TRANSFORMING AGRICULTURE: THE ROLE OF GIS IN MODERN FARMING

Ramkrushna Murmu

M.Tech (Soil and Water Engineering), Irrigation and Drainage Engineering Division (IDED), ICAR-CIAE, Bhopal, Madhya Pradesh

INTRODUCTION:

As the global population nears 10 billion by 2050, food production must increase by 50% to meet demand, despite challenges like climate change, limited arable land, and dwindling water resources. Technologies such as GIS, remote sensing, GPS, AI, and IoT enable efficient crop monitoring, resource management, and sustainable agriculture. Precision farming, which leverages these technologies for site-specific crop management, aims to enhance productivity while minimizing environmental impact. By integrating data and optimizing inputs, precision agriculture promotes both higher yields and environmental sustainability, addressing modern agricultural challenges with advanced decision-making tools.

What is GIS?

GIS is crucial for mapping and managing natural resources, especially in diverse topographies like hilly regions. It supports precision agriculture by integrating GPS, remote sensing, and data analytics to improve crop yield, manage resources, and reduce agrochemical use. Despite challenges in data storage and analysis, GIS provides valuable insights for site-specific management and informed decision-making in agriculture.

Main supporting technologies in GIS

GPS: GPS satellites provide precise location data, aiding in accurate tractor positioning for efficient planting, fertilizing, and harvesting. When integrated with GIS, this enables precision farming, allowing for optimal use of fertilizers, pesticides, and water. Real-time monitoring through GIS helps in managing crop conditions and identifying issues swiftly. Additionally, GPS data supports detailed field planning, improving crop yields, and reducing waste through better resource management.

Remote Sensing: Remote sensing uses satellites and aerial imagery to collect data on crop health, soil moisture, and field conditions. Integrated with GIS, this data helps monitor crop growth, identify pest infestations, and optimize resource use. It supports precision agriculture by providing timely information for better decision-making, leading to improved yields and sustainable farming practices.

APPLICATION OF GIS IN THE FIELD OF AGRICULTURE

Soil Health and Fertility Management:

GIS and remote sensing play crucial roles in soil health and fertility management by enabling the collection, analysis, and visualization of spatial data. They help map soil properties like pH, nutrient levels (N, P, K), organic carbon, and moisture content. This supports precision agriculture by identifying soil health variations, optimizing fertilizer use, and enhancing crop yields. Techniques like spatial interpolation, MCDA, and OWA help map soil variability, while GIS-based systems offer actionable insights for sustainable farming. These technologies aid in erosion risk assessment, land-use planning, and real-time monitoring, ensuring effective soil management, increased productivity, and environmental sustainability. Soil fertility maps, influenced by factors such as pollution and erosion, guide resource management and site-specific practices for improved crop productivity and sustainability.

Water Resource Management:

Water supply is crucial for meeting global food production demands, especially with a growing population. Dependence on rainfall is no longer viable, making water resource management essential. GIS and remote sensing technologies have proven their value in managing water resources by enabling groundwater potential assessment, irrigation suitability, and watershed prioritization. GIS helps in delineating groundwater zones, assessing irrigation needs, and optimizing water use. GIS aids in water resource management by delineating watersheds and analysing runoff patterns for effective watershed management. It identifies and models flood-prone areas for flood risk assessment. GIS optimizes irrigation schedules by mapping soil moisture levels and tracks pollution sources for water quality monitoring. Additionally, GIS simulates water flow and predicts droughts, making it

an invaluable tool for hydrological modelling and sustainable water management.

Land suitability assessment and land use planning:

In an era where we face the challenge of feeding billions while fertile land is shrinking, optimizing natural resource use is crucial. GIS plays a vital role in land suitability assessment and land use planning by enabling the collection, analysis, and visualization of spatial data. It assesses soil type, texture, water levels, fertility, pollution, and climate conditions by integrating data from remote sensing and field surveys.

The Multi-Criteria Decision-Making (MCDM) approach, such as the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP), is widely used for evaluating land suitability for various crops. These models help in planning land reclamation and conservation practices, ensuring sustainable use of resources. Fuzzy logic combined with GIS allows for more precise classification of land suitability, outperforming traditional methods.

GIS-based land suitability assessment aids in optimizing agricultural practices by identifying the best use for each parcel of land. It helps in determining crop suitability, managing soil erosion, and planning irrigation. Researchers also explore artificial intelligence integrated with GIS to enhance efficiency in land use planning.

These tools support informed decision-making, maximizing productivity, and promoting sustainable agricultural practices, crucial for addressing global food security challenges. GIS thus empowers effective management of shrinking fertile land, ensuring optimal utilization and sustainability.

Crop monitoring and yield production:

GIS is a powerful tool in crop monitoring and yield prediction, enhancing precision agriculture through spatial data collection and analysis. It integrates various data

sources, such as satellite imagery, UAV (drone) data, and ground sensors, to monitor crop health in real time. This helps in identifying stress factors like pests, diseases, and water deficiencies early, enabling timely interventions. In yield prediction, GIS uses historical crop performance data, soil health information, and weather patterns to model and forecast crop yields. Spatial analysis identifies zones within fields that may produce higher or lower yields, guiding management practices to optimize production. For example, farmers can apply variable rates of fertilizers and water based on GIS data, improving efficiency and reducing input costs.

Moreover, GIS can assess the impact of different farming practices and climatic conditions on crop performance. By mapping these variables, it supports strategic planning and decision-making, helping farmers to maximize yields sustainably. Advanced GIS models can simulate future scenarios, aiding in long-term agricultural planning and risk management. GIS provides a comprehensive framework for monitoring crops and predicting yields, facilitating data-driven decisions that enhance productivity and sustainability in agriculture.

Precision farming:

GIS (Geographic Information System) is a cornerstone in precision farming, enhancing agricultural productivity and sustainability through spatial data analysis. It creates detailed maps showing soil types, nutrient levels, and crop health, enabling targeted interventions. Farmers use GIS to apply fertilizers, pesticides, and water variably across fields, based on specific needs, reducing waste and improving efficiency. Integrating data from sensors, satellites, and UAVs, GIS monitors crop growth, detecting stress factors like pests, diseases, and water deficiencies early. Historical data and current field conditions analysed through GIS help predict crop yields, aiding in better planning and resource allocation. It also maps soil moisture levels and weather patterns to optimize irrigation schedules, conserving water and ensuring crops receive the right amount. Additionally, GIS assesses soil fertility and health by mapping soil properties and monitoring changes over time. It evaluates and manages risks related to weather, pests, and diseases, improving resilience and decision-making in farming operations.

Precision farming uses GIS, GPS, and Variable Rate Technology (VRT) to enhance crops are collected and stored in GIS to aid in variable planting and soil mapping. During the Crop Growth Stage, this data is used to manage irrigation, soil fertility, and pest control, with GIS and remote sensing assessing plant health and managing stress. Finally, in the Harvesting Stage, GIS aids in yield monitoring and mapping, informing strategies for future crop seasons. Integration of GIS in these stages promotes sustainable and efficient agricultural practices. crop productivity through three stages: Preparatory, Crop Growth, and Harvesting. In the Preparatory Stage, data on soil nutrients, groundwater, and past.

CONCLUSION

The rapid adoption of GIS in agriculture has revolutionized the sector, enhancing productivity and sustainability. Advances in digital technology have integrated GIS into all stages of the agricultural value chain, from land suitability and water management to precision farming and supply chain management. The ability to collect and analyse real-time data has further elevated GIS's importance, providing essential spatial intelligence for optimizing agricultural practices and achieving sustainable productivity. GIS continues to play a pivotal role in modern agriculture's evolution.