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REMOTE SENSING FOR CROP ACREAGE ESTIMATIONS: A NEW ERA IN AGRICULTURAL MONITORING

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Introduction

In this modern era of agriculture, technologies and innovations will always be key factors to help the farmers and the policy-makers in facing the challenges. Among such modern technologies, remote sensing emerged as the most powerful tool which revolutionized the estimating and monitoring of crop acreage. Traditionally, collecting data regarding crop acreage is a cumbersome process that includes travel and different interpolation techniques. Various factors like delayed monsoon and uneven rainfall affect crop acreage and yield. It is crucial to track, estimate, and forecast agricultural production to manage the global, regional, or local food supply and demand balance for social security (Bingfang *et al.,* 2004). Remote sensing contributes to food security and sustainable farming practices globally by offering precise, timely, and comprehensive data that improves agricultural management precision.

The Need for Accurate Crop Acreage Estimations

Estimating crop acreage is essential for efficient agricultural planning and policy formation. Precise estimations enable governmental bodies and institutions to anticipate food output, arrange for import and export requirements, and address the possible scarcity of food. Crop acreage assessment has historically been based on ground surveys, which, although useful, are labour-intensive, time-consuming, and frequently prone to human error. The need for food is increasing along with the world's population, making more dependable and efficient techniques necessary (Craig *et al.,* 2013). Through the use of remote sensing technologies say the drone technology, satellite imagery, and aerial photography, remote sensing offers an unmatched perspective of agricultural landscapes. It makes it possible to gather data over large regions that are sometimes inaccessible for ground surveys and provides quick and accurate insights.

Remote Sensing for Crop Acreage Estimation

Remote sensing is the process of gathering data and pictures from the Earth's surface without direct contact with it using sensors in airplanes, drones, or satellites. Depending on the crop type, its health, and its stage of growth, these sensors pick up electromagnetic radiation that is reflected or released from the crop (Maurya *et al.,* 2011). The acreage estimation when combined with NDVI will help in estimating the yield (Rao *et al*., 2002). Experts can assess the extent of each crop, classify and identify distinct crop types, and estimate the total acreage by analysing this data. The important remote sensing methods for area estimation include

- Satellite remote sensing
- Drone remote sensing
- Aerial Photography

Satellite remote sensing

Satellite imaging is crucial in estimating modern agricultural areas as it provides an overview of huge areas of farmland from above. The advances in satellite technology have enabled high-quality images that can cover wide terrains, thus making it possible to monitor and assess the crop's growing status accurately. This is not the case with other conventional techniques that require detailed and elaborate ground surveys since satellite imagery offers a more comprehensive monitoring scheme for agricultural fields regardless of their sizes and

locations. In some places where physical accessibility is limited by geographical hindrances or conflicts, this service becomes extremely critical.

Satellite data is one of the most powerful tools that can be used in estimating crop area because it can collect multispectral information. Satellites have attached sensors which can pick up on a variety of light wavelengths including those beyond the visible part of the spectrum like near-infrared (NIR). Additionally, this multispectral approach increases precision when estimating cropland areas while at the same time revealing more details regarding the overall condition of the crop thus enabling proper management of inputs as well as better choices between competing uses for land.

On another note, data that are gathered consistently and frequently by satellites enable them to make crucial decisions when estimating crop areas. Where ground surveys may take time due to seasons or periods, satellites can take images of the same places within specified intervals thus they can be used for continuous monitoring during the growing season. Changes in crop coverage can only be tracked correctly using this temporal aspect; it helps in spotting early signs of potential problems and adjusting estimates where necessary. Moreover, high-resolution satellite images have become accessible, helping us to achieve levels of detail previously believed unattainable, such as identifying individual fields amidst vast farming landscapes. In this regard, constant precise surveillance facilitates flexible crop management and responsive actions against fluctuations resulting in more efficient and sustainable agricultural practices.

GIS is used to supplement and manage spatial information. It helps in increasing the accuracy of acreage estimation. In 2007, Madhya Pradesh, soybean crop acreage estimation using daily available MODIS (TERRA) earth observation satellite data where integration of GIS increased the qualitative and quantitative assessment of soybean crop (Maurya *et al.,* 2011).

Remote sensing and GIS based wheat acreage in district level has been done in Indore district, Madhya Pradesh, India. Single data at flowering stage from Resourcesat-1, LISS-III was used (Goswami *et al*., 2012).

Drone remote sensing

As we reach a turning point in agriculture and technology, there is a need to acknowledge one important tool that has come to play a major role in crop area estimation – drones. These flying devices are perfect for crop area estimation and they should not be viewed as a rival to other methods of aerial data collection. Unlike satellites, which deliver rough images over wide areas at once, drones provide more accurate information from less visible areas on Earth's surface because they are capable of flying over specific fields within the designated covered land. Drones have advanced sensors that allow for high-resolution capture of images with wide-ranging applications such as identifying individual plants or determining borders between different species of cereals (Ahmed *et al.,* 2023). This is because small-scale farming relies heavily on field-by-field assessments in terms of acreage assessment depends largely upon such factors. Their ability to take detailed images on every single level is particularly valuable for smallholder farms since varied factors may lead to differences in total crop mapping within fields.

The ability of drones to collect data consistently regardless of weather conditions constitutes one of the major benefits of drone usage in crop area estimation. In regions where satellite images are often obscured by clouds, drones serve as an alternative source of vital information that can be gathered without any delays. In addition, drones can be deployed at will making it possible to time data collection with certain growth stages or vital moments in the life cycle of crops. By doing this, farmers can make very accurate and timely estimates that help improve farm management and decision-making.

Drones are not only utilized for taking high-quality images, can be outfitted with multispectral and hyperspectral sensors that allow detection of changes in crop health, moisture levels and nutrient content. This means

they can supply accurate area estimation for different types of crops and their growth stage. Hence, this is a way to obtain not only accurate area estimation of crops but also monitor crop growth. By integrating this data with GIS (Geographical Information Systems) and other analytical tools, farmers and other agricultural experts can prepare comprehensive maps which depict the detailed distribution of crops across an area. This localized data with high precision improves on the general precision of estimations for crop acreage; hence drones have become an unbeatable technology in modern farming. Thus, the use of localized data at high precision improves the overall accuracy of estimating acreage; therefore, these machines are essential in modern agriculture.

Additionally, such localized data at a high level of accuracy support better estimates when it comes to yield reports; hence drones stand out as the best option in contemporary farming.

Aerial Photography

Aerial photography is not as commonly utilized as satellites or drones, but it is still an important means of estimating crop areas especially when one wants to take advantage of its distinct benefits. Aerial photography has one major advantage which is its ability to generate high-resolution images that can show fine features within the cultivated fields. Manned aircraft aerials differ from satellite imagery in that they are not hindered by clouds or low spatial resolution; they can be organized according to weather forecasts and hence fly at lower sites with better clarity levels. This makes it particularly applicable in situations requiring precision such as subdivided farming regions and gardens where crops are patterned irregularly.

Amidst other remote sensing techniques, aerial photography can act as an associate data source to augment the overall examination and raise the level of correctness concerning crop area assessments. To illustrate, aerial photographs verify and fine-tune crop classification models which are built using satellite data, thus ensuring that these estimates are both correct and in agreement at various levels. The combination of various remote sensing technologies provides a stronger and all-inclusive method for monitoring agriculture so that it is easier for the stakeholders to comprehend better how crops are distributed and what their state is under different geographical zones.

Applications and Benefits of Remote Sensing in Crop Acreage Estimation

The remote sensing techniques used for estimating crop areas provide certain distinct advantages including:

- Accuracy and Precision
- Promptness
- Economical
- Scalability
- Monitoring Environment

Future of Remote Sensing in Agriculture Area Estimation

- **Advancements in Sensor Technology:**
  - Improved sensor resolution and sensitivity are expected.
  - Future sensors (satellites, drones, etc.) will capture data with unprecedented detail.
  - Enables accurate identification and measurement of small-scale and heterogeneous fields.
  - Beneficial in complex landscapes and regions with diverse cropping patterns.
  - Enhanced ability to distinguish between similar crop types.
- **AI Algorithms:**
  - Capable of processing large amounts of data.
  - Identifies patterns and makes accurate predictions.
  - Automates crop classification and area estimation.
  - Reduces human intervention and minimizes errors.
- **Machine Learning Models:**
  - Recognize subtle changes in crop health, growth stages, and environmental conditions.

- Allows for dynamic and responsive crop area estimates.
- Enables real-time monitoring and decision-making.

- **Decreasing Costs:**
  - Lower costs of deploying and accessing remote sensing tools.
  - More farmers, especially in developing countries, will benefit.

Conclusion

Remote sensing is revolutionizing estimating and monitoring crop area (Mulla *et al.,* 2023). It provides farmers with relevant data that supports them in making decisions critical for food security and sustainable farming. Reliable and timely information about the acreage of various crops cultivated helps in taking decisions by policy makers and planners for agricultural related activities in terms of procurement, storage, import, export and in case of national emergency. Rising consequences as a result of climate change urges the need to have data of crop acreage and take mitigation measures to ensure food supply. The need for acreage estimation for various crops at a particular region helps in its development ensuring the nation's security. Moving into the future, this continued development and use of remote sensing technology will play a big role in determining what global agriculture will look like because we need to feed an increasing population while taking care of the earth.