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Role of Geographical Information System (GIS) in Modern Agriculture

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Agriculture is the backbone of Indian economy and the pivotal sector for ensuring food security. Timely availability of information on agriculture is vital for taking informed decisions on food security issues. India is one of the few countries in the world that uses space technology and land-based observations for generating regular updates on crop production statistics and providing inputs to achieve sustainable agriculture. In India, Agriculture plays a vital role in the Indian economy. Over 50 per cent of the rural households depend on agriculture. Agriculture is an important sector of Indian economy as it contributes almost 18 per cent to the total GDP and provides employment to over 42 per cent of the population. In the early 1960's the first Geographical Information System (GIS) was developed by the Canadians to store geospatial data and produce maps for the Canadian Land Inventory. This data provides an indication of the lands capability to support agriculture, wildlife, forestry and recreational activities. Today however, GIS is a widely used tool with significant relevance for farmers and the agriculture industry. GIS applications play an important role in production of crops, both locally and across the globe. Through assisting farmers in increasing production, reducing costs, and providing an effective means of managing land resources, GIS has become an increasingly invaluable resource. Its applications come in a variety of forms, including precision farming, drone and satellite technologies and the capabilities of Geographical Information System themselves.

Geographical Information System (GIS)

GIS is a powerful set of tools for collecting, storing, and retrieving the data at will, transforming and displaying the spatial data for particular purpose (Burrough and McDonnell, 1998). The ability of GIS to analyse and visualize agricultural environments and work flows has proved to be very beneficial to those involved in the farming industry. Balancing the inputs and outputs on a farm is fundamental to its success and profitability. In GIS, the spatial data are commonly in the form of layers, which may depict topography or environmental elements. Application of these technologies in the management of natural resources are increasing rapidly due to great strides made in space borne remote sensing satellites in terms of spatial, temporal, spectral and radiometric resolutions (Venkataratnam, 2001). GIS can be used to produce images, not just maps, but drawings, animations, and other cartographic products. From mobile GIS in the field to the scientific analysis of production data at the farm manager's office, GIS is playing an increasing role in agriculture production throughout the world by helping farmers increase production, reduce costs, and manage their land more efficiently. While natural inputs in farming cannot be controlled, they can be better understood and managed with GIS applications such as crop yield estimates, soil amendment analyses, and erosion identification and remediation. GIS is a layer based and thematic system which provides the flexibility to overlay and review the indices for various changes in the site. The technology is utilised to its fullest in the planning and managing.

Importance of GIS in Modern Agriculture

- To identify the potential land for any particular crop, GIS is the best technique as it brings all the data on a single platform for the analysis. Different vegetation indices like NDVI, FPAR and TVI are widely used to monitor crop health which is also directly proportional to yield. In case of crop insurance, actual damage can be assessed. Claims and compensations can be given on fair basis.
- To monitor crop health, its growth and production various factors come into play such as temperature, irrigation facilities and the most important soil health condition. For this purpose government has launched a nation-wide scheme called soil health card.

Applications of GIS in Agricultural Practices

1. 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.

2. Irrigation Management

GIS has become an indispensable tool for effective irrigation management. GIS technology allows for the creation of irrigation plans across different areas of the field. Farmers can identify the water needs and then optimize the water usage throughout the crop cycles. Through soil moisture mapping, farmers can ensure that they are applying the right amount of water in different parts of the field. By doing so, both *overwatering* and *under-watering* of the fields can be avoided. In addition to that, farmers can also study the weather and climate patterns in detail to efficiently schedule irrigation plans. By utilizing GIS in irrigation management, farmers make sure that there is no or reduced water waste and that their crops will have better yields to offer.

3. Field Mapping and Land Use Planning

GIS plays a crucial role when it comes to field mapping and land use planning. Let's discover how farmers can assess and analyse various factors to ensure maximum crop yields. Having knowledge about factors like elevation, slope and proximity to water resources is crucial for several actions. This can include optimized crop selection, improved irrigation practices as well as reduced soil erosion. When farmers have access to elevation data of a certain piece of land, they can select crops that will grow well in certain temperatures and other growing conditions. Similarly, farmers can plan out the slopes to ensure a proper drainage system. This can help farmers maintain soil fertility while also reducing soil erosion.

4. Pest and Disease Management

GIS can also help in pest and disease management. Let's discover *how GIS helps in predicting pest outbreaks.* Here, you will also get to know *how GIS allows for careful monitoring of the spread of diseases based on historical and real-time spatial data.* GIS helps process past records of pest infestations and then offers insights to prevent the infestation from occurring. The obtained data is highly detailed as farmers can predict where and when pest infestations can occur. One of the best features of GIS technology is that it allows for *real-time monitoring* which helps the concerned professionals *track all that's happening in their fields* and then make *informed decisions*. The decisions can be related to optimizing temperature and humidity. Moreover, farmers can also track disease activities and take action accordingly.

5. Precision Farming

In order to initiate precision farming, farmers must have access to field-level data that is not only highly detailed but also accurate. Once they have that data, they can take various decisions considering several factors such as optimized use of water, fertilizers as well as pesticides based on specific needs, reducing waste and improving efficiency.

6. Yield Prediction and Planning

By using GIS technology in agriculture, farmers can also forecast crop yields by analysing a number of factors. Those can include *soil conditions, weather data* as well as the *past performances* of a certain crop. When farmers have access to that kind of data, they can streamline several activities effectively. *For example;* while facilitating the process of forecasting crop yield, *GIS allows for a better planning of harvest*. And then, they can also schedule other logistics as well such as *distribution and storage* of yields as per their production, etc.

Supporting Technologies for GIS in Agriculture

1. **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. Information collected from different satellite data and referenced with the help of GPS can be integrated to create field management strategies for chemical application, cultivation and harvest. (Liaghat and Balasundram 2010).
2. **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.
3. **Drones and UAVs:** Satellites, when used for monitoring crops, they gather data that is not in high resolution for the concerned professionals to analyse things in detail. However, by using drones and Unmanned Aerial Vehicles (UAVs), farmers, agriculturists, etc. can not only gather high resolution data but they can also make the drones fly extremely close to the ground. This enables farmers to have access to highly detailed and accurate data in the form of images, etc. We must also mention that the farmers can gain information on specific pieces of land by using drones and UAVs. Starting with high-resolution imagery; the drones that are used to capture data are designed to collect highly detailed images of the crops and soil. By having access to the land that is deep, farmers, etc. can monitor problems and work towards their healthy solutions well before time. In addition to that, drones also offer localized mapping, facilitating small farmers to analyse pieces of land more closely. It must be mentioned here that *this is something which is not possible with satellites*.

Conclusion

In order to implement these programs effectively it is vital to use the latest technologies like remote sensing and GIS. The decision makers can visualize all the farmlands with their allied information and current situation on one click. The tasks like yield estimation & crop damage assessment done by traditional means take month or two and a whole lot of manpower to complete the work. By using these technologies the same task can be completed within half or even in lesser time frame with minimum number of resources and high accuracy. Balancing the inputs and outputs on a crop farm is essential to its success and cost effectiveness. The ability of GIS to study and envisage agricultural environments and workflows has proved to be favourable to those involved in the farming industry. While natural inputs in farming cannot be measured but, can be better understood and managed with

GIS applications such as crop yield estimates, soil amendment analysis, erosion identification and remediation. GIS Applications in modern agriculture examines ways that this powerful technology can help farmers produce a greater abundance of crops with more efficiency and at lower costs.

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