B., Yang C. H., and Srilakshmi K. R., 2008. Combination of multispectral remote sensing, variable rate technology andenvironmental modeling for citrus pest management. Journal of Environmental Management, Vol. 86:14-26.

Donoghue D., Watt P., Cox N., and Wilson J., 2006. Remote sensing of species mixtures in conifer plantations using LiDAR height andintensity data, International Workshop 3D remote sensing in Forestry, Retrieved March 12, 2012 form http,//www.rali.boku.ac.at/fileadmin/_/H857VFL/workshops/3drsforestry/presentations/6a.5-donoghue.pdf.

Doraiswamy P. C., Moulin S., Cook P. W., and Stern A., 2003. Crop yield assessment from remote sensing. Photogrammetric Engineering andRemote Sensing Vol.69: 665-674.

Ehsani R., Sankaran S., Maja J., and Neto J.C., 2014. Affordable multirotor Remote sensing platform for applications in precision horticulture. Paper presented at the 12 th International Conference on Precision Agriculture.

Enclona E. A., Thenkabail P. S., Celis D., and Diekmann J., 2004. Within-field wheat yield prediction from IKONOS data A new matrix approach. International Journal of Remote Sensing, Vol.25:377–388.

Erickson B. J., Johannsen C. J., Vorst J. J., and Biehl L. L., 2004. Using remote sensing to assess st andloss anddefoliation in maize. Photogrammetric Engineering and Remote Sensing, Vol.70: 717–722.

Everaerts J., 2008. The use of unmanned aerial vehicles (UAVs) for remote sensing andmapping. The International Archives of the Photogrammetry, Remote Sensing andSpatial Information Science, Vol.37:1187-1192.

Foody G.M., 1988. Crop classification from airborne synthetic aperture radar data. International Journal of Remote Sensing, Vol.9(4): 655-668.

Fornace K. M., Drakeley C. J., William T., Espino F., and Cox J., 2014. Mapping infectious disease landscapes, unmanned aerial vehicles andepidemiology. Trends in parasitology, Vol.30(11):514-519

Franke Ulrike Esther, 2015. Civilian Drones, Fixing an Image Problem? andquot;. ISN Blog, International Relations andSecurity Network.

Gago J., Martorell S., Tomas M. Pou., 2013. A High-resolution aerial thermal imagery for plantwater status assessment in vineyards using a multicopter-RPAS. In Proceedings of 2013 VII Congreso Ibérico de Agroingeniería y Ciencias Hortícolas, Madrid, Spain, 26–29 August 2013, 1–6.

Garcia-Ruiz F., Sankaran S., Maja J. M., Lee Lee W.S., Rasmussen J., and Ehsani, R., 2013. Comparison of two aerial imaging platforms for identification of Huanglongbinginfected citrus trees. Computers andElectronics in Agriculture, Vol.91:106-115.

Gardner R., Nielsen C., and Shock C., 1992. Infrared Thermometry andthe Crop Water Stress Index, Sampling Procedures andInterpretation. J. Prod. Agric., Vol.5: 466-475. doi,10.2134/jpa1992.0466.

Gitelson Anatoly A., Kaufman Yoram J., 1998. MODIS NDVI Optimization To Fit the AVHRR Data Series—Spectral Considerations. Remote Sensing of

Environment, Vol.66: 343-350.

Godwin R. J., Richards T. E., Wood G. A., Welsh J. P., and Knight S. M., 2003. An economic analysis of the potential for precision farming in UK cereal production. Biosystems Engineering, Vol.84:533–545.

Gomez C., Rossel R. A. V., and McBratney A. B., 2008. Soil organic carbon prediction by hyperspectral remote sensing andfield vis-NIR spectroscopy An Australian case study. Geoderma, Vol.146: 403–411.

Gomez-Casero Castillejo-Gonzalez M. T., Garcia-Ferrer I. L., Pena-Barragan A., Jurado-Exposito J. M., Garcia-Torres M., Lopez-Granados F., 2010. Spectral discrimination of wild oat andcanary grass in wheat fields for less herbicide application. Agronomy for Sustainable Development, Vol.30: 689–699.

Government Of India Office Of The Director General Of Civil Aviation, 2016. Guidelines for obtaining Unique Identification Number (UIN) andOperation of Civil Unmanned Aircraft System (UAS), http,//www.dgca.nic.in/misc/draft%20circular/AT_Circular%20-.

Grenzdörffer G., Engel A., and Teichert B, 2008. The photogrammetric potential of Lowcost UAVs in forestry andagriculture. The International Archives of the Photogrammetry, Remote Sensing andSpatial Information Sciences, Vol.31(B3):1207-1214.

Harwin S., and Lucieer A., 2012. Assessing the accuracy of georeferenced point clouds produced via multiview stereopsis from unmanned aerial vehicle (UAV) imagery. Remote Sensing, Vol. 4(6):1573-1599.

Herwitz S. R., Johnson. L. F., Dunagan S. E ., Higgins R. G., Sullivan D. V., Zheng J., Lobitz B.M, Leung J.G., Gallmeyer B.A., Aoyagi M., Slye R.E., and Brass J.A., 2004. Imaging from an unmanned aerial vehicle, agricultural surveillance and decision support. Computers and Electronics in Agriculture, Vol.44(1):49-61, doi, http,//dx.doi.org/10.1016/j.compag.2004.02.006.

Huang Y., Thomson S.J., Hoffmann W.C., Lan Y., and Fritz B.K., 2013. Development and prospect of unmanned aerial vehicle technologies for agricultural production management. International Journal of Agricultural and Biological Engineering, Vol.6(3):1-10.

Huete A. R., 1988, A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, Vol.25: 295-309.

Hunt E. R., Cavigelli M., Daughtry C. S. T., McMurtrey J. E., and Walthall C. L., 2005. Evaluation of digital photography from model aircraft for remote sensing of crop biomass and nitrogen status. Precision Agriculture, Vol.6: 359–378.

Jackson R. D., 1984. Remote sensing of vegetation characteristics for farm management. In Proceedings of the Society of Photo-Optical Instrumentation Engineers, Vol. 475:81–96.

Jewel N., 1989. An evaluation of multi-date SPOT data for agriculture and land use mapping in the United Kingdom. International Journal of Remote Sensing, Vol.10, : 939-951.

Jianwei Yue, Tianjie Lei, Changchun Li, and Jiangqun Zhu., 2004. The Appli Cation Of Unmanned Aerial Vehicle Remote Sensing In Quickly Monitoring Crop Pests. Computers andElectronics in Agriculture, Vol. 44:49–61.

Jose A. J. Berni,Pablo J. Zarco-Tejada, and Lola Suarez, 2009. Thermal and Narrowb andMultispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle. IEEE Transactions on Geoscience andRemote Sensing, Vol. 47(3): 722 – 738.

Lumme J., Karjalainen M., Kaartinen H., Kukko A., Hyyppä J., Hyyppä H., Jaakkola A., and Kleemola J., 2008. Terrestrial Laser Scanning of Agricultural Crops. The International Archives of the Photogrammetry, Remote Sensing andSpatial Information Sciences, Vol.XXXVII(B5): 563-566, Beijing.

Kauth R. J., and Thomas G. S., 1976. The tasseled cap--a graphic description of the spectral-temporal development of agrictdtural crops as seen by Landsat. Proc. Symp. on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, 41 -51.

Lamb D. W., Frazier P., and Adams P., 2008. Improving pathways to adoption, Putting the right P's in precision agriculture. Computers andElectronics in Agriculture, Vol. 61: 4–9.

Lan Y., Huang Y., Martin D. E., and Hoffmann W. C., 2009. Development of an airborne remote sensing system for crop pest management, System integration andverification. Transactions of the ASABE, Vol. 25: 607–615.

Lelong C. C. D., Pinet P. C., and Poilve´ H., 1998. Hyperspectral imaging andstress mapping in agriculture, A case study on wheat in Beauce (France). Remote Sensing of Environment, Vol.66: 179–191.

Lelong C. C. D., Burger P., Jubelin G., Roux B., Labbe S., and Barett F., 2008. Assessment of unmanned aerial vehicles imagery for quantitative monitoring of wheat crop in small plots. Sensors, Vol. 8 :3557–3585.

Lopez-Lozano R., Baret F., de Cortazar-Atauri I. N., Bertrand N., and Casterad M. A., 2009. Optimal geometric configuration andalgorithms for LAI indirect estimates under row canopies, The case of vineyards. Agricultural andForest Meteorology, Vol,149:1307–1316.

Lorenzen B., and Jensen A. , 1989. Changes in leaf spectral properties induced in barley by cereal powdery mildew. Remote Sensing of Environment, Vol.27:201–209.

Lucieer A., Malenovský Z., Veness T., and Wallace L., 2014. HyperUAS-Imaging spectroscopy from a multirotor unmanned aircraft system. Journal of Field Robotics, ol.31(4):571-590.

Malthus T. J., and Maderia A. C., 1993. High resolution spectroradiometry, Spectral reflectance of field bean leaves infected by Botrytis fabae. Remote Sensing of Environment, Vol.45:107–116.

Markets and Markets, 2013. Unmanned Aerial Vehicle Market (2013–2018), Dallas, TX, USA.

McNairn H., and Brisco B., 2004. The application of C-b andpolarimetric SAR for agriculture, A review. Canadian Journal of Remote Sensing, Vol. 30:525–542.

Monmonier M., 2002. Aerial photography at the Agricultural Adjustment Administration, Acreage controls, conservation. Photogrammetric Engineering andRemote Sensing, Vol.68:1257–1261.

Moran M. S., Inoue Y., and Barnes E. M., 1997. Opportunities andlimitations for image-based remote sensing in precision crop management. Remote Sensing of Environment, Vol.61:319-346.

Nagai M., Chen T., Shibasaki R., Kumagai H., and Ahmed, A., 2009. UAVborne 3D mapping system by multisensor integration. IEEE Transactions on Geoscience andRemote Sensing, Vol. 47(3):701-708.

Nebiker S., Annen A., Scherrer M., Oesch D., 2008. A light-weight multispectral sensor for micro UAV- Opportunities for very high resolution airborne remote sensing. In International Archives of the Photogrammetry, Remote Sensing andSpatial InformationSciences; International Society for Photogrammetry andRemote Sensing (ISPRS), Beijing, China 37, (B1).

Nex F., and Remondino F., 2014. UAV for 3D mapping application A review, Appl. Geomat., Vol. 6:1–15.

Nonami K., 2007. Prospect andrecent research anddevelopment for civil use autonomous unmanned aircraft as UAV andMAV. Journal of system Design and Dynamics, Vol.1(2):120-128.

Pena-Barragan J. M., Lopez-Granados F., Garcia-Torres L., Jurado-Exposito M., de la Orden M. S., and Garcia-Ferrer A., 2008. Discriminating cropping systems andagro-environmental measures by remote sensing. Agronomy for Sustainable Development, Vol.28: 355–362.

Perculija G., Bošnjak. K., Vranic M., Leto J. and Kutnjak H., 2015. Potential of aerialrobotics in crop production, high resolution NIR/VIS imagery obtained by automatedunmanned aerial vehicle (UAV) in estimation of botanical composition of alfalfagrassmixture. Paper presented at the 50th Croatian and10th International Symposium on Agriculture.

Press Information Bureau Government of India Ministry of Agriculture, 2015, KISAN project, http,//pib.nic.in/newsite/PrintRelease.aspx?relid=128429

Price P., 2004. Spreading the PA message. Ground Cover, Issue 51 Grains Research and Development Corporation, Canberra, Australia Capital Territory, Australia.

Primicerio J., Di Gennaro S., Fiorillo E., Genesio L., Lugato E., Matese A., and Vaccari F.P., 2012. A flexible unmanned aerial vehicle for precision agriculture. Precis. Agric., Vol.13:517–523.

Quilter M. C., 1997. Vegetation monitoring using low altitude, large scale imagery from radio controlled drones. PhD dissertation, Department of Botany andRange Science, Brigham Young University, Provo, UT, USA.

Quilter M. C., and Anderson V.J., 2001. A proposed method for determining shrub utilization using (LA/LS) imagery. Journal of Range Management, Vol.54:378-381.

Rajvanshi, Dr. Anil K., 2016. Precision Agriculture Could Start A Green Revolution in India, www.huffingtonpost.in/dr-anil-k-rajvanshi/precision-agriculture-can_b_6845378.html,

Rango A., Laliberte A. S., Herrick J. E., Winters C., Havstad K., Steele C., 2009. Unmanned aerial vehicle-based remote sensing for rangel andassessment, monitoring, *a*ndmanagement. Journal of Applied Remote Sensing, 3033542.

Rise Above Custom drone solution, 2016. Agriculture Drones. http,//www.riseabove.com.au/agriculture-drones/.

Robertson M., Carberry P., and Brennan L., 2007. The economic benefits of precision agriculture, cast studies from Australia grain farms, Retrieved March 12, 2012, from http://www.grdc.com.au/uploads/documents/Economics%20of%20Precision%20agriculture%20Report%20to%20GRDC%20final.pdf.

Rouse J. W., Jr., Hass R. H., Schell J. A., and Deering D. W., 1973. Monitoring vegetation systems in the Great Plains with ERTS, In Proceedings 3rd Earth Resources Technology Satellite (ERTS) symposium, Washington, DC, USA, NASA SP-351, NASA, Vol.1:309-317.

Santhosh K.S., Soizik L., Grant M.C. and George A.S., 2003. Remote sensing applications for precision agriculture, A learning community approach. Remote Sens. Environmen, Vol. 88(1-2):157-169.

Sampaio C. B., Hernandes A.C., Becker M., Catalano F.M., Zanini F., Nobrega J.L., and Martins J., 2014. Novel hybrid electric motor gliderquadrotor MAV for inflight/ VSTOL launching. Paper presented at the Aerospace Conference IEEE.

Sato A., 2003. The rmax helicopter uav. DTIC Document.

Sebastian Candiago , Fabio Remondino , Michaela De Giglio , Marco Dubbini , and Mario Gattelli, 2015. Evaluating Multispectral Images andVegetation Indices for Precision Farming Applications from UAV Images. Remote Sensing, Vol. 7(4):4026-4047, doi,10.3390/rs70404026.

Seelan S. K., Laguette S., Casady G. M., and Seielstad G. A., 2003. Remote sensing applications for precision agriculture, A learning community approach.

Remote Sensing of Environment, Vol. 88:157–169.

Shenghui Fang, Wenchao Tang, Yi Peng, Yan Gong, Can Dai, Ruhui Chai and Kan Liu, 2016. Remote Estimation of Vegetation Fraction andFlower Fraction in Oilseed Rape with Unmanned Aerial Vehicle Data Remote.Sensors, Vol.8: 416-435

Spanoudakis, P., Doitsidis, L., Tsourveloudis, N. andValavanis, K., 2003. Vertical TakeOff andLanding vehicle market overview. KOREA, 1,4.

Stafford J. V., 2000. Implementing precision agriculture in the 21st century. Journal of Agricultural Engineering Research, Vol.76:267–275.

Stefanakis D., Hatzopoulous J.N., Margaris, N.S., Danalatos N.G., 2013. Creation of a remote sensing unmanned aerial system (UAS) for precision agriculture andrelated mapping applications, In Proceedings of 2013 ASPRS Annual Conference, Baltimore, MD, USA, 24–28 Marrch 2013, p. 13.

Sugiura R., Fukagawa T., Noguchi N., Ishii K., Shibata Y., and Toriyama K., 2003. Field information system using an agricultural helicopter towards precision farming. IEEE/ASME Proceedings. Advanced Intelligent Mechatronics AIM 2003.

Sugiura, R.; Noguchi, N.; Ishii, K., 2005. Remote-sensing technology for vegetation monitoring using an unmanned helicopter. Biosyst. Eng., Vol.90:369–379.

Sullivan D. G., Shaw J. N., and Rickman D., 2005. IKONOS imagery to estimate surface soil propertyvariability in two Alabama physiographies. Soil Science Society of America Journal, Vol.69:1789–1798.

Sullivan D. G., J. P. Fulton, J. N. Shaw, and G. Bland, 2007. Evaluating the Sensitivity of an Unmanned Thermal Infrared Aerial System to Detect Water Stress in a Cotton Canopy. American Society of Agricultural andBiological Engineers, Vol.50(6): 1955-1962, ISSN 0001-2351.

Swain K. C., Jayasuriya H. P. W., and Salokhe V. M., 2007. Suitability of low-altitude remote sensing images for estimating nitrogen treatment variations in rice cropping for precision agriculture adoption. Journal of Applied Remote Sensing, 1, 013547 , http,//dx.doi.org/10.1117/1.2824287

Swain K.C., Thomson S. J., and Jayasuriya H. P. W., 2010, Adoption of an Unmanned Helicopter for LowAltitude Remote Sensing to Estimate Yield andTotal Biomass of a Rice Crop. American Society of Agricultural andBiological Engineers, Vol.53(1):21-27 , ISSN 2151-0032.

Tamouridou A., Alexandridis T. K.,. Pantazi X. E, Lagopodi A. L., Kashefi J., and Moshou D., 2017. Evaluation of UAV imagery for mapping Silybummarianum weed patches. International Journal of Remote Sensing, Vol.38(8-10): 2246-2259.

Tenkorang F., and DeBoer L., 2007. On-farm profitability of remote sensing in agriculture. Journal of Terrestrial Observation, Vol.1:50–59.

Tice Brian P., 1991. andquot;Unmanned Aerial Vehicles – The Force Multiplier of the

1990s andquot;. Airpower Journal, Archived from the original on 24 July 2009, Retrieved 6 June 2013.

Tomlins G., and Lee Y., 1983. Remotely Piloted Aircraft—An Inexpensive Option for LargeScale Aerial Photography in Forestry Applications, Canadian journal of remote sensing, Vol.9(2):76-85.

Turner D., Lucieer A., and Watson C., 2011. A flexible unmanned aerial vehicle for precision agriculture. In Proceedings of 34th International Symposium on Remote Sensing of Environment, Sydney, Australia.

Ugur Ozdemir, Yucel Orkut Aktas, Karaca Demirbag, Ahmet Erdem Ganime Duygu Kalaycıoglu, Ibrahim Ozkol, andGokhan Inalhan, 2014. Design of a Commercial Hybrid VTOL UAV System. Journal of Intelligent andRobotic Systems, Vol.74 (1),:371–393.

Unmanned Aircraft System, 2016. andquot;ICAO and#39;s circular 328 AN/190 , Unmanned Aircraft Systems andquot; (PDF), ICAO, www.icao.int/Meetings/UAS/Documents/Circular%20328_en.pdf.

Vega Francisco Aguilera, Fernando Carvajal Ramirez, Monica Perez Saiz, and Francisco Orgaz Rosu 2015. Multi-temporal imaging using an unmanned aerial vehicle for monitoring sunflower crop. Biosystems Engineering, Vol. 132: 19–27.

Warren G., and Metternicht G., 2005. Agricultural applications of high-resolution digital multispectral imagery, Evaluating within-field spatial variability of canola (Brassica napus) in Western Australia. Photogrammetric Engineering andRemote Sensing, Vol.71: 595–602.

Wu J. D., Wang D., and Bauer M. E., 2007a. Assessing broadb andvegetation indices andQuickBird data in estimating leaf area index of corn andpotato canopies. Field Crops Research, Vol.102: 33–42.

Yang C., Everitt J. H., Bradford J. M., and Escobar D. E., 2000. Mapping grain sorghum growth andyield variations using airborne multispectral digital imagery. Transactions of the ASAE, Vol.43:1927-1938.

Yao H. L., Tang L., Tian Brown R. L., Bhatnagar D., and Cleveland T. E., 2010, Using hyperspectral data in precision farming applications, Ch. 25, In P. S. Thenkabail, J. G. Lyon, andA. Huete (Eds.), Hyperspectral remote sensing of vegetation (pp. 705), Boca Raton, FL, CRC Press.

Xiang H., and Tian L., 2011b . Method for automatic georeferencing aerial remotensensing (RS) images from an unmanned aerial vehicle (UAV) platform. Biosystems Engineering, Vol.108(2): 104-113.

Zarco-Tejada P. J., Gonzalez-Dugo V., and Berni J. A. J., 2012. Fluorescence, temperature andnarrowb andindices acquired from a UAV platform for water stress detection using a micro-hyperspectral imager anda thermal camera. Remote Sensing of Environment., Vol. 117:322–337.

ZarcoTejada P. J., DiazVarela R., Angileri V., and Loudjani P., 2014. Tree height antification using very high resolution imagery acquired from an unmanned aerialVehicle (UAV) andautomatic 3D photo reconstruction methods. European Journal of Agronomy, Vol. 55:89-99, doi, http,//dx.doi.org/10.1016/j.eja.2014.01.004.

Zhang J. H., Wang K., Bailey J. S., and Wang R. C., 2006. Predicting nitrogen status of rice using multispectral data at canopy scale. Pedosphere., Vol.16: 108–117.

Zhao D. H., Huang L. M. L., and Qi J. G. 2007. A comparative analysis of broadb and andnarrowb andderived vegetation indices in predicting LAI andCCD of a cotton canopy. ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 62: 25–33.