Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 5, Issue 08, August -2018

A REVIEW OF REMOTE SENSING SENSORS AND FUSION IN PRECISION AGRICULTURE

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Abstract —*Precision agriculture merges the new information technologies with agricultural industry. With a drone or UAV we can capture highly accurate images of fields, covering hundreds of hectares in a single flight .Without cost and hassle of manned services. And by using image processing we can then transform these shots into information and systems that allow optimizing and customizing time, amount, and placement of inputs (seed, fertilizer, pesticides, irrigation, etc.). Remote sensing techniques, mainly aerial imagery in the visible and infrared bands, have been employed to achieve this goal. This article presents a state-of-the-art review on precision agriculture especially in remote sensing sensors. This analysis is based on a literature research, an important contribution to this paper is a characterization of high quality sensors and performance metrics to allow simple comparison between different types of sensors that can be used by unmanned aerial vehicles (UAV).*

Keywords-*Remote sensing, Unmanned aerial vehicles ,Multispectral images, Hyperspectral image, Thermal sensors, light detection and ranging .*

I. INTRODUCTION

Global food security is threatened by increased demands from a growing global population, increased competition for land, and the need for sustainable production to lead a healthy and active life. Precision agriculture is an innovative, integrated and internationally standardized approach it depends on a combination of fundamental technologies such as remote sensing , global positioning system (GPS), geographic information system (GIS), image processing. Protocols for PA implementation can be encapsulated in three general steps: (1) Gathering information about variability, (2) Image processing and analyzing information to assess the significance of variability and (3) Decision and implementing change in the management of inputs. This tree steps helps to optimize the quantity and quality of agricultural production.

Over the past four decades, the development of precision agriculture technologies opened up new horizons for supporting agricultural crop, High-resolution satellite imagery is now more commonly used to study these variations for crop and soil. However, the unavailability of service and the prohibitive costs of such imagery would suggest an alternative product for this particular application in Precision agriculture. Specifically, images taken by low altitude remote sensing platforms, or unmanned aerial vehicles (UAV), are shown to be a potential alternative given their low cost of operation in environmental monitoring, high spatial and temporal resolution, and their high flexibility in image acquisition programming, current research on precision agriculture also focuses on the development of sensors with which crop and soil properties can be remotely detected in real-time, including digital image analysis and remote sensing which provides an efficient way to identify variation in crop biophysical status information, such as canopy nitrogen content, leaf coverage, and plant biomass [1]. It plays a crucial role in agricultural monitoring [2], mainly in the identification of nitrogen stress [3-5]. It is admitted as one of the most useful to quantify both temporal and spatial variations of crop conditions which are necessary for the application of precision agriculture.

Yield-prediction models are often based on the assumption that yield production is influenced by measureable biophysical parameters such as Leaf area index (LAI) and chlorophyll content which are important vegetation variables which can be monitored using remote sensing. Typically, healthy plants are green. Long before the stress factors that endanger plants can be seen in the visible spectrum, they appear in the near-infrared (NIR) (Figure1), plants absorbs visible light and reflects near infrared, healthy plants reflect more than stressed plants, Thus, analyzing a plants spectrum of absorption and reflection in visible and infrared wavelengths can provide meaningful information about the plants' health and productivity. This is why optical sensors in the visible and near-infrared parts of the electromagnetic spectrum have become popular [6].

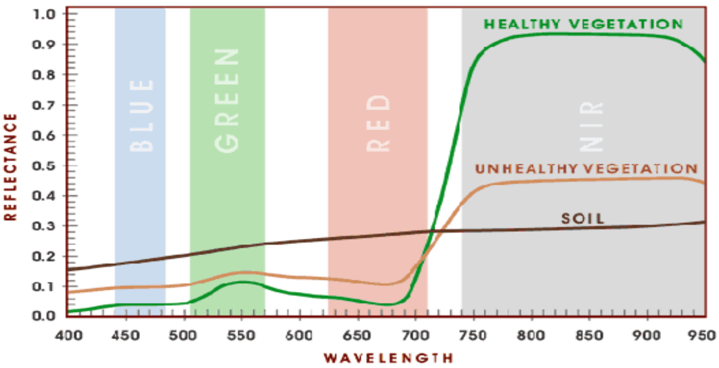

Fig.1: spectral signature of plant and soil.

Changes in vegetation reflectance in the visible region due to stress conditions is apparent by the changes in chlorophyll content as a function of metabolic change , in which can be identified in remotely-sensed images through the use of vegetation indices [7-11]. Normalized difference vegetation index NDVI and simple ratio indexes SRI [12] are among the examples of standard graphical indicators that exploit the relationship of chlorophyll content absorption and the overall health of plants to the structural reflectance in the NIR region.

II. OVERVIEW AND CURRENT SITUATION

In the 1960s, a new dimension was added with the development of airborne and satellite platforms for remote sensing of land surface features. In the 1970s the well-known Landsat series of satellites was in use for biomass sensing and crop/soil moisture sensing, based only on spectral analysis of the solar radiation reflected by plants and soils. Over the past four decades, a variety of remote sensing devices, ranging from satellites to the general digital camera, have been utilized and evaluated for precision agriculture applications. In previous researches, remote sensing is used for precision agriculture in different methods for example by monitoring seasonally variable crop condition [13-14], or by creating biomass estimation during the growing season using the traditional approach based on vegetation indices [15], or by providing information on soil and plant condition and variability to the overall crop management and decision support system. According to article [16] they introduced an effective method based on remote sensing detect specific insect pests and to distinguish between insect and disease damage on oat. Results showed that spectral reflectance differences between these two damages, but these differences may not be consistent from one growing season to the next.

In recent years, Synthetic Aperture Radar (SAR) data can be used to estimate the near-surface soil moisture content [17-18], it also can provide useful information about crop and soil parameters, such as weed infestations and soil moisture, with low spatial resolution. Research in remote sensing has led to the development of methods for retrieving wetland biomass from backscattering values collected by Radar system in order to quantify biomass for optimizing livestock management [19]. Even though remote sensing technologies (Figure2) plays an important role in overall applications of precision agriculture, most of practices of researches are based on single source of remote sensing platform, either from satellite data, or from airborne data, or from ground-based data. There exist the significant merits and drawbacks (See table 1).

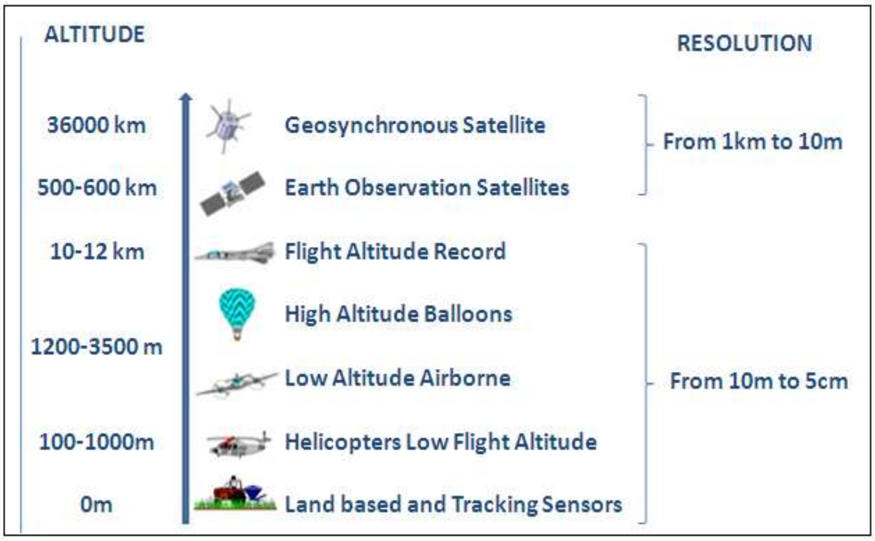

Fig.2. Remote sensing technologies

Type	Advantages	Disadvantages
Satellite	Data are already available Cost of large area image is very low Data for radiometric bands up to 16 micro meters	Resolution is lower Repeat cycle is out of control Atmospheric interference
Aerial photogrammetry	Quick scan of large area Low cost when scanning large area High resolution data	High cost for small area Affected by Weather condition Calibration
Low-altitude remote sensing	Very high resolution data Flexibility for data acquisition	Hard to Geo-referencing
Close range photogrammetry	immediate recording Accurate	Not applicable for large surface

Table1. Comparison between different remote sensing platforms.

Satellite and low-altitude remote sensing platforms provides detailed information on the reflected spectrum, The advantages of low altitude imaging systems are their low cost, high spatial resolution, real-time or near-real-time availability of imagery for visual assessment and computer image processing.

III. SENSING TECHNOLOGIES FOR PRECISION AGRICULTURE

The implementation of Precision Agriculture has become possible thanks to the development of sensor technologies, especially aerial imagery in the visible and infrared bands, it have been employed to achieve this goal. The GPS (Global Positioning System) system allows easy geo-referencing of these images, making it possible to produce maps showing problems in the crop that can be easily located and corrected.

Remote sensing is a data acquisition technique that has been used extensively to identify, document and solve several problems in agriculture. Aerial images are a very precise and convenient source of data for agricultural management. Direct image acquisition of aerial images has become a useful resource for aerial photography [20-23]. These images can be useful to detect problems that can be corrected in the same or in the next agricultural season.

The purpose of remote sensing is to acquire information about the Earth's surface without coming into contact with it. One objective of remote sensing is to characterize the electromagnetic radiation emitted by objects [24]. Typical divisions of the electromagnetic spectrum include the visible light band (380-720nm), near infrared (NIR) band (0.72-1.30µm), and mid-infrared (MIR) band (1.30-3.00µm). The advantage of an ability to examine different bands is that different combinations of spectral bands can have different purposes. For example, the combination of red-infrared can be used to detect vegetation and the combination of red slope can be used to estimate the percent of vegetation cover [25].

3.1. Remote sensing sensors

Precision agriculture helps identifying, understanding and utilizing information that quantifies variations in soil and crop within agricultural season. The information needed is generally data provided by sensors. Many sensors are currently available and used for data gathering or information provision as part of the Precision Agriculture implementation, digital cameras for example Kodak DCS cameras [26, 27] have Bayer-pattern filters which the red, green and blue filters all transmit significant amounts of NIR light [28]. Spectral remote sensing sensors can be divided into multispectral sensor and hyperspectral sensor. Multispectral sensors consists of a limited number of spectral bands[24], and contains information about vegetation crop greenness and structure[29], and hyperspectral imagery contains more than 100 spectral bands, which are narrower than multispectral bands ,they provide a continuous reflectance spectrum [28]. Every pixel has a complete spectrum and this can be used for agricultural surveillance. With lightweight hyperspectral imaging systems can be mounted on small UAVs. These systems can effectively monitor more detailed information and specific crop physiological parameters, such as chlorophyll, water conditions and carotenoids [29]. Hyperspectral solutions can detect chlorophyll or very small color-changes on foliage, and capture imagery from tens to hundreds of narrow spectral bands and offer new opportunities for better differentiation and estimation of biophysical attributes, but it has not been used as widely as multispectral imagery partially due to the high costs of data acquisition and the special needs for handling and processing vast volumes of data. Hyperspectral and Multispectral sensors have been developed using modern CCD(Charge-Coupled Device) and CMOS (Complementarity metal-oxide-semiconductor)fabrication techniques combined with advanced filters. The resulting sensors are more cost effective while maintaining the high performance needed in remote sensing applications. Finally imaging systems can contain multiple high-resolution image sensors such as:

3.1.1. Visual sensor

- *High resolution, low distortion camera (RGB)*
- *Produces images or video*
- *Longer focal length lens on for high resolution images*
- *Skis to protect larger lens*
- *Higher data rate storage card*

Ideal for:

- *Aerial mapping and imaging*
- *Photogrammetry and 3D reconstruction*
- *Plant counting*
- *Surveillance*
- *Emergency response*
- *Surveying and land use applications*

3.1.2. Multispectrak sensor

Multispectral sensors are used widely in:

- *Plant health measurement*
- *Water quality assessment*
- *Vegetation index calculation*
- *Plant counting*

3.1.3. Hyperspectral sensor

Hyperspectral sensors are used widely in:

- *Plant health measurement*
- *Water quality assessment*
- *Vegetation index calculation*
- *Full spectral sensing*
- *Spectral index research and development*
- *Mineral and surface composition surveys*

3.1.4. Thermal infrared sensor TIR

Thermal sensors are best utilized in:

- *Heat signature detection*
- *Livestock detection*
- *Surveillance and security*
- *Water temperature detection and water source identification*
- *Emergency response.*

3.1.5. light detection and ranging sensor LIDAR

- *Short range, 270° scanning LASER rangefinder*
- *Useful in 3D digital surface modeling, stockpile calculation, surface variation detection and flood mapping*
- *Penetrates through vegetation*

Robustness of single-sensor measurements is often less than ideal because virtually all currently used sensor technologies can respond to more than one basic parameter of interest. For example, crop canopy reflectance sensors can be affected by multiple stressors such as water or nitrogen deficiencies, the reflectance of the underlying soil, and the size of the crop plants. As every soil-sensing technology has strengths and weaknesses and no single sensor can measure all soil properties, nevertheless, when different sensors are assigned different functions in the development of a multisensory system, more robust solutions can be found and deployed over a wider range of farm operations. Sensing systems that combine multiple sensors already available in groups of 4, 6 or 12 sensors. Cameras may be cascaded together or individual sensors may be removed to provide the precise number of sensors required [30], and others are in various stages of development. However, multisensory platforms are difficult to implement in an agricultural setting due to constraints such as cost and durability. Typically low profit margins mean that agricultural producers are not willing to adopt technology with a high added cost. New research in the area of sensor fusion for precision agriculture is expected to provide a variety of such examples.

IV. MULTISENSORY SYSTEM AND DATA FUSION TECHNOLOGIES

Image Fusion is a process of combining the relevant information from a set of images into a single image, where the resultant fused image will be more informative and complete than any of the input images. Image fusion techniques can improve the quality and increase the application of these data.

In general, remote sensing fusion techniques can be classified into the pixel level and the high level (i.e. feature level, and decision level) [31].The pixel level fusion is mainly applied to optical images, such as panchromatic and multispectral images [32-36]. Pixel level fusion is the combination of raw data from multiple sources into single resolution data, which are expected to be more informative and synthetic than either of the input data or reveal the changes between data sets acquired at different times. The data gathered from multiple sources of acquisition are delivered to preprocessing such as denoising and image registration. This method helps to associate the corresponding pixels to the same physical points, and the input images are compared pixel by pixel Figure4.

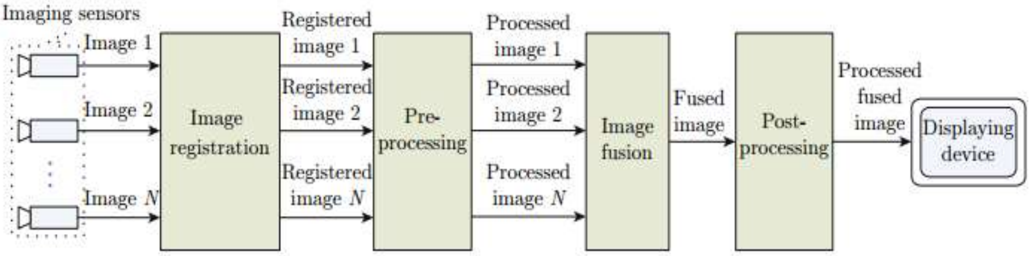

Fig.2. Image Fusion

The high level fusion includes multi-source data fusion, such as SAR, optical images, GIS data, LiDAR data, and in-situ survey data [37-38] In some applications on precision agriculture and forest, plant growth model combining hyperspectral, LiDAR, TIR, and field data could be proposed to estimate plant heights. In conclusion remote sensing data fusion, is one of the most commonly used techniques, aims to integrate the information acquired with different spatial and spectral resolutions from sensors mounted on aircraft to have a high-resolution multispectral image which combines spectral characteristic of the low-resolution data with the spatial resolution of the panchromatic image so as to produce fused data that contains more detailed information [39]. Thus Image fusion is the combination of two or more sensors to improve visual perception or feature extraction, PA is an excellent example of a system approach where the use of the sensors fusion is important..

V. CONCLUSION

Remote sensing sensors collects data on energy reflected from the plants and soil. There is multiple remote sensing technologies available to measure variability in plants and soils. It can be used to identify plant diseases, water deficiency, weed infestations, damage, and plant populations. Information given by remotely sensed images allows farmers to treat only affected areas, problems can be identified remotely by robust sensors before they can be visually identified. Remote sensing is the key component of the precision agriculture. It has not yet developed into a practical and profitable management tool for agriculture. This paper mainly focused on remote sensing sensors and fusion on precision agriculture. Due to the fast development of various sensor technologies, development of effective methods for automatic fusion of the multi-platform remote sensing data will be difficult.

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