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Role of Remote Sensing and Geographic Information Systems in Modern Agricultural Management

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ABSTRACT

Agriculture is an important component of the economy of every nation, acting as a large trading industry for economically healthy countries. The use of remote sensing and Geographic Information Systems (GIS) to evaluate and depict Farming sceneries has proven immensely helpful for both the farming community and adjacent sectors. The combination of Remote Sensing and GIS gives useful insights into crop health evaluation, crop area estimation, soil moisture monitoring, vegetation analysis, and yield prediction. These technologies also enhance precision agriculture by enabling farmers and agricultural organizations to manage land resources more effectively and optimize inputs such as fertilizers, water, and pesticides. Furthermore, the application of geospatial technology supports governments and policy makers in planning agricultural growth, analyzing catastrophe impacts such as floods and droughts, and assuring sustainable use of natural resources. As a result, the combination of Remote Sensing and GIS helps to enhanced crop management, higher production, and better environmental conservation.

Keywords: *Agriculture, Crop, Remote Sensing, Flood, Vegetation.*

I. INTRODUCTION

An important part of every country's economy is agriculture. The country's robust economy is reflected in its huge trade business. Effective food production at a reasonable cost is the holy grail of all farmers, farm managers, and regional agricultural agencies. Benefiting both farmers and businesses, remote sensing and geographic information systems have made agricultural environment analysis and visualization a breeze. In helping farmers increase productivity, decrease expenses, and manage their land more efficiently, it plays a significant role in agriculture globally. Land cover and land use change detection using geographic information systems (GIS) has been widely implemented and acknowledged as an effective and strong technology. Crop health, infestation extent, prospective yield, and soil conditions may be better understood with the use of remote sensing and GIS. It has

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several potential uses in agriculture, including crop identification, area estimation, crop condition evaluation, soil moisture estimation, yield estimation, agro meteorology, water management in agriculture, and more.

Some of the most significant agricultural uses of remote sensing technology include mapping of disturbances and changes in land use and cover, precision agriculture, irrigation management, monitoring of vegetation vigor and drought stress, estimation of crop acreage and mapping of cropland, and assessment of crop phenological development. Using a geographic information system (GIS) based mapping tool, we may find out where crops are grown all across the nation, adjust various variables, keep tabs on the health of specific crops, estimate field yields, and increase agricultural output. Automated field operations rely on GIS, which helps find areas in need and the root causes of food insecurity by analyzing land-use and primary food crop statistics and data collected from various sources, including mobile devices.

The ability to make informed decisions about crop planning and production maximization has been greatly enhanced by data acquired from both distant sensors and sensors installed on farm machines. Prior crop yields, topographical details, soil organic matter content, pH, moisture, and nutrient levels all contribute to accurate agricultural preparation. By installing GPS tracking devices on their combine harvesters, farmers can monitor not just crop yields but also quality metrics such as plant water content and chlorophyll levels as they are harvested, all in real time and precisely where they were planted. The sustainable use of natural resources and agricultural output may be greatly enhanced by the use of newly developed geospatial and remote sensing technologies, which can monitor crop development, identify and manage various pressures, and estimate regional yields.

II. REMOTE SENSING

In contrast to on-site observation, remote sensing involves gathering data about an item or phenomena without actually touching it. Geographical surveying, land surveying, and the majority of Earth Science disciplines (e.g., hydrology, ecology, oceanography, glaciology, and geology) are just a few of the many areas that make use of remote sensing. The military, intelligence community, businesses, economic planners, and humanitarian organizations all find uses for remote sensing.

In modern parlance, "remote sensing" usually means the practice of detecting and categorizing things on Earth, whether they are on the surface, in the atmosphere, or in the waters, by means of signal propagation, such as electromagnetic radiation. "Active" remote sensing involves a satellite or plane sending out a signal and then the sensor detecting the object's reflection; "passive" remote sensing involves, for example, a sensor detecting the sun's rays.

Decisions about national agricultural policy or action can be informed by the use of remote sensing data by either governmental or local bodies. When it comes to their own crops, individual farmers may also benefit from remote sensing photos by learning more about their health and how to address any issues.

Types of Remote Sensing

1. **Passive Remote Sensing:** It makes use of seasons that detects the reflected/emitted electromagnetic radiation natural sources.

2. **Active Remote Sensing:** It makes the use of seasons that detects reflected responses from object that are irradiated from artificially generated energy sources, such as radar.

Remote Sensing Platforms

1. **Ground Based:** Infrared thermometer, spectral radiometer, pilot balloons, & radars are some of the ground based remote sensing tools.
2. **Air Based:** Aircrafts are air based remote sensing tools.
3. **Satellite Based:** Satellite technology has become handy for wider application of remote sensing techniques. The satellites are subdivided into two classes. These are

    a) **Polar Orbiting Satellites-**These satellites operate at an altitude between 550 &1600 km along an inclined circular place over t5he poles. LANDSAT (USA), SPOT (France), & IRS (India) series are some of the remote sensing satellite.

    b) **Geostationary Satellites-** In order to provide a constant view of the same location on Earth, these maintain a constant speed while they orbit the equator at an altitude of 36,000 km. For the aforementioned reason, India launches the INSAT series of satellites.

III. GEOGRAPHICAL INFORMATION SYSTEM (GIS)

In order to display, analyze, and present information using maps and charts, a Geographical Information System (GIS) integrates location data with both quantitative and qualitative information about the area. The technology allows you to see outcomes, answer queries, and run what-if scenarios. Among the many uses for geographic information systems (GIS) is the management of infrastructural assets, natural resources, and other items. More effective and lucrative design, building, and maintenance are possible thanks to GIS-stored facility and asset data that is easier to evaluate and manage.

The geographic information system (GIS) is a software-based platform that allows users to access, manage, and display, in raster and vector formats, all the necessary information about assets and other things. Geographic information systems (GIS) provide any necessary customization in the following areas: location; parent-child relationships; unique identification; characteristics; technical parameters; and 2D and 3D views. The information and data provided by GIS is the most suitable for meeting the general needs of operations and other software applications since it is easily adaptable, accurate, and user-friendly. The primary GIS application makes it easy to build other GIS-based apps to suit user needs. Utilities (Water, Electric, Gas), Government Agencies, Aerospace, Defense, Mining, Roads, Transportation, Space, and Multi-Locational Work Needs Such systems are crucial. Services like this are overseen by a number of GIS-based departments, such as Utility GIS and Municipal GIS.

They seemed to have a firm grasp on the idea of distant sensing in ancient India. As an example, in the epic "Maha Bharata," Sanjaya was supposedly given special powers that allowed him to report live on the unfolding events on the faraway "Kurukshetra" battlefield, regardless of whether they were revealed or concealed, during the day or night. Recent years have seen the first images taken

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from a balloon while over Paris by a Frenchman named Mr. Tournachen in 1858. The United States Naval effort that studied aerial images in 1961 was rebranded as "remote sensing" and the phrase was first used. In 1968, during a United Nations conference on peaceful uses of space, a couple of papers discussed the potential of remote sensing technology in agriculture and forestry. The first satellite using this technology was launched in July 1972 in the United States. Agricultural plants, like all living things, are vulnerable to pests, diseases, and extreme weather events; furthermore, they require water and nutrients for growth. Information pertaining to crop identification and tracking may be derived using remote sensing. With the addition of other criteria and their organization in a Geographical Information System (GIS), these data become a valuable resource for agricultural strategy and crop decision-making.

Types of Geographic Information System Data

GIS data is mainly of two types: Vector data and Raster data.

1. Vector Data: Geographical characteristics are represented by points, lines, and polygons in vector data. Points depict exact places like wells or schools, lines show larger features like rivers, roads, and railroads, and polygons show larger regions like lakes, woods, or administrative borders. You may use it to draw sharp borders and pinpoint exact places on maps.

2. Raster Data: In raster data, the surface of the Earth is shown as a grid of tiny cells, or pixels, with a value reflecting a property such as elevation, temperature, precipitation, or land cover. Its primary usage is in environmental research and the visualization of continuous characteristics like weather patterns and landscapes in satellite pictures and aerial photography.

Government Initiatives Related to GIS in India

A number of programs have been initiated by the Indian government to encourage the use of GIS and other geospatial technologies for improved development, administration, and planning. Digital governance, disaster response, infrastructure development, and land management are all aided by these endeavors.

- **National Geospatial Policy 2022:** Aims to make India a global leader in the geospatial sector by promoting the use of geospatial data, developing geospatial infrastructure, improving skills, and encouraging private sector participation.
- **SVAMITVA Scheme: Uses GIS and drone mapping to provide property cards to rural households and digitize** land records. It helps reduce land disputes, improve financial inclusion, and support rural planning.
- **Bhuvan:** A geoportal developed by Indian Space Research Organisation that provides satellite imagery and geospatial data for applications such as disaster management, environmental monitoring, and development planning.
- **Bharat Maps:** Developed by the National Informatics Centre, this multi-layer GIS platform supports e-governance and digital infrastructure projects.

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- **Survey of India Online Maps and Data Portal:** Provides digital access to topographic maps, geospatial datasets, and mapping tools for government agencies and the public.
- **Gram Manchitra:** A GIS-based platform by the Ministry of Panchayati Raj that helps Panchayati Raj Institutions prepare village development plans using spatial data.
- **Geospatial Energy Map of India:** Launched by NITI Aayog with Indian Space Research Organisation, it provides GIS-based information on India's energy resources and infrastructure to improve energy planning.
- **Sarthi Web GIS Platform:** One web-based GIS platform is Sarthi Web GIS, which offers data visualization tools and interactive maps. In fields including public administration, environmental monitoring, and infrastructure development, it aids planners and policymakers in analyzing geographic information and making better judgments.

IV. USES OF GIS & REMOTE SENSING TECHNIQUES IN AGRICULTURAL SECTOR

1. Crop Sown / Crop Average Area Estimation

One of the main areas of agricultural remote sensing operations is crop planted area estimation. Estimating the area seeded with different crops relies heavily on remote sensing for mapping and monitoring purposes. For accurate evaluation of crop loss due to several catastrophic catastrophes, satellite data like Sentinel-1, 2, Landsat-8, World View-3, and LISS-IV are invaluable.

2. Normalized Difference Vegetation Index (NDVI)

This is mostly utilized for evaluating the dynamics of plants, especially when trying to figure out how healthy a crop is. Because it clarifies the crop chronology and their connection to weather and climate (season), NDVI increases the likelihood of comprehending the crop phenology. There is a strong association between normalized difference vegetation index (NDVI) and green biomass, which is an indicator of healthy crops or vegetation, and NDVI is calculated mathematically using spectral bands inside satellite images.

3. Crop Diseases Identification

Information on the geographical distribution of diseases and pests over a vast area is provided by remote sensing technologies at a low cost. regions with Mealybug, Plant Hopper, and White Fly infected crops are located using satellite images and spatial analytic tools. This provides an overview for analyzing the possibly contaminated regions.

4. Soil Properties

Because soil characteristics affect crop yields, they play an important role in agricultural management strategies. Agricultural soils have a wide range of significant properties, including pH, organic matter, texture, and wetness. From surface-level changes in plant development, these traits deduce soil moisture mapping and soil condition information. Soil changes brought upon by shifts in agricultural practices and land management threaten both the present and the future of micronutrient mapping's ability to reliably produce and provide food.

5. Flood Impact

Most of India's farmland is ruined every year during the Kharif harvest by flash floods and heavy rains. In order to calculate an accurate damage estimate, satellite remote sensing uses satellite pictures in conjunction with data gathered from ground surveying teams. This gives a wealth of information. When it rains too much, the agricultural land without a drainage system becomes inundated with all the water that has accumulated. The overflowing water eventually produces smaller streams that pour into the river, causing flooding along the riverbanks and in the flood plains. One way that land use planning might help with flood risk management is through damage assessment after floods.

6. NATCAT Modelling

The goal of natural catastrophe modeling is to use a probabilistic technique to estimate the potential outcomes and behaviors of natural disasters, either in real-time or in the future. Here, cutting-edge IT and geographic information systems (using Remote Sensing & GIS) are integrated with scientific research and past events to create computer-simulated disaster models, which aid in risk mapping and hazard measurement. Based on the projected flood depth, flood risk maps are created. Areas with a greater potential for flooding will be given a higher "hazard denomination" in the estimation, which is often based on a variety of hydrological and remotely sensed data.

7. Drone Image Analysis for Crop Damage Assessment

The micro-level evaluation of crop loss due to hailstorm, the counting of horticultural trees, illnesses, and many more uses drone image analysis extremely well. Drone image data accuracy is proportional to input imagery spatial resolution, which is extremely high (starting at 50 cm and adjustable to meet specific needs).

8. Crop Yield Prediction

By analyzing the color image of high resolution satellite data (HR), farmers may use the GIS approach to make an accurate assessment of the crop's health and the expected yield. The forecast was determined to be around 90% accurate, according to the average user's viewpoint.

V. CONCLUSION

A revolutionary method in environmental assessment, the combination of Remote Sensing (RS) with Geographic Information Systems (GIS) provides a complementary combination of data collection, spatial analysis, and well-informed decision-making. Capturing important factors including land cover, vegetation health, water quality, and climatic indicators, remote sensing offers unmatched access to large-scale environmental data in real-time via aerial surveys and satellite imaging. By utilizing a GIS framework, this mountain of data may be sifted for geographical patterns, changes throughout time, and trends in the environment to come. Researchers, politicians, and environmental managers tasked with addressing global environmental challenges will find this combination indispensable. The RS-GIS integration improves the accuracy, efficiency, and breadth of monitoring activities, which in turn allows for proactive management of resources and environmental protection. Stakeholders are able to make evidence-based decisions based on precise spatial information through this technology alliance, which finds applications in catastrophe risk reduction, biodiversity

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protection, land use planning, and climate change adaptation. Embracing this integration helps build a more resilient environment and encourages responsible use of resources, which protects ecosystems and communities for future generations.

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