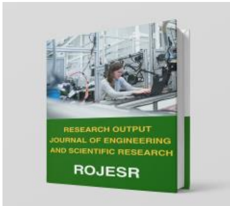

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Applications of Remote Sensing in Precision Agriculture

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ABSTRACT

Precision agriculture (PA) is revolutionizing modern farming by integrating advanced technologies like remote sensing, GIS, GPS, and various proximal sensors to enhance farm management. Remote sensing, in particular, provides valuable data on soil properties, crop health, moisture levels, and more. This paper explores the key applications of remote sensing in precision agriculture, focusing on crop monitoring, resource optimization, and yield estimation. Despite its potential, the adoption of remote sensing technologies faces challenges such as high costs, complexity in data processing, and the need for skilled personnel. Future directions include improving cost-effectiveness, data integration, and developing regulations to support sustainable farming practices.

Keywords: Precision Agriculture, Remote Sensing, Crop Monitoring, GIS, GPS.

INTRODUCTION

Precision agriculture is an emerging field of interest that utilizes satellite information and high-resolution imagery with global positioning system (GPS) locations of the field to create the field map. This map shows the variability in the field like soil quality, soil type, organic matter content, yield, and growth. Remote sensing-based information has the complementary data regarding the field properties. However, the integration of both sensor-based soil properties and remote-sensing data can provide synchronized and detailed information and may prove fruitful for diagnostic and action-based research applications in precision agriculture. The details of soil property mapping using various types of proximal sensors are given in the next section. In the emerging frontiers, the use of unmanned aerial vehicles has crept in for measuring these biophysical variables. This is in contrast to the use of larger commercial models of sensors installed on drones. The working and schematics of these devices are presented in a later section [1, 2]. Precision agriculture is a technology-based system to manage each farm unit as a single farm, considering diversification standards, economic discrimination, and optimized deployment of resources. A precision approach is an emerging field of studies by utilizing high-resolution satellite and high-resolution multispectral imagery to identify the field map and plans variation for the production units. Today's precision agriculture is introducing the era of automata (i.e., sensors equipped to the machines to perform some specific functions in a zone-specific manner). The use of GPS is made for mapping and spatial planning of inputs according to location-specific soil stratification and plant development. The basis of precision agriculture was laid down in the mid-1980s. Post-liberalization, the economic change in agriculture in developed countries led to the introduction of precision agriculture techniques that gave due importance to maintaining the uniform stratification of the soil. In precision agriculture, techniques focus on the consideration of the specific source of factors impacting soil-management options. The development of sensors for topographic and thematic stratification of soil and plant properties resulted in increased production and profit as well as improved quality of products [3, 4].

DEFINITION AND PRINCIPLES

Precision agriculture is one of the most exciting and promising fields of scientific research. Precision agriculture depends on adopting recent and advanced techniques. It is essential to understand the basic principles of precision agriculture to make use of different scientific techniques in the right way. Precision agriculture refers to the controlling, measuring, and guiding of agricultural and forestry fields through new technology such as remote sensing, geographical information system (GIS), global positioning system (GPS), and information collection software and hardware. There are two basic principles of precision agriculture: potential production of the field and field variable signals; variation in the field [5, 6]. Many people could not understand what this field is. According to some researchers, precision agriculture is an innovative way of handling the land. Many researchers believe that precision agriculture is a subtle use of new tools in connection with the old standards of mountain works. According to the researchers who had been focusing on velocity, high working width machines, these processes of precision agriculture also existed, and the calculation methods are based on the most recent captors used. However, no mechanism is always under control and must still be manually initiated. In addition, farmers must still rely on their senses to stop seeding in case of rust, perform an in-depth inspection of the hopper, consult the pressure gauge, search and uncork the blocked hoses, etc [7, 8].

ROLE OF REMOTE SENSING IN PRECISION AGRICULTURE

Low labor cost and requirement of less space and fuel are the driving forces behind the development of precision agriculture (PA). The adoption of this farming process results in a decrease in the use of fertilizers, chemicals, seeds, and costs related to irrigation. The machines cannot solely perform the complete PA practice without skilled manpower for selecting the plant, variety, and parameters to maintain the quality of crops. Many studies have stated that the quality crop can be achieved from better management and careful maintenance of the crops. One of the most important parts of PA is the applications of remote sensing which have been discussed here for the selection of spectral sensors to monitor the crops [9, 10]. Remote sensing (RS) has revolutionized the concept of collecting data for precision farming. In PA, yield and quality map generation based on inputs and data obtained by remote sensing have practical and efficient applications. The employment of remote sensing technology in precision agriculture (PA) is essential for routine field information assessment. This technology plays a significant role in determining crop health, the detection of invading weeds, and the description of soil chemical and moisture content. This has made in-field decision making possible. In addition, remote sensing has the added advantage of being quick, precise, and providing faster results. Remote sensing has now become an essential tool for resolving such agricultural issues, though other strategies are now obsolete. It is noteworthy that soil-related issues are also linked to the environment, but this article primarily focuses on precision farming apart from the remote sensing related to soil and natural resources [11].

TYPES OF REMOTE SENSING TECHNOLOGIES

Types of remote sensing technologies in the past, astronauts were able to capture images containing detailed data about the Earth's cover from space. At present, the collection of information about the Earth's surface and its cover from distant locations, known as remote sensing, has become quite invaluable. Onboard sensors, flying in satellites or relatively lighter vehicles, help gather data for various global applications, including the application of remote sensing in the field of agriculture. Researchers have deployed a variety of sensors onto vehicles or carriers to address issues in precision agriculture. These technologies primarily include digital cameras, electro-optical sensors, and thermal sensors [12]. Remote sensing involves the aerial-based or space-based collection of information regarding the Earth's surface from certain specified heights. With the help of image processing software, researchers can integrate these data sources to get information on, for example, a farmer's field. Such data sources help calculate the boundaries and areas of various types of geometric fields. This helps the farmer manage his resources with the help of GIS, which converts the raw data to useful information. Subsequent research in remote sensing has revealed, through the captured information, detailed insights about the health and fertilization status of a farmer's field, which can help the farmer manage his resources using optimal inputs. With the help of these technologies, one can survey a large area of land and derive results on the behavior of the constituents of the land. Precise application of inputs reduces the cost of production [13, 14].

KEY REMOTE SENSING APPLICATIONS IN PRECISION AGRICULTURE

In former times, remote sensing applications were usually limited to research or small pilot projects, often in the field of land use and land cover classification or resource and environmental monitoring. This has changed, and today many applications have reached full operational capacity over large areas, up to a global scale, due to the availability of spaceborne data. The main reason for this significant trend is the development, advancement, and operational utilization of remote sensing as a standard tool for crop monitoring and management. This section mainly focuses on the agricultural applications of remote sensing data with a particular emphasis on crop-related applications, including image data processing steps and solutions that can support decision-making for authorities, researchers, or stakeholders [15]. To give an overview of the numerous practical applications of remote sensing data, we start with a brief classification that will then guide the reader through this paper. For a more detailed understanding of the application scenarios, we provide a selected range of examples at the end of each chapter. Today, one of the principal domains of application of remote sensing data is the agricultural sector. Despite the fact that remote sensing initially targeted scientific and geological applications, increasing availability and technical improvement of remotely sensed data have facilitated their integration into daily decision and policy-making in agriculture. This thematic section on Remote Sensing in Agriculture intends to give a contribution to the scientific community by showing new relevant applications of remote sensing data that provide novel and added scientific and operational value to the technically-oriented rural stakeholder and farmer [16].

CROP MONITORING AND MANAGEMENT

Crop monitoring and management is one of the primary applications of remote sensing, and a variety of remote sensing techniques have been employed. The coarse to fine spatial and temporal resolution of images captured from satellites and fixed-wing UAVs makes them a prominent choice for wide-area and field-scale monitoring, respectively [17]. In precision agriculture, the useful information acquired through remote sensing is used to manage various aspects such as sowing and harvesting, crop fate due to water stress and disease, to estimate yield, and quantify and optimize inputs like water, fertilizer, and pesticide. Remote sensing techniques such as hyperspectral and multispectral technology, which record both optical, visible, and near-infrared (VNIR) and short-wave infrared (SWIR), are used widely for these purposes. The optical camera records two to 10 bands typically, whereas hyperspectral sensors are employed to collect a range of 100 to 250 bands with a bandwidth of 1 to 10 nm. Applications of hyperspectral sensors are widespread and include monitoring stress plants due to pathogens [18]. Fixed-wing UAVs and ground-based sensors are capable of monitoring stress in the plants by acquiring the thermal images due to crop water stress, recording the temperature of the plants. The thermal cameras used by fixed-wing UAVs are less expensive than hyperspectral cameras and are widely applied. However, the thermal camera provides only surface plant temperature, which changes with some time delay in the higher plant stress compared to the thermal cameras that acquire temperature at the leaf level of the plants [19]. The studies of assessment of irrigation on different crops using remote sensing involves the change in the spectral reflectance of nitrogen, carbon, and water in the fields. Non-imaging sensors such as Light Detection and Ranging (LiDARs) are also another choice used in agriculture for monitoring plant height, canopy structure, and crop yield [20].

CHALLENGES AND FUTURE DIRECTIONS

A broad range of sensing technologies are currently available, which are very powerful tools for measuring several agrobiophysical variables. Nevertheless, the use of remote sensing based on proximal and aerial data among farmers or agriculturally oriented contractors is limited in comparison to the area-wide use in scientific studies. The price of purchase and application often exceeds the incomes and increased margins achieved on the farms, which oscillate mostly around 5% of acreage costs. Another challenging perspective representing a trend of future extensive development is the lack of experienced people who are involved in mathematical, informatics, and decision-making processes built in the remote sensing technologies to pull the base knowledge of the precise location of all agricultural systems in relation to inputs and climate projection [21, 22]. In a broad formula for future activities, remote sensing in precision agriculture in sustainable and organic systems should be used not only for operational approaches but also for checking compliance of integrated farm activities in relation to the POSM. It would allow the development of a digital report of farm operations that can be accompanied by a production certificate based on compliance of activities. It should underline other significant results of stems and leaves close-up sensors, which could also be combined with precision agriculture oriented to further opening new products in agriculture and forestry to reduce the use of man-made herbicides and fertilizers in human nutrition and the environment. A great challenge in this regard is to develop regulations drafted in advance and followed up. The use of technology to collect field data was also discussed during the workshop, linking investment in new technique application, interest, and income per crop/philosopher on the sample [23].

CHALLENGES IN IMPLEMENTING REMOTE SENSING TECHNOLOGIES

Challenges exist in the practical implementation of remote sensing (RS) technologies in precision agriculture due to reasons specific to agriculture and/or to remote sensing. Precision agriculture features a highly variable and disconnected agriculture sector. Although we aim for a landscape process, an optimal solution will often be the combination of different technologies. The advent of low-cost satellite or unmanned aerial system (UAS)-based RS is certainly promising. These technologies are halves of processes, which adds to the complexity [24]. Challenges include the strongly interconnected and multistage nature of the data processing pipelines, which have to take into account the complete data processing cycle, particularly data pre-processing. The application essentially involves three domains: (i) the sensing process where different optical, microwave, or other related sensors and platforms are used, (ii) data analysis where large or fragmented data sets have to be treated, a processing strategy has to be determined, and models have to be calibrated and validated, and (iii) the actual implementation phase of the system in which selective techniques are redistributed or combined such that the process can run smoother and more accurately in time. The realization of those process steps is non-trivial in remote sensing. Domain (i) involves techniques that have been researched and continued for the last decades, resulting in the current mainstream available satellite and UAS technology. Domains (ii) and (iii) are currently in the full attention of recent researchers. More attention will be made to the realization of full functionalities and applicable systems that allow sustainable care and decisions for growing plants in agriculture or knowing the state of animal yards in livestock farming [14].

CONCLUSION

The integration of remote sensing in precision agriculture offers significant advantages in terms of enhanced crop monitoring, resource optimization, and yield prediction. By providing detailed and timely data, remote sensing helps farmers make informed decisions, ultimately leading to increased productivity and sustainability. However, the widespread adoption of these technologies is hindered by challenges such as high costs and the need for specialized knowledge in data processing and interpretation. To fully realize the potential of remote sensing in precision agriculture, future efforts should focus on making these technologies more affordable, user-friendly, and integrated with existing agricultural practices. Moreover, developing regulatory frameworks and fostering collaboration between stakeholders will be crucial in advancing the adoption of remote sensing technologies for sustainable and efficient farming.

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