A review on the application of RS, GIS and GPS in agriculture and allied sector

Abstract

In developed and developing nations, agricultural sustainability is of utmost importance. This study aims to discuss the impacts and applications of geospatial information technology in agriculture and related fields. These cutting-edge technologies offer multi-scale benefits and can be used to create and synthesise new low-cost information and documents. Accurate input data for diverse agricultural production techniques and pollution from diffuse sources can be obtained quickly through data sources and integration techniques. These tools can be utilised to create maps and charts that satisfy particular requirements. Direct information about production indicators (cultivated area and yield) can be obtained by geospatial technology. For efficient agricultural monitoring, agricultural factors including soil moisture, soil type, and cultivation stage are necessary. Multifunctional photos can be used to derive mask removal. Cloaking is a necessary prerequisite for satellite remote sensing applications that anticipate or estimate crops and are helpful in the spread of precision farming. In order to allocate time and resources where they are most required and will yield the most return for the farmers, it entails the use of spatial asset allocation and management. An overview of remote sensing technology, GPS, and GIS, as well as potential applications in agriculture, will be provided by this paper.

Keywords

Vegetation Indices, Cropping Pattern, GIS, Remote Sensing, Big data analysis, disease and pest management, nutrient management

Introduction

While protecting the ecosystems that provide a living for impoverished rural populations, sustainable farming practices and rural development (SARD) have the potential to lessen hunger and poverty [14]. Research indicates that issues with long-term growth and planning, business diversification, agricultural efficiency, sustainability of agriculture, and natural resource management exist because of the dearth of rural areas [2]. Since there didn't seem to be a threat to food supplies in the 1970s, sustainable agricultural output was not a major concern. To address the current food shortages, focus has been directed into food production.

However, intensive agriculture had detrimental environmental repercussions on the environment, such as soil erosion, salinisation, contamination of soil and surface waterways, and loss of biodiversity, because the land was not managed in accordance with its sustainable capacity. In the end, this sparked worries about problems with agricultural production on a global and national scale [1]. Sustainable agriculture requires the effective and efficient management of the environment, economy, and society. It also implies how society, technology, and the environment interact dynamically.

The transition to sustainable agricultural development, including the idea of functional sustainability of agricultural research policies, programs, and projects, is the focus of 21st-century agricultural task management systems research [3-5]. Geographic information technology can be used to overcome this issue [6].

Geographic Information Systems (GIS) have shown to be a useful tool for managing natural resources and conducting spatial analyses. The field of geospatial information technology, or GIS, is devoted to the storing, managing, and analysis of geographical data. Land use, land cover, and other thematic data are periodically provided by remote sensing data gathering technologies, such as satellites and aerial photos [7, 8].

Geographic Information System (GIS), Global Positioning System (GPS), and image processing software that manages RS data are the core components of geospatial information technology. These geospatial technologies form the foundation of precise agriculture, a paradigm shift in the agricultural industry [9]. Decision-making systems in geotechnical engineering rely on the soil, crop, and other pertinent variable variability. Using GIS technology and local survey data, a land assessment study for agricultural planning was carried out in the Seoni District of Madhya Pradesh, India [4].

The geographic area has been assembled and analysed with respect to the Seoni district's fertility evaluation and appropriateness of land use. Territorial suitability and fertility maps were used to construct the records of the geographic information system. Using precision farming techniques, the climatic and soil parameters of each crop in the research area were combined to create the suitability map for each agricultural site [10, 11]. They realised how critical it is to employ geographic technology in agricultural production planning and decision-making. Geographic information technology are currently playing a bigger role in the decision-making process when it comes to spatial planning. When combined with satellite data, GIS gives decision-makers a distinctive, all-encompassing perspective that helps land managers manage natural resources more effectively [13-17]. The utilisation of georeferenced data facilitates communication between national development plans and local expertise and science. Increasing the accuracy of data gathering and analysis is one benefit of using geographic data [19]. Most highly industrialised nations have effectively managed their land resources through the application of these technologies.

The development of monitoring systems capable of automatically generating and routinely updating the coverage map soft hear territory is becoming increasingly interesting due to the increasing availability of remote sensing images, which are periodically obtained with satellite sensors in the same geographic area [20]. [22] Norway is using GIS technology as a decision support tool to conserve forest biodiversity. Decision-makers can create more effective land use management plans by using digital analysis of a remote satellite data sensor to measure changes in land cover more accurately [21-24]. Issues pertaining to agricultural policy and natural resources in South Africa are predominantly founded on data supplied by the scientific community. To achieve political decisions, this data is incorporated with the data of other social science departments. In South Africa, remote sensing has been applied to agricultural and natural resource monitoring. Information that affects development decisions is provided using it in a policy-oriented manner [25, 76].

Application of RS in Agriculture and Allied Sector

Remote sensing systems, using information and communication technologies, usually generate a large volume of spectral data due to high spatial/spectral/radiometric/temporal resolutions needed for application in PA [26]. Emerging data processing techniques such as Big Data analysis, artificial intelligence, and machine learning have been utilized to draw useful information from the large volume of data [27]. Also, cloud computing systems have been used to store, process, and distribute/utilize such a large amount of data for applications in PA [28,29,30]. All these advanced data acquisitions and processing techniques have been applied globally, to aid the decision-making process for field crops, horticulture, viticulture, pasture, and livestock [27,31,32,33,34,35,36].

A number of previous studies have reviewed the methods and uses of remote sensing in agriculture. Some studies included more than one application area [41,42,43], while others concentrated on particular application areas including disease and pest management [40], evapotranspiration (ET) estimation [38,39], and soil characteristics estimation [37]. Numerous of these research demonstrated the current state of remote sensing-based approaches, as well as their shortcomings and potential obstacles when it comes to agricultural application. Among these noteworthy initiatives are [42, 43, 44, 45]. The primary purpose of this review is to complement these efforts to provide a comprehensive background and knowledge on applications of remotely sensed data and technologies in agriculture, focusing on precision agriculture. Specifically, we provide an overview of remote sensing systems, techniques, and applications in irrigation management, nutrients management, disease and pest management, and yield estimation along with a synthesis table of vegetation indices used for a variety of applications in PA.

Based on the spatial, spectral, radiometric, and temporal resolution they provide, several sensors are employed in remote sensing [46]. The size of the pixel that depicts the area on the ground determines the spatial resolution of a sensor. Large footprint sensors typically have limited spatial resolution, while small footprint sensors typically have high spatial resolution. It is possible to think about temporal resolution as being related to the sensor platform as opposed to the sensor itself. For a satellite, for instance, temporal resolution is the amount of time it takes to finish an orbit and return to the same observation area. The number of bands recorded in a given electromagnetic spectrum range indicates the spectral resolution of a sensor [47].

In order to achieve optimal crop development and yield while reducing crop water stress, irrigation application timing and rate are crucial. Farmers employ a range of irrigation management techniques based on a number of variables, such as the availability of water, the infrastructure for managing it currently on the property (such as the type and storage of irrigation systems), local and regional water regulations, the size and economic standing of the farm, the farmer's level of expertise, and others. [48, 49].

Global estimates of soil moisture have been made using remote sensing data collected in a variety of bands, including optical, thermal, and microwave [28, 77]. The land surface temperature-vegetation index (LST-VI) method, often known as the "triangle" or "trapezoid" approach, has been widely utilised to estimate soil moisture and ET using optical and thermal remote sensing data [50]. The physical link between the properties of vegetative cover and land surface temperature and consequently soil moisture and latent heat fluxes is the foundation of the triangle or LST-VI approach. This method's interpretation of the pixel distribution in the LST-VI plot-space serves as the basis for estimating the moisture content of the soil. The LST-VI space resembles a triangle or trapezoid if a sufficiently enough number of pixels are included in a picture encompassing the whole range of soil moisture and vegetation density and when cloud, surface water, and other outliers are eliminated [54, 78]. In order to maximise crop growth and yields while minimising environmental damage from nutrient losses to surface and groundwater, timely and proper fertiliser application is crucial.

Fertiliser is typically sprayed evenly at the recommended rate throughout the planting and subsequent phases of crop growth. However, crop fertiliser requirements vary both geographically and temporally (during and among seasons) due to changes in soils, management, terrain, weather, and hydrology [51, 52]. Using widely known tools like chlorophyll meters, it might be challenging to map these kinds of fluctuations in crop nutritional status and need for PA treatments [53].

Diseases have the potential to significantly reduce agricultural yields and farm income. Plant diseases can be contained and output losses can be minimised by early detection of the disease's spatial extent. The traditional approach to disease identification, field scouting, is labour-intensive, time-consuming, and prone to human error [55]. Furthermore, it could be challenging to identify the illness in its early stages when the symptoms are not entirely evident when doing field scouting. Moreover, some illnesses have no outward signs at all, or their effects might not become apparent until it is too late to take action [57]. With the conventional approach of field scouting, mapping the spatial range and severity of the disease transmission is also challenging. For site-specific weed management, remote sensing has been routinely utilised to map weed patches in crop fields [56]. Based on their distinct spectral signature that is associated with their phenological or morphological characteristics that set them apart from crop plants, weeds can be distinguished from crop plants. In the past few years, machine learning techniques have become a very effective and accurate way to classify images for weed mapping [58, 59].

Application of GIS in Agriculture and Allied Sector

GIS is regarded as the brains of precision agriculture because of its support for feature and location data collection, storage, retrieval, and analysis as well as its usefulness for data-driven solutions, particularly in site-specific management [60]. Unlike traditional maps, digital GIS maps have multiple layers of data, each layer offering details or a map about a particular attribute like yield, pest infestation, nutrient status, precipitation, soil survey, etc. Additionally, GIS offers the analytical capacity by utilising geospatial analytics and statistical tools to enable the extraction of correlations between features. The insights obtained from this process are helpful when making decisions regarding management procedures. Currently, there is a shortage of arable land and a problem to feed billions of people. As a result, we must maximise the advantages of our usage of natural resources. GIS offers a great platform for evaluating a piece of land's suitability for a certain use. Researchers most often choose the multi-criteria decision-making (MCDM) technique based on GIS for land use planning. The distribution of soil types, soil textures, buried deep underground water levels, soil fertility, soil pollution, slopes, hydraulic conductivity of soil (Ks), soil texture (ST), depth to water-table (DTW), electrical conductivity of groundwater (ECw), topography, climate, and satellite data are just a few of the features that researchers can use to identify the various interactions, dependencies, and effects of these interacting factors on sustainable land use.

[61] evaluated the weight sensitivity of the MCDM model to ascertain if a plot of land is appropriate for irrigated farming. Their objective was to look at potential effects on the model's output from changing the input feature weights. Researchers have shown a compelling case for the use of remote sensing in conjunction with traditional geophysical models for groundwater potential evaluation and recharge experiments [62, 33]. Several researchers have recognised the usefulness of GIS in groundwater management [64, 65]. [66] combined the GIS and the MODFLOW groundwater model to prioritise watersheds. GIS and remote sensing were integrated [63] to identify groundwater potential zones. Using photos from remote sensing, lineament and hydro-geomorphological maps were created. For the purpose of organising efficient site-specific management or precision farming techniques, it is important to ascertain the fertility and health of the soil [67]. In order to measure the soil fertility state, a variety of features are commonly utilised, including soil macronutrients (N, P, and K), micronutrients (Zn, Mn, and Fe), pH, soil organic carbon (SOC), water holding capacity, erosion status, and moisture content [68]. The most widely used geospatial analysis approaches that give decision-makers access to the spatiotemporal variability of soil health and fertility status are spatial interpolation, Multi-Criteria Decision Analysis (MCDA) [52, 53, 54, 55], and Ordered Weighted Averaging (OWA) [56, 57, 58, 59]. Because they are useful for planning management strategies, evaluating the impact of climate fluctuations on crop performance, and forecasting yields, crop simulation models have gained popularity [69]. A state-of-the-art method for using the leftovers from current agricultural techniques is made possible by GIS-based calculation of bioenergy potential, which promises even greater advantages when farmers transition from traditional to smart farming [70, 79].

Application of GPS in Agriculture and Allied Sector

The latitude, longitude, and elevation of a location are provided by this satellite-based positioning and navigation system, which makes it possible to determine positional information. Farmers and researchers can reliably identify fields, map field boundaries, water bodies, infested or problematic areas in the field, and understand the relationship to several other attributes both inside and outside the boundaries of a given field thanks to the location data gathered by GPS receivers [71]. Precision agriculture is all about lowering input costs and increasing output by applying water, fertilisers, herbicides, and pesticides just where needed. This kind of high-fidelity field mapping makes this possible. A satellite-based radio-navigation system called the Navigation Satellite Timing and Range Global Positioning

System, or NAVSTAR GPS, is able to provide incredibly accurate 3-dimensional (latitude, longitude, and elevation) location data that is available around the clock. The US Department of Defence (DoD) created and maintains the system as an accurate, all-weather navigation system. Despite being intended for military use, people can freely use it for positioning, albeit with some limitations. With a full set of at least 24 satellites orbiting the planet in a precisely planned configuration, the system has reached its maximum operational capability [72].

Manufacturers of GPS equipment have created a number of solutions to assist agribusinesses and farmers in increasing productivity and efficiency in their precision farming endeavours. These days, a lot of farmers employ items developed from GPS to improve farming operations. GPS receivers map field boundaries, roadways, irrigation systems, and crop problem areas like weeds and disease by gathering location data. Farmers may make farm maps with exact acreage for agricultural areas, road locations and distances between points of interest thanks to GPS precision. According to [73-75], GPS enables farmers to precisely locate particular sites in the field year after year for the purpose of gathering soil samples or keeping an eye on crop conditions.

Conclusion

Agriculture has witnessed a notable increase in the use and acknowledgement of GPS, GIS, and RS technologies in recent times. This is attributable to the advancement of digital technologies, which have made RS and GIS instruments for decision-making and problem-solving. Crops, soils, and their environs have all been assessed using these instruments. This is due to the advancement of digital technology, which have made GIS an essential instrument for assessing soils, crops, and their environs. The use of GIS along the whole agricultural value chain is covered in this review. The introduction of digital agricultural tools and technologies has further enhanced the potential of GIS beyond its traditional and widespread applications in planning land suitability and use, managing water, soil, and biotic and abiotic stresses, and high fidelity crop monitoring, yield prediction, precision farming, and supply chain management for primary produce and biomass utilisation for energy production. Through the use of precision farming, these invaluable geospatial tools offer the location and spatial intelligence required to increase farm productivity and profitability. They have the capacity to gather, store, analyse, and present data/information in real time, and they can deliver precise, reasonably priced georeferenced data quickly. These qualities have increased the instruments' relevance even more. Because of its various present and emerging applications and its compatibility with both older and newer partner technologies, RS and GIS are critical to ensuring sustainable agricultural output.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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