Geospatial Techniques in Crop Inventory: An In-Depth Review

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Abstract

One of the most often applied strategies for decision support systems and land use planning is the use of geospatial tools. With its ability to provide precise information on agricultural activities like crop identification and the categorization crop health inspection, development of crops, crop area and yield estimation, soil characteristic mapping, and precision farming, remotely sensed imagery is especially useful for agricultural production. Farmers can collect data over large portions of a field using information from global positioning systems (GPS), geographic geographic information systems (GIS), and remotely sensed photography. Using remotely sensed photos, problems in the field can be found before they become significant problems in agricultural productivity. This work aims to cover several methods for using GIS and remote sensing (RS) in many fields, such as soil mapping, precision farming, crop growth, crop condition monitoring, crop identification and categorization, and crop area and yield prediction. It is possible to increase crop productivity by using RS and GIS.

Keywords: Crop acreage, soil mapping, RS and GIS, precision farming, and yield estimation

Introduction

The amount of agricultural land is declining daily as a result of the fast urbanization, industrialization, and population growth. For many nations, agriculture is the main source of food, and it also has a major influence on how their economies are evolving. All farmers and large-scale agricultural agencies want to produce food as cheaply as possible, which emphasizes the need of farmers having a thorough understanding of food production. Farmers may monitor their crops, measure growth conditions, estimate yields, check soil conditions, and apply precision farming with the use of technologies like GPS, GIS, and remote sensing.

For decision support systems pertaining to crops and agricultural strategies, Geographic Information Systems (GIS) in conjunction with Remote Sensing (RS) along with additional data types are essential. For agricultural land, collecting land use and land cover (LU/LC) data is essential. This process is very helpful for planning, development, and decision support systems. Through the use of technology, remote sensing is able to get exact data from patterns on the earth's surface without requiring direct physical touch. These days, this technology uses electromagnetic radiation signals from aircraft or satellites to identify and classify items on the surface of the earth, in the atmosphere, and in the oceans.

A computer system called a geographic information system (GIS) is made specifically for gathering, storing, integration, analyzing, and presenting data from a geographic viewpoint. It examines events and processes, both natural and man-made, from a spatial perspective, emphasizing three different kinds of properties: elements, characteristics, and relationships. Through numerical modification and modeling, measurements can be digitally stored in a computer database, facilitating the analysis of gathered data to generate new insights and linkages. The measured or analyzed information can be shown using a variety of formats, such as lists, graphs, maps, or summary statistics.

2. USES IN AGRICULTURE

In order to estimate crop area, monitor crop conditions, and estimate crop yield, spectral reflectance data is essential for differentiating and classifying crops. The distinct spectral signature of data from remote sensing is useful for classifying and identifying crops. To distinguish two crops that occur on the same day and have the same spectral signature, multi-date data is needed. Utilizing remote sensing imagery, mapping technologies are employed to categorize crops, track crop health, and evaluate agricultural techniques. The following are some of the principal uses of remote sensing in agriculture:

1. Classification and identification of crop types
2. Estimating crop area and yield
3. Evaluation of crop condition (monitoring)
4. Soil characteristic mapping
5. Using precision agricultural techniques

3. Identification and classification of crop type

Crops should be identified and categorized for a number of reasons. Estimating crop acreage and crop productivity greatly benefits from accurate crop identification. The method of remote sensing is essential for distinguishing and categorizing various crops according to acreage. Based on the vegetation's spectral reflectance and other patterns, it displays the development and health of the vegetation. Multispectral and multitemporal data, along with mostly supervised and unsupervised labeling approaches, are utilized for crop identification and categorization. In supervised classification, information categories (i.e., crop type) that are relevant in the image are identified by first classifying the pixels of a certain class using training sets. We refer to these as "training signatures." Conversely, unsupervised classification looks at a lot of unknown pixels and groups them into multiple classes according on spectral groups that are present in the image data. Analyst-specified training data is not necessary for unsupervised classification.

4. Subsystems for crop area estimation

The four primary procedures for crop identification, area estimation, and distribution mapping comprise the subsystems of crop inventory. These include stratification, remote sensing area estimates, area estimates derived from area frames sampling, area estimates derived from a mixture of the two sub-processes, and aggregation/desegregation to various administration levels.

1. Regional Stratification: This technique divides the territory into uniform zones based on patterns of agricultural fields and use-type by utilizing a variety of data sets, including soil, topographic, and Landsat satellite data.

2. Area Frame Sampling: Based on sample parcel surveys, this tried-and-true method is utilized in agricultural statistics. It has demonstrated its accuracy and dependability. However, a substantial amount of samples and measurements in the field must be taken each year in order to produce a trustworthy estimate. Costs are significant and errors can occur in the process as a result. The output does not include a map of the distribution of the crops; instead, it is a projection of the total surface area of each crop per stratum. While keeping the quality and dependability of the estimations, the use of remote sensing techniques (pictures) can offer complete coverage of the region and minimize the total amount of segments that need to be surveyed.
3. Area Estimate using Remote Sensing: Based on years of research in Europe, JRC has advocated the so-called "regression estimator" as one of the practical ways to use remote sensing in agricultural statistics. Preprocessing satellite data to eliminate geometric and radiometric defects from the data set is one step in the process. The next step is to classify the data using supervised procedures that involve training classifiers using sample segments. With this approach, an enhanced area estimate per crop in each stratum is obtained by statistically relating the outcomes of the area frame sampling with the image processing.

4. Combination/Diversification to Different Administrative Levels

The above method yields an area estimate at the stratum level, which is an imaginary level. The lowest administrative maps are superimposed on top of the result to convert it into the necessary administration units, which are then aggregated to the necessary level.

5. Crop Condition Evaluation

Monitoring crop conditions is one of the primary benefits of remote sensing. Accurate and timely crop monitoring is essential to the nation's food preservation. Crop acreage and crop yield estimation greatly benefit from crop condition monitoring. Crop condition may be impacted by a number of factors, including weather, pest attacks, disease outbreaks, and the availability of water and nutrients. Crop condition is mainly concerned with the crop's many indicators and specific physical characteristics. Due to the assessment of crop health and the early discovery of crop pests, it is challenging to guarantee high agricultural productivity. Some illnesses, such moisture deficits, insect, fungal, and weed infestations, should be identified early enough to give the farmer a chance to alleviate them. Remote sensing imagery delivers regular photos, ideally within two days, to aid in the early detection of illnesses.

Crop growth is not uniform throughout the field; it varies from one area to another. Different factors, such soil nutrition or other types of stress, contribute to the variations in growth. With the aid of remote sensing technology, farmers may locate regions of their property where crop development is sluggish or absent. This would enable the farmers to treat the affected crops with the proper dosage of pesticides, herbicides, and fertilizers. In addition to raising farmland production, it will also save farm input costs and have negligible environmental impact. The necessary spatial overview of the farms is provided by the remote sensing image. A farmer can use it to view photos of his fields and decide on crop management in real time. Insect, weed, or fungal infestations, weather-related damage, or excessively dry or wet conditions can all influence crops, which can be identified using remote sensing. Pictures taken throughout the course of the growing seasons will be useful in monitoring both the success rate of the treatment and the detection of issues.

We require cloud-free data in order to monitor the condition of the crop, but it is challenging to do so since crop signatures are either not all the same or there is too much variety in a single crop's signature. In this situation, the biomass and structure of the vegetation are greatly influenced by radar remote sensing, and these sensors are highly helpful for crop monitoring. Numerous researchers have documented crop monitoring using remote sensing techniques. The following are some primary helpful techniques for crop condition monitoring:

1. Direct Observation Technique

Because greater vegetation indices indicate better crop condition, vegetation indices are highly helpful in monitoring agricultural condition. Vegetation indicators are the foundation of this direct monitoring approach and are user-friendly. The key indicators that are helpful in tracking crop condition.

2. Monitoring Crop Growth Profile Technique

Using data from a longer growing season, the crop growth profile method assesses the variations in crop growth profiles from year to year. The creation of these profiles involves acquiring NDVI data at the province level. Crop growth profiles are created using the NDVI time series data collected during the crop season. The NDVI profiles of various crops each have distinctive qualities, and even the same crop cultivated in a different environment will show a varied growth profile. An essential tool for evaluating agricultural growing conditions is the NDVI profile.

3. Modeling Crop Growth

This method simulates the many stages of the crop life cycle using a crop growing model. The simulation's outputs are the anticipated crop condition and the growing state.

4. Diagnosis Framework

Using the traits of the situation and the surrounding conditions that affect crop growth, the diagnosis model evaluates the crop condition.

6. Estimating Crop Area and Yield

Estimating crop area is important for a number of reasons, most notably yield estimation. Planning professionals and legislators involved in the procurement, storage, and import/export of food might benefit from accurate and timely crop acreage estimation. Estimating crop area is the foundation of agricultural operations. The following are the essential steps that comprise this procedure:

1. Selection of single-date data with greatest growth of vegetative crops
2. Using ground truth to identify cropping in photos
3. Creation of signatures for the training area
4. Using training statistics to classify images

5. Estimate crop area using district masks or other administrative boundaries.

To estimate crop areas using remote sensing, there are three primary methods:

7. Sub-Pixel Analysis and Pixel Counting

Pixel counting or sub-pixel analysis can be used to determine the area using remote sensing imagery. Due to the possibility of commission or omission errors in picture classification, this method has several limitations.

8. Soil Characteristic Mapping

A deeper comprehension of soil properties is advantageous for agricultural development and management. Conventional techniques for collecting soil samples and laboratory analysis are expensive, time-consuming, and inefficient in fully capturing the temporal and geographical variation of soil quality. In this situation, mapping soil quality parameters is greatly aided by optical and microwave remote sensing, both active and passive. Numerous applications benefit from mapping soil characteristics, including precision agriculture, land-atmosphere exchange of gases studies for modeling climate change, soil and crop management to improve crop yield estimating, sustainable land use preparation, runoff and soil loss modeling in watershed management, and studies of biogeochemical cycles. Mapping soil properties has been studied through the use of microwave (passive and active) remote sensing.

9. Texture of Soil

Precise assessment of spatially fluctuating soil physical attributes, like texture and hydraulic characteristics, is essential for creating dependable water flow models and effectively allocating soil resources to enhance crop yield and environmental standards. Quantifying the space-time variability of soil physical parameters requires a large number of observations, which can be costly and time-consuming.

10. Drainage of Soils

Crop development, water movement, and solute transport in soils are all directly impacted by soil drainage. Soil data will be useful for decision-making on a number of levels, as drainage is a significant concern. Soil drainage, for example, can be effectively mapped and analyzed using radar remote sensing.

11. Roughness of Soil Surface

The thermal characteristics of the soil, the rate of infiltration, surface runoff, and erosion susceptibility are all influenced by soil surface roughness (SSR).

11.1. Methods of Precision Farming

The idea behind precision farming, or agriculture, is to manage the farm by identifying and reacting to different intra-field changes in order to maximize input returns without modifying resource availability. Precision agriculture makes use of GPS or GNSS technology, remote sensing, and GIS to pinpoint the exact location of the farmer in the field. Controlling crop production with the help of fertilizer, seeds, water, and other resources is crucial to boosting yield, quality, and profit while lowering waste. Making eco-friendly decisions at the correct moment is made easier with precision farming. Precision farming enables focused treatment, in contrast to conventional farming methods that distribute crop treatments—such as irrigation, fertilizers, insecticides, and herbicides—uniformly throughout the entire area without taking variability into account. These facilities may readily be utilized in farming to detect specific regions that require treatment, lowering the amount of pesticides used and conserving the environment while saving money. This is made possible by advanced remote sensing technology and lower sensor costs.

To improve agricultural productivity and reduce environmental pollution, precision farming is an emerging technology that links management activities to site-specific soil and crop conditions. It does this by applying pesticides, herbicides, and fertilizers where and when they are most needed. The use of remote sensing, GPS, and GIS are key technologies in precision agriculture. The significance of these technologies for agriculture was highlighted when NASA (Stennis Space Center) launched the Ag 2020 program at the beginning of the twenty-first century. The program's goals include commercializing geospatial technologies, creating useful tools for farmers, and working on projects involving a variety of crops to demonstrate the technologies' applications.

12. Conclusion

Many researchers employ a variety of remote sensing techniques to identify, classify, and analyze different locations or regions, as well as to classify land use and land cover. The properties of the soil are essential for crop growth and productivity. The most beneficial method for analyzing land cover and keeping track of crop conditions is the Normalized Difference Vegetation Index (NDVI) methodology. Precision farming improves crop yield and quality while cutting costs associated with production. It also minimizes the use of chemicals in crop production and maximizes the use of water resources. Technology from the Global Positioning System (GPS), Geographic Information Systems (GIS), and remote sensing (RS) are used to make these advancements.

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