Chapter 2
Applications of Geospatial and Big Data Technologies in Smart Farming

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Introduction

Globally, food production should be increased up to 70% by 2050 against the increasing population of 9.6 billion by 2050 [10]. On the other hand, the challenges from climate change in the form of increasing temperatures, weather variability, shifting agro-ecosystem boundaries, invasive pests and extreme weather events are affecting agriculture production [15]. In the context of pressure on land resources to enhance food production on one side and adverse impacts of climate change on the other, there is a need to adopt smart agriculture practices, where geospatial and big data technologies play an important role. Smart agriculture is a key tool to primarily handle and manage the threats, challenges and risks in the context of climate change, diseases and pest attacks and ensure sustainability. Smart farming practices include identification and localization of crops, insects and weeds; performance monitoring; machinery; variable rate of fertilizers, herbicides, insecticides and fungicides; planting monitoring and mapping [6]. Smart agriculture uses the knowledge of information science, environmental science, computer engineering, Geographic Information System (GIS), Global Positioning System (GPS), remote sensing technology and virtual satellite imaging for better integration with soil, climate, environment with agriculture [36]. In recent decades, due to the continuous development of Internet technology, various data explosions took place, among them, sensing technology and cloud computing technology play an important role in

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smart farming. These two technologies revolutionized the amount of data generated, stored, analyzed and utilized on the basis of storage technology and cloud computing technology. The development of earth observation and sensing technology, especially satellite remote sensing, has made massive remotely sensed data available for research and various applications in smart farming [7, 20]. Spatiotemporal data derived from remote sensing are a valuable resource for smart farming to potentially generate voluminous big data and perform historical trends. Agricultural remote sensing is one of the backbone technologies for smart agriculture, which considers within-field variability for site-specific management instead of uniform management as in traditional agriculture.

Big data can be defined as the dataset that are too large, complex and exceeds traditional datasets for its acquisition, storage and management and analysis [47]. Big data is emerging as a potential technology for farm-level decisions to enhance farm productivity by detecting and overcoming cumbersome practices. Advantages of big data are high-speed transactions, provide access to large amounts of data and user can perform several operations simultaneously [34]. Smart agriculture uses the ICT, modern machinery equipment, Internet of Things (IoT), cloud computing, machine learning and big data analytics for crop's vegetative growth intercultural operation, climate-smart management, harvesting, post-harvest management and marketing management. In the IoT, wireless technologies play a central role in data gathering and data communication [1]. Wireless sensor networks (WSNs) and radio-frequency identification (RFID) are considered the two main building blocks of sensing and communication technologies for IoT [11, 22]. Wireless sensor networks' sensors, smart devices, RFID tags, tablets, palmtops, laptops, smart meters, smart phones, smart healthcare, social media, software applications and digital services generate the volume of data [22]. They continuously generate large amounts of structured, semi-structured and unstructured data, which are strongly increased in the field of smart agriculture. The combination of geospatial and big data applications in smart farming plays important role in various farm operations.

Geospatial Technologies and Their Components

Geospatial technologies comprise photogrammetry, satellite remote sensing, GIS and GPS, which have immense potential in the collection, analysis and interpretation of spatial data in the field of agriculture. These play a vital role in providing precise information on the nature, extent and spatial distribution of agricultural resources to assess their potential and limitations for planning, monitoring and management toward sustainable development [30, 32]. Remote sensing integrated with GIS provides an effective tool for the analysis of land resources at macro, meso and microlevels, which could potentially enhance the management of critical areas [35]. Several geospatial technologies are actively being used in the management of natural resources, including remote sensing from terrestrial, aerial and satellite platforms with various sensors, GPS and GIS [19]. The aerial and satellite remote sensing techniques by virtue of their speed and cost-effectiveness have an edge over conventional methods of the survey in mapping, monitoring and detecting the temporal changes in land degradation. High-resolution remotely sensed data provide an unparalleled view of the earth for studies that require synoptic or periodic observations such as inventory, surveying, mapping and monitoring in land resources, land use/land cover and environment. The integration of spatial data and their combined analysis could be performed through GIS and simple database query systems to complex analysis and decision support systems for effective land resource management. Agricultural remote sensing is a highly specialized field to generate images and spectral data in huge volume and extreme complexity to drive decisions for agricultural development. In the field of agriculture, conducted various remote sensing data-based studies in monitoring soil properties, crop stress and development of decision support systems in fertilization, irrigation and pest management to enhance crop production.

Remote Sensing

Information on the nature, extent and spatial distribution of various agricultural resources is a prerequisite for achieving sustainable agriculture. The advances in remote sensing technology provide data for detailed inventory and mapping of natural resources at different scales. A wide variety of satellite remote sensing data from Landsat OLI, IRS-P6, Cartosat-I, Cartosat-II, QuickBird, Sentinel-2 and Google are now available to the earth scientists for the generation of spatial databases on natural resources for various applications. Since remote sensing may not provide all the information needed for a full-fledged soil and land resource assessment, field survey and other ancillary information from various sources are needed to be integrated with remote sensing data. Various satellite sensors and their image characteristics are shown in Table 2.1.

Remote sensing technology allows us to observe the earth's features from space, and users can analyze the information collected from remote sensing of our interest. The advances in remote sensing technology offer data for detailed inventory, mapping and monitoring of agricultural resources at a large scale. A wide variety of satellite remote sensing data from MODIS, Landsat-ETM$^+$, IRS-IC, IRS-ID, IRS-P6, Sentinel, Cartosat-I Cartosat-II, QuickBird and Google are now available to the users for the generation of the spatial database on agricultural resources for various applications. These technologies are extensively used in land use/land cover changes, precision agriculture, yield estimation and other need-based agricultural applications. However, remotely sensed data coupled with field observations and contemporary technology provide more realistic datasets as compared to image interpretation alone. In this age of the twenty-first century with advancements in the computer field and in the field of geographic information systems, the resource management issues in smart agriculture are to be dealt with more efficiently, effectively and a convincing way by applying these geospatial technologies rather than the traditional methods

Table 2.1 Important multispectral and hyperspectral satellites, sensors and their image characteristics

	Satellite	Sensor	Year of launch	Spatial resolution (m)	Swath (kms)	Revisit (in days)
Multispectral	Terra	MODIS, ASTER, CERES, MOPITT, MISR	1999	250, 500 and 1000	2330	16
	Aqua	MODIS, AIRS, AMSR-E, AMER-U, CERES, HSB	2002	250, 500 and 1000	2330	16
	Landsat 8	OLI, TIRS	2013	15, 30 and 100	185	16
	Sentinel-2A	MSI	2015	10, 20 and 60	290	5
	Sentinel-2B	MSI	2017	10, 20 and 60	290	5
	Resourcesat-2A	AWiFS, LISS-3, LISS-4	2016	5.8, 23.5 and 56	370, 140 and 23.9	5 and 24
	Resourcesat-2	AWiFS, LISS-3, LISS-4	2011	5.8, 23.5 and 56	370, 140 and 23.9	5 and 24
	SPOT 6	NAOMI	2012	1.5	10	1
	SPOT 7	NAOMI	2014	1.5	10	1
	CartoSat-2B	PAN	2012	0.8	9.6	4
	GeoEye-1	GIS-MS, GIS-PAN	2008	0.41 and 1.65	15.2	
	WorldView-3	CAVIS, MSS, PAN, SWIR	2014	0.31, 1.24, 3.7 and 30	13.1 and 13.2	1
	CartoSat-3	MX, PAN	2019	0.28	16	4
Hyperspectral	GEO-KOMPSAT-2B	GEMS, GOCI-II	2020	250 and 7000	2500	
	HysIS	HySI	2018	30	30	
	PRISMA	PRISMA	2019	5 and 30	30	29
	EnMAP	HSI	2020	30	30	27
	HISUI	HISUI	2019	20	20	

Source Reddy and Kumar [29]

of management. In land resources' applications, there are a wide range of satellite platforms providing imagery at multiple resolutions with frequency at the global to local scale. Microwave remote sensing is highly useful, as it provides observation of the earth's surface, regardless of day/night and atmospheric conditions. Spaceborne microwave remote sensors provide perspectives of the earth's surface and atmosphere, which are of unique value in studies of geomorphology, topography and vegetation classification. Hyperspectral remote sensing imagers acquire many, very narrow, contiguous spectral bands throughout the visible, near-infrared, mid-infrared and thermal infrared portions of the electromagnetic spectrum enabling the construction of an almost continuous reflectance spectrum for every pixel in the scene.

Geographic Information System (GIS)

GIS is defined as a powerful set of tools for collecting, storing, retrieving at will, displacing and transforming spatial data [5, 33]. GIS is a computer system capable of capturing, storing, analyzing and displaying geographically referenced information, i.e., data identified according to location. A true GIS is designed to accept, organize, statistically analyze and display diverse types of spatial information that is geographically referenced to a common coordinate system of a particular projection and scale. GIS is a potential tool for handling voluminous remotely sensed data and can support spatial statistical analysis, presentation of spatial data in the form of a map, as well as storage, management, modeling of input data and presentation of model results [31]. Data derived from the latest remote sensing and information technology techniques could be effectively integrated in GIS to perform the analysis. Applications of GIS range from simple database query systems to complex analysis and decision support systems. GIS techniques are playing an increasing role in facilitating the integration of multilayer spatial information with statistical attribute data in the sustainable management of agricultural resources.

Global Positioning System (GPS)

GPS has revolutionized research in the areas of surveying, engineering, monitoring positions and navigation [28, 45]. GPS technology enables real-time data collection and accurate position information, which in turn leads to efficient analysis and manipulation of large amounts of geospatial data in smart farming. For mapping, where surveying accuracy better than a meter is required, specialized DGPS techniques have been developed. These techniques are being employed increasingly for detailed topographic, soil, geological, engineering and environmental-related surveys at different scales. GPS-based surveying systems allow surveys to increase accuracy in mapping over conventional surveying techniques. GPS plays a significant role in field data collection, surveying and monitoring the crops on a periodical basis. GPS provides current position, anywhere and at any time on the globe, with a reasonable degree of accuracy. In the field of smart agriculture, GPS technology can help to map the relief, farm boundaries and assets more precisely, which serves as a “baseline” for further farm decision activities. Tractor-mounted GPS with variable-rate applicators’ farmers can identify locations that are nutrient deficient and apply the appropriate amounts of fertilizer in specific locations to enhance the fertilizer efficiency and improve the crop production in smart agriculture.

Big Data and Its Components

Big data is described as a collection of data that is extremely large and cannot be collected, processed, stored and calculated within the time required by traditional data processing methods or tools. Big data represents the information assets characterized by high volume, velocity, variety, veracity, variability and value to require specific technology and analytical methods for its transformation into value. Big data is being used to provide predictive insights in smart farming operations, drive real-time operational decisions and redesign business processes for game-changing farm operations. Big data consists of large datasets (*volume*), which have different types of datasets. *Velocity* consists of the speed by which information moves through the system, where data flow into the system from multiple sources. A *variety* of data can be found in big data, which is often unique because of a wide range of both the sources being processed and their relative quality. *Veracity* helps to evaluate the quality of data and processing quality of result analysis. *Variability* includes variation in the data that leads to wide variation in quality, where additional resources can be used to identify, process or filter low-quality data to make it more useful. To measure the *value* of data, the big data ecosystem deals with boundless processes and approaches both in structured or unstructured data. Agricultural big data is mainly used in agricultural condition monitoring, agricultural product monitoring and early warning, precision agricultural decision-making and the construction of a rural comprehensive information service system [14, 40].

Big data is considered a potential technology for the assessment of farm-level decisions, policy decisions and market-distorting actions for increasing the productivity in agriculture properly. Big data technology in agriculture can collect and analyze lots of data, which are usually generated from various sectors and stages in agriculture. Big data-driven agriculture provides an opportunity to transform traditional decision-making to database decision-making. Cloud computing platforms are efficient ways of storing, accessing and analyzing datasets on very powerful servers, which virtualizes supercomputers for the user. These systems provide infrastructure, platform, storage services and software packages in a variety of ways for the customers [7, 21]. Google earth engine (GEE) is a big data cloud computing platform, and it facilitates scientific discovery processes with free access to numerous remotely sensed datasets to perform various geo-big data analytics in the field of agricultural applications [12,

Fig. 2.1 Potential applications of GEE cloud computing platform in smart farming

39]. GEE provides various functions to perform spectral and spatial operations on either a single image or a time-series images. Different operations within the GEE platform range from simple mathematical operations to advanced image processing and machine learning algorithms. The important GEE applications in smart agriculture are real-time weather monitoring, terrain analysis and landform mapping, digital soil mapping, soil moisture monitoring, automated irrigation systems, crop identification and monitoring, yield monitoring and mapping, pest monitoring and surveillance and variable-rate technology (VRT) which are briefly summarized (Fig. 2.1).

Applications of Geospatial and Big Data Technologies in Smart Farming

In smart farming, geospatial technologies like high-resolution remote sensing, GIS, GPS and field sensors play an important role in the reorganization of spatial variations at individual farm level and to address those using appropriate strategies.

Weather Monitoring

One of the biggest challenges for smart farming is climate change and its impact on crop productivity and farm operations. In smart farming, farmers essentially need accurate information on various weather parameters like rainfall, temperature, humidity and weather forecasts. A wide range of ground, aerial and space-based earth

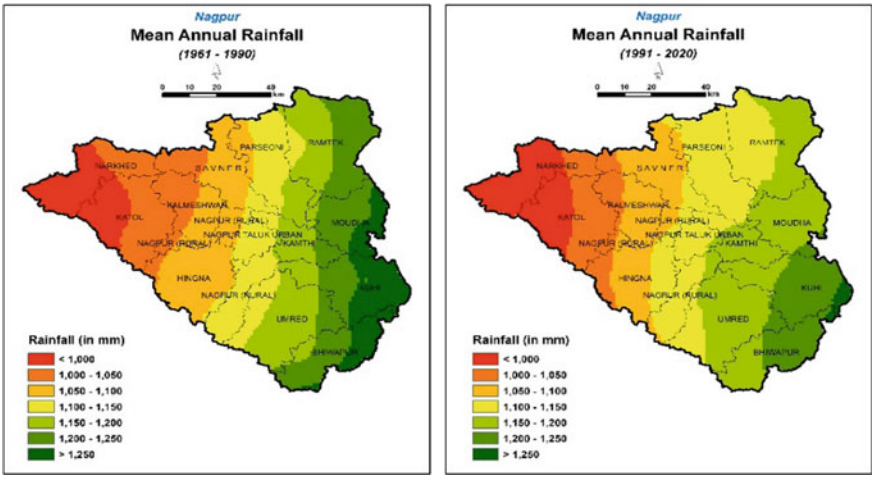

Fig. 2.2 Mean annual rainfall pattern of Nagpur district, Maharashtra, India, during 1961–1990 and 1991–2020

observation platforms are available to collectively enable real-time weather observation and dynamic monitoring of accurate, comprehensive, continuous and diverse information on weather parameters. Automatic weather station (AWS) provides information on various meteorological parameters, which include rainfall, temperature, humidity and soil moisture for better-informed decisions in smart farming. By collecting the data on time-series various weather parameters, one can analyze the climatic trends by using data analytics tools in GIS to assess the climatic conditions for smart farming. As an example, the mean annual trends' rainfall of Nagpur district of Maharashtra, India, was analyzed for the period from 1960 to 1990 and 1991 to 2020. The analysis shows that there is a slight change in the mean annual rainfall pattern in the district over a period of 60 years. The mean annual rainfall in the eastern regions of the district shows a decreasing trend, and it has an impact on agriculture and crop production (Fig. 2.2).

Terrain Analysis and Landforms Mapping

Integration of satellite-based remote sensing with photogrammetry, GIS and GPS has enhanced its capabilities in the area of agricultural resource management and solving environmental problems very rapidly and efficiently in comparison to others [18]. Remote sensing integrated with GIS provides an effective tool for the analysis of land resources at macro, meso and microlevels, which could potentially enhance the management of critical areas [35]. High-resolution remotely sensed data provide an unparalleled view of the earth for studies that require synoptic or periodic observations such as inventory, surveying, mapping and monitoring of land resources,

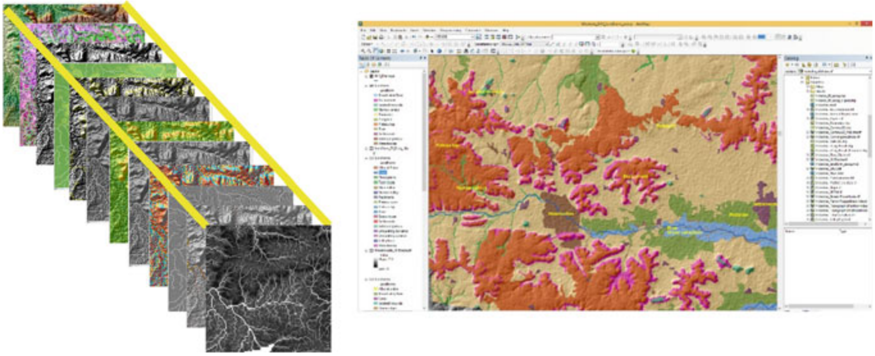

Fig. 2.3 Delineation of landforms through digital terrain modeling in basaltic terrain of Central India

land use/land cover and environment. Traditional mapping approaches are qualitative interpretation with inherent limitations associated with fieldwork and human interventions and domain knowledge. Nowadays, with access to fast computers and digital sources such as digital elevation models (DEMs) acquired by remote sensing, landforms can be analyzed and mapped digitally. In digital terrain parameterization, various attributes such as elevation, slope, aspect, plan and profile curvature and flow accumulation were analyzed and mapped [24] to obtain distinct landforms units. Relatively recent advances in geospatial technologies and developments in numerical modeling of surface processes have revolutionized the field of geomorphology. The digital terrain modeling approaches help to quantify landscape morphology [13, 26], assess surface biophysical conditions [38], landform process [2] and improve the landform mapping accuracy. The automatically extracted landforms from digital terrain modeling of SRTM (30 m) data for basaltic terrain of Central India are shown in Fig. 2.3.

Digital Soil Mapping

Intimate knowledge of the kind of soils and their spatial distribution is a prerequisite in developing site-specific land-use plans in smart farming, irrigation scheduling, drainage management, etc. Space technology plays a significant role in digital soil mapping efforts. Digital soil mapping involves the quantitative prediction of soil properties by using some observed soil data and some soil-forming factors [8]. Advances in digital soil mapping have created a tremendous potential and transformed the procedure and the way the soil maps are produced [23]. However, in general, soils appear to be more continuous variables than discrete objects [27]. Therefore, the conceptualization of various terrain variables as discrete objects involves uncertainties. Such variables are best predictors through the fuzzy logic approach and minimize the uncertainties. The application of fuzzy logic models in digital soil mapping requires the establishment of knowledge bases to define the fuzzy membership criteria. For digital soil mapping, the fuzzy logic approach uses the principle that a spatial unit, e.g., a pixel, can contain soil, which cannot be exclusively classified into one soil class. Membership values in fuzzy mapping can be determined using deterministic or empirical approaches. Digital soil mapping begins with the development of a numerical or statistical model of the relationship between environmental variables and soil properties, which is then applied to a geographic database to create a predictive map. Digital soil mapping helps to exploit the relationship between environmental variables and soil properties in order to more efficiently collect soil data, produce and present data that better represent soil-landscape continuity and explicitly incorporate expert knowledge in model design. Soil parameters' map developed through digital soil mapping with raster grid allows better characterization of soil-landscape variability, which in turn significantly helps to formulate land-use plans in smart farming based on the spatial variability of soil characteristics.

Soil Moisture Monitoring

In smart farming, soil moisture is a fundamental factor that is used to control the water management system for sustained crop yield. Agricultural UAV or drone platforms become one of the most promising technologies utilized in soil moisture monitoring. The agricultural UAV with a combination of IoT sensors can detect moisture conditions of the soil and helps in the identification of zones that suffer from water scarcity and dryness of soil profile [37]. Such information helps the farmers to take appropriate interventions such as irrigation scheduling and amount of water to be released. High-resolution satellite imageries can be effectively used for monitoring soil moisture and assessment of surface moisture conditions in real time across the entire surface, rather than for a single point like the soil moisture, and weather sensors provide soil moisture. It is important to build time-series soil moisture data for individual fields to interpret and understand the spatial patterns as soil type and texture affect the soil physics of moisture and storage. Real-time monitoring of soil moisture helps to generate timely soil moisture information and inform crop management decisions, such as fertilizer inputs, yield mapping and pest risk assessment in smart farming.

Automated Irrigation Systems

An automated irrigation system does the work without the involvement of many manual operations by using computers and sensors. A rule-based expert system helps to save the water a lot, where field sensors collect and analyze data by an automated program, and accordingly, required water is supplied to the required part of the farm. An IoT-enabled, remote-controlled cross-platform system equipped with big data analytics and intelligent irrigation scheduling can be accessed through web and mobile applications, which are hosted on the enterprise cloud. These systems control the operation and help in crop field assessment for irrigation and applying fertilizers and pesticides. An automated irrigation system using WSN and General packet radio service (GPRS) module could be used to optimize the use of water for crops [16]. This system works based on the distributed wireless sensor network with soil moisture and temperature sensor in WSN. Gateway systems could be used to transfer data from the sensor unit to the base station, send commands to the actuator for irrigation control and manage data of the sensor unit. The traditional techniques like drip irrigation and sprinkler irrigation adopted in smart farming can be combined with IoT-based systems to improve water-use efficiency. IoT helps to access information and make major decision-making processes by getting different values from sensors like soil moisture, water level sensors and water quality.

Crop Identification and Monitoring

Geospatial and big data technologies enable us to identify and monitor crop conditions on a periodical basis. High-resolution satellites and drones are capable of collecting spatial data on various parameters of crops that help in analyzing and monitoring the current crop health. Drones equipped with various types of high-frequency sensors are capable of capturing and transmitting the data on the go. Drones can identify crop growth by comparing time-series images taken by the satellite and can assist farmers to reduce excessive use of water and reduce the chemical load on the environment by spraying required pesticides on the plant require. Object-based image analysis techniques [3, 44] provide an innovative approach to perform image segmentation with similar spectral signatures into objects to classify. IoT-based crop monitoring provides a data-driven approach with the use of sensor devices, gateway connectivity and a user-friendly dashboard to identify and monitor the crops in real time.

Yield Monitoring and Mapping

In fully mechanized farming systems, grain yield monitors are continuously monitored and measured in the clean-grain elevator of a combine. When systems are coupled with a GPS receiver, yield maps can be prepared with the help of yield monitors, which significantly helps in making sound management strategies. In yield mapping, soil, landscape and other environmental factors should also be weighed. The yield information provides insights into determining the effects of managed inputs. Various metrological factors like precipitation, temperature, humidity and solar light were used for crop yield maximization and to improve the quality of crops by considering real-time data and ML algorithms [25]. GPS sensors can be mounted on harvesting equipment to fetch the spatial coordinates and generate a crop yield map.

Pest Monitoring and Surveillance

Recent advances in remote sensing technology and geospatial image processing using drones have enabled the rapid monitoring, detecting and surveillance of insect pests and diseases in smart farming [42]. For detection of the occurrence and monitoring of pests and diseases on farms, remote-sensing technologies like satellites and drones can be employed to find insect pests and inform farmers of the state of affairs promptly [46]. In smart farming, an automatic insect identification system with various sensors can be built for insect and pest detection on crops through image analysis. Low-altitude remote-sensing technology like drones has the characteristics of high flexibility and image definition which can be deployed in pest and disease monitoring for crops. The deep learning and image process models enable us to identify any crop diseases or pest infestation within the crops [43]. The application of deep learning algorithms is an innovative method for image processing and object detection in the classification of various crop diseases [17]. Smartphone-based AI-powered applications could alert farmers and expedite disease diagnosis, potentially preventing or limiting pest and disease outbreaks. The IoT technology used to monitor pests and diseases has not yet fully developed as a unified standard in terms of services and equipment development.

Variable-Rate Technology (VRT)

Variable-rate technology (VRT) is an integral part of smart farming that allows data to be used effectively both in time and space. It combines the necessary farm equipment, control mechanisms and software tools to apply required quantities of inputs at specific times or locations to optimize fertilizer-use efficiency. Farm inputs like fertilizers, agrochemicals and irrigation water can be applied and monitored at different rates across a field, without manually changing rate settings on equipment. By utilizing geospatial technologies like GIS, GPS and field variability maps, VRT helps to increase the input efficiency, minimize overapplication of inputs and reduce the risk of pesticide and fertilizer runoff or leaching into water sources. Tractor-mounted sensor-based VRT utilizes sensors effectively to assess crop or field variability to provide real-time variable-rate application (VRA) of inputs.

Geospatial and Big Data Technologies in Smart Farming—Challenges

In the field of geospatial and big data technologies, the acquisition and creation of valuable data need strong hardware and software infrastructure for seamless data collection, quality, storage and integration. It would need high-performance computing for subsequent data processing, analysis and effective management of big data. Availability of reliable, timely and quality of spatial and non-spatial data is often a challenge in smart farming applications. Interoperability becomes the most important point of concern in a seamless flow of information [9]. This involves a number of issues like technical, semantic, syntactic and organization interoperability to be addressed [4, 41]. Designing high-performance systems is essential for easy access to distributed data by different users. Big spatial data computing requires modern computing and analytical methods to analyze the unevenly distributed data originating in real time from different locations. The innovative open-source cloud platforms like GEE can be used to access services to analyze voluminous data. In data-driven smart farming, data privacy issues and rights to data usage are quite obvious. The lack of data governance and suitable policies in place hinders data privacy and security. Hence, privileged access to big data and building trust with farmers should be a starting point in developing robust applications in smart farming. Since big data is from various sources in the agriculture supply chain, multistakeholder collaboration is needed for improved decisions and quick access to the right data to evaluate key performance indicators in building successful applications.

Geospatial and Big Data Technologies in Smart Farming—Opportunities

Some of the emerging opportunities of geospatial and big data applications in smart farming are to design and develop GPS-enabled tractors**.** These systems help to find out soil quality and quantity of crops from different areas of the field and determine how much fertilizer is to be applied in each part of the field. Such systems help the farmers to accurately navigate to specific locations within the field to collect soil samples or monitor crop conditions. As per requirement, different sensors can be established in the field to acquire the required data in real time. An environmental monitoring system can be implemented for real-time measuring temperature, humidity, illumination and soil moisture by using an array of sensors. Smart greenhouse helps to monitor temperature, humidity and soil moisture to change the climate conditions according to the requirement of plants for effective growth. These smart greenhouses minimize the human efforts in handling the operations. There is an ever-increasing awareness of the necessity to develop and apply robotic systems in agriculture, forestry, greenhouses, horticulture, etc. Smart robotic vehicles are capable of working round the year in all weather conditions and have the intelligence embedded within them to behave sensibly in a semi-natural environment, unattended while carrying out many useful tasks in smart farming. In smart farming, farmers take final decisions using various strategies and different services. In this process, all the decisions are based on the previous result and different algorithms come into the action to analyze the previous results and enable the user to take the final decision in smart farming operations. In the supply chain, perishable and sensitive materials such as seeds, plants and food products prevent spoilage which is a matter of concern, where big data has proven useful at various stages. At the production stage, automated systems handle data to show performance and reveal issues in critical equipment. Big data helps farmers and suppliers optimize fleet management to increase delivery reliability. Big data tracking solutions, smart meters and GPS-oriented analytics improve routing, cutting transportation costs and offering advanced mapping of the locations. The other common challenges are the big data life cycle in different applications, such as the appropriate data identification, data deployment, data representation, data fusion, as well as data visualization and interpretation.

A Way Forward

The convergence of multiple technologies such as geospatial, big data, AI, IoT and cloud computing has a significant impact on various operations and applications in smart farming. In smart farming, there are several processes, which demand higher energy input, and markets require products of high quality. Such a process can be classified according to the requirement, technology and applications. AI can augment automation and cost reduction and enhance revenue. ML algorithms can overcome human limitations in terms of speed, accuracy, reliability, consistency and transparency in performing the assigned tasks. Robotics associated with AI need intelligence to handle tasks like object manipulation and navigation in conjunction with subproblems of localization, motion planning and mapping. IoT is used mainly for the automation of equipment and application development using data analytics. In IoT-based smart farming, monitoring crop fields with the help of sensors and automating the irrigation systems are possible, where farmers can monitor and control the farm conditions from a remote. IoT enables farmers to take a data-driven approach to collect vast amounts of information from instrumented sensors about the status of their farms to improve farm yield and mitigate risks from weeds, pests and diseases. The advanced sensing technologies that can be deployed for smart farming include proximal, airborne and satellite-based sensors. The use of mobile and smart phone technologies in smart farming could be effectively used in harnessing the full potential in the communication space. Several smart phone applications are available for agriculture, horticulture and farm machinery to make farm operations smarter and easier.

Conclusions

The integration of remote sensing data with GIS, machine learning and deep learning offers great potential for better extraction of geographical information from remote sensing data and images. With the increased volume and complexity of remote sensing data acquired from multiple sensors using multispectral and hyperspectral devices with multiangle views with time, new development is needed for visualization tools with spatial, spectral and temporal analysis. Temporal satellite data have become valuable tools in studying the spatial extent of degraded lands and for mapping and monitoring the changes that have taken place over a period of time due to reclamation/conservation measures. Smart farming powered by geospatial and trending technologies like AI with big data analytics, IoT, AI, ML and DL immensely helps in making farming smarter with good profit margins. In data-driven smart farming, big data access, the availability of quality data, big spatial data computation, spatial data integration, data privacy and rights to use data are some of the important challenges. On the other hand, these technologies offer immense opportunities in smart farming. Farmers can access the facilities of the greenhouse through the dashboard, and operations can be managed by using voice commands. In a smart farming supply chain, the use of big data is found to be immensely useful at all stages. The geospatial technologies in conjunction with data science techniques have immense potential in spatiotemporal analysis of land resources and land transformation processes, which in turn helps to plan and manage them for optimum utilization of land resources to achieve sustained production levels and food security.

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