Chapter

Application of Geospatial Techniques in Agricultural Resource Management

Syeda Mishal Zahra, Muhammad Adnan Shahid, Zahid Maqbool, Rehan Mahmood Sabir, Muhammad Safdar, Muhammad Danish Majeed and Aneela Sarwar

Abstract

Although technological advancements have sparked the beginning of the fourth agricultural revolution, human beings are still facing severe problems such as shrinking croplands, dwindling water supplies, negative consequences of climate change, and so on in achieving agricultural resilience to meet the demands of the growing population over the globe. Geospatial techniques involving the integrated use of geographic information system (GIS), remote sensing (RS), and artificial intelligence (AI) provide a strong basis for sustainable management of agricultural resources aimed at increased agricultural production. In recent times, these advanced tools have been increasingly used in agricultural production at local, regional, and global levels. This chapter focuses on the widespread application of geospatial techniques for agricultural resource management by monitoring crop growth and yield forecasting, crop disease and pest infestation, land use and land cover mapping, flood monitoring, and water resource management. Moreover, we also discuss various methodologies involved in monitoring and mapping abovementioned agricultural resources. This chapter will provide deep insight into the available literature on the use of geospatial techniques in the monitoring and management of agricultural resources. Moreover, it will be helpful for scientists to develop integrated methodologies focused on exploring satellite data for sustainable management of agricultural resources.

Keywords: geospatial techniques, agricultural resource management, crop growth monitoring, flood monitoring, land cover mapping

1. Introduction

Agriculture is the backbone of the economy, particularly in developing countries, and plays a pivotal role in economic stability and ensuring food security. As a matter of fact, the global population is increasing exponentially and is expected to reach 10 billion by 2050. This drastic increase in global population puts pressure on agricultural resources for more food production despite the constraints of the environment [1, 2].

Changes in climatic conditions, restrictions on expanding agricultural land, and scarcity of water are among the major complications for increasing crop production. Therefore, cropland management, protection of soil quality, judicious use of water, and increase in species diversity are the few basic steps for sustainable management of agricultural resources to meet future food demands [3]. More importantly, monitoring of crop growth and health coupled with timely intervention strategies are necessary for enhanced agricultural crop production along with a reduction in the use of input resources in accomplishing global food security goals.

Technological advances in recent years have shown much development in sensor technology, communication systems, and data analysis tools. Such advances in technologies have facilitated the sustainable use of agricultural input variables along with mitigation of future losses while promoting increased and sustainable yield to accomplish global food security goals. Numerous existing and newly developed techniques and tools such as Geographic Information System (GIS), Artificial Intelligence (AI), Remote Sensing (RS), Global Navigation Satellite Systems (GNSS), Internet of Things (IoT), and Big Data Analytics (BDA) have become essential for global food security through effective analysis of crops as well as soils. When merged with other sources of evidence, these technology solutions are supplying data-driven information and insight for focused or site-specific management of crops, trying to ensure higher production [4]. GIS is a type of database system that includes tools for gathering, storage, and information retrieval in addition to tools for analyzing, converting, and demonstrating spatiotemporal data for a particular intention [5–7]. GIS is one of the key technologies that gives the spatial frame of reference and information on numerous attributes, each of which can be accessed as a separate data layer. Furthermore, it supplies the tools necessary to modify both spatial and non-spatial data and illustrates the results in map formats that are both intuitive and demonstrative [8]. GIS has widespread applications in environmental studies, medical services, and resource management in food, industrial, and agricultural sectors. In recent times, GIS tools have been increasingly used in agricultural production at local, regional, and global levels. GIS together with other techniques such as RS, GNSS, and data analytics has been widely utilized to facilitate crop and soil interventions [9–11].

Remote sensing is a type of geospatial technique that involves acquisition of information about an object or phenomenon without making physical contact with the object using space-borne or airborne satellites. Remote sensing technique captures images of the earth's surface in different wavelength regions of Electro-Magnetic Spectrum (EMS). Some of the images symbolize reflected solar radiation in visible and near infrared regions; a thermal infrared wavelength region represents estimations of energy emitted by the earth's surface, and a microwave region represents a measure of relative return from the earth's surface. The basic mechanism of remote sensing technology involves emitted electromagnetic radiations coming from sun, falling on different objects on earth and reflected to atmosphere, which is captured by the distantly placed satellite sensor as images of different wavelengths. However, the process involved in acquiring information about an object or area of interest by means of measuring radiant energy reflected or emitted by an object or surface has been summarized in **Figure 1**. The complete processing of remote sensing involves various steps including (1) emission of electromagnetic radiations; (2) energy transmission from source to earth's surface; (3) interactions of EMR with the earth's surface, that is, reflection and emission; (4) energy transmission from the surface to satellite sensors; (5) sensor data output; and (6) transmission, procession, and analysis of satellite data. This remotely sensed data is comprised of spatial information (size, shape, and

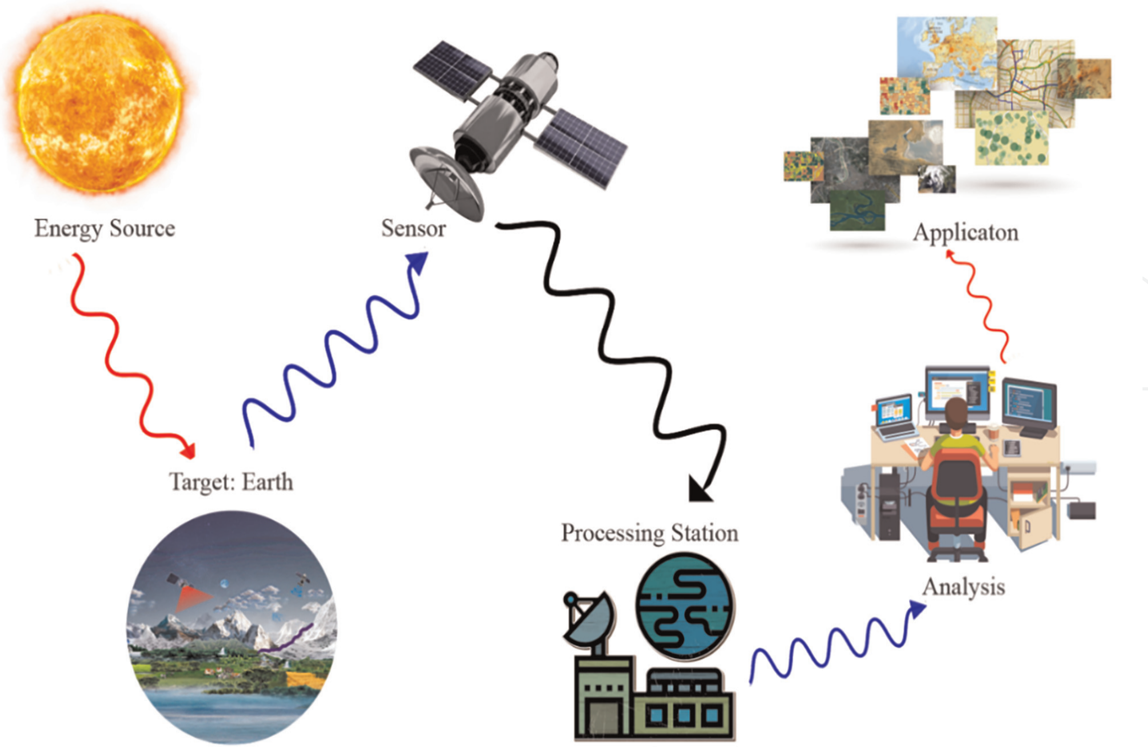

Figure 1.
Concept of remote sensing and GIS - applications of remote sensing.

orientation) as well as spectral information (tone, color, and spectral signature). As it is known, GIS creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there). This provides a basis for mapping and analysis in almost every industry and assists users to understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making. Although RS and GIS have been widely utilized in various domains of agriculture such as soil mapping, terrain analysis, crop stress mapping, crop yield mapping, soil nutrient assessment, and organic matter mapping, it has been suggested that the potential of high-resolution remotely sensed data to deal with spatiotemporal variations make it valuable to be utilized in precision agriculture. When it comes to precision agriculture, various combinations of spatial resolutions, spectral coverage, and frequency ranges are utilized. It has been reported that monitoring of crop growth and mapping of crop yield can be achieved using low-resolution satellite data; however, mapping the severity of disease infestation necessarily requires fine-resolution satellite data. Literature suggests that RS and GIS are the core of precision agriculture because they collect, store, retrieve, and analyze feature- and location-based information and provide statistics alternatives particularly for site-specific monitoring [12].

Since its inception in the 1960s, remote sensing technology has been widely used in agriculture [13]. Several global and national agricultural monitoring systems based on remote sensing platforms are now in operation. These systems deliver consistent, timely, and important information to agricultural producers, managers, and policymakers. Crop identification and cropland mapping; crop growth monitoring and yield estimation/prediction; inversion of key biophysical, biochemical, and environmental parameters; crop damage/disaster monitoring; precision farming; and so

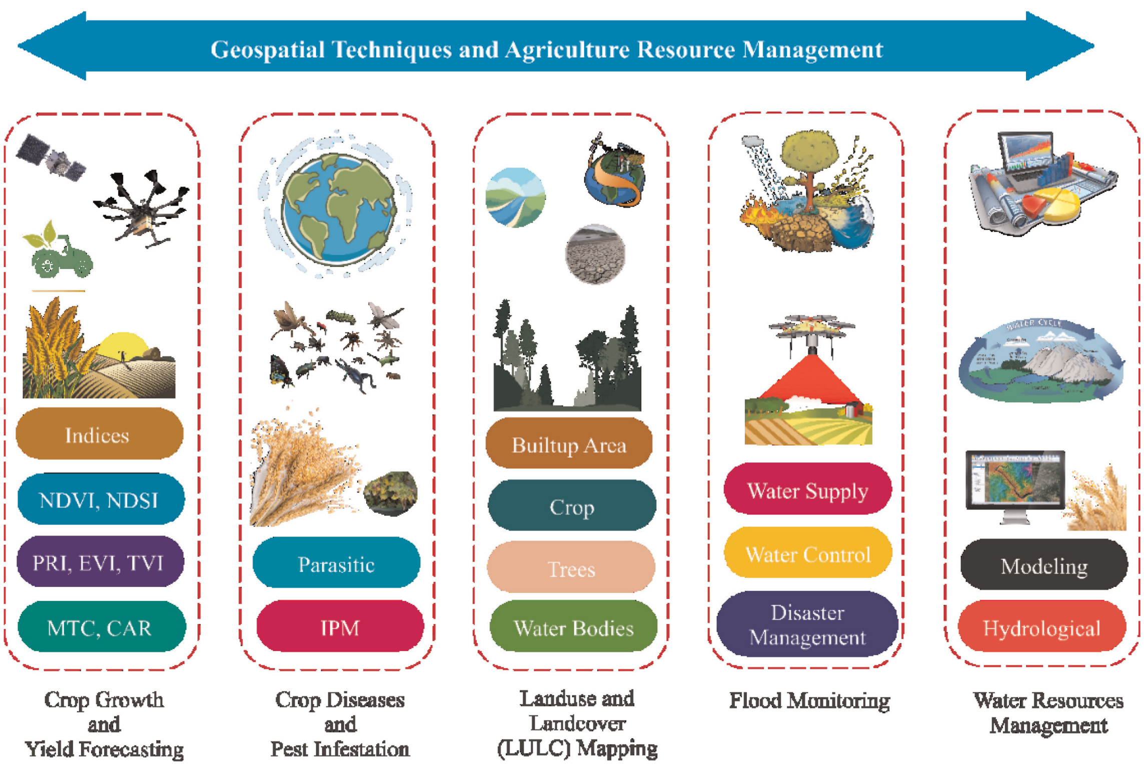

Figure 2.
Different indices/ parameters for monitoring and management of various agricultural resources.

on are all important applications of geospatial techniques in agriculture resource monitoring. This chapter is focused on the use of geospatial techniques for agricultural resource management. The various indices and other parameters determined using geospatial techniques for mapping and monitoring of crop growth and yield forecasting, crop disease and pest infestation, nutrient deficiency, land use, land cover mapping, flood monitoring, and water resource management are summarized in **Figure 2**.

Digital maps based on RS data and GIS differ broadly from traditional maps. In these maps, satellite data is utilized to map a given attribute such as soil analysis, crop yield, precipitation, nutrient availability, pest infestation, and so on. Satellite-based positioning or navigation system provides information about longitude, latitude, and altitude. GIS provides sophisticated abilities by using statistical techniques and geospatial predictive analysis to retrieve inter-attribute interactions. Such observations are beneficial for decision making and management of resources on a sustainable basis. These digital maps help farmers and researchers to identify hotspot regions, map field boundaries and water bodies, and recognize the relationship of different features inside and outside the field's boundary lines. High-fidelity field visualization allows site-specific implementation of nutrient content, herbicides, pesticides; irrigation to improve productivity; and to reduce input costs. In this chapter, we present the scientific work associated with the use of remote sensing and GIS techniques for sustainable management of agricultural resources. This chapter is organized in such a way that it starts with highlighting the need of RS and GIS technologies for mapping and monitoring agricultural resources. Afterward, research presents the recent developments in RS and GIS technologies involved in agricultural resource management.

2. Crop growth and yield forecasting

Monitoring development of crops and making estimates of their yields are both extremely vital for any nation to be able to make decisions on food production for its consistently expanding population. Typically, crop yield forecasting across crop growth includes models that integrate global climatic and soil conditions and other ancillary data as executed accordingly to characterize the development, photosynthetic activity, evapotranspiration, and yield of a particular crop relying on reliable physical and physiological theories. However, these models are a poor significant predictor when variations in soils, stress, pressure, or management practices are present. The process of anticipating crop growth and initial crop yield over agricultural fields is a crucial method for both the planning of food security and the prediction of agricultural economic return. Monitoring the growth of crops and estimating their output have been easier thanks to the ongoing development of RS and GIS technologies, which have led to improvements in both the process and procedures involved [14–16]. Estimation of crop yield has been demonstrated by multiple studies to benefit from the integration of GIS and RS technology. The research carried out by Memon et al. [17] evidenced how efficient integrating hyperspectral Landsat satellite imagery and contrasting various RS-based spectroscopy indices was in monitoring crop growth and early crop yield forecasting over agricultural fields. The focus of this research was on the impact of rice yields. The information can be useful in the long-term planning of agricultural sustainability in cropping systems involving rice and wheat. The findings of the study that was conducted by Hassan and Goheer [18] demonstrated that an accurate early forecast of wheat crop yield prior to growing crops could be achieved through the utilization of vegetation indices deduced from modest resolution imaging spectroradiometer satellite imagery in conjunction with crop yield information and a strategy that is based on GIS modeling. Muslim et al. [19] employed a GIS-based environmental policy-integrated climate model in yet another research. This model served as an effective tool for forecasting rice yield and was based on integrated climate policy. Several of the most popular vegetation indices (VIs) used in remote sensing are included in **Table 1** along with details such as their mathematical formulations, the scales they are designed for, and the factors they assess. These vegetative indices have several applications, including crop monitoring, stress detection, biomass estimation, and yield forecasting. However, the correct index must be selected considering the given task and surrounding factors.

The prototype regional- and local-crop-level data, soil data, agricultural production data, and climatic data to spatial and temporal approximate variability in crop yield. In a similar manner, Al-Gaadi et al. [16] predicted potato tuber crop yield by extracting the normalized difference vegetation indices and the soil-adjusted vegetation index from Landsat satellite data obtained during the different phases of potato growth. Simulations of crop yield prediction that are premised on GIS and RS have the potential to have broad applicability in the process of notifying agricultural production regulations that are geographically centered. For instance, based on the results of these modeling techniques, compliance review can be designed to change the contributing factors to crop yield and quality (that include farm management strategies, wind patterns, availability of water, altitude, terrain, plant health, and inclusive growth) [20, 21]. This is possible because policy intervention is a form of intervention. It is essential to make yield projections for crops well in advance of harvest time, especially in areas where there is a high degree of climatic variability. Planning and

Index	Scale	Parameter	Formula
Normalized Difference Vegetation Index (NDVI) [14, 15, 19–21]	Canopy	Biomass; Vegetation Fraction	$\frac{NIR-Red}{NIR+Red}$
NDVI is used for assessing the robustness and density of vegetation. It has important applications in crop growth monitoring, land-use planning, and ecological research. NDVI values closer to 1 suggest that the plants are in better health [22].			
Green Normalized Difference Vegetation Index (GNDVI) [23–26]	Canopy	Chlorophyll; Vegetation Fraction	$\frac{NIR-Green}{NIR+Green}$
GNDVI is a tool developed based on satellite data, frequently used for assessment of crop health and growth. Higher GNDVI values indicate more robust plant life. Values between 0 and 1 are possible [27].			
Photochemical Reflectance Index (PRI) [27–32]	Canopy	Photosynthesis efficiency/ RUE	$\frac{R570-R531}{R570+R531}$
PRI is a valuable tool for assessing photosynthetic activity and stress in plants. PRI reflects changes in pigment composition of leaves and the quantity of light that is absorbed by chlorophyll. PRI values are directly proportional to vegetation health and its numerical scale ranges from −1 to 1, where higher values indicates better health [33].			
Normalized Difference Red Edge (NDRE) [34–37]	Canopy	Chlorophyll/ Nitrogen	$\frac{R790-R720}{R790+R720}$
NDRE is a vegetation index developed using geospatial data for assessing plant health and biomass production. NDRE index determines the alterations in vegetation cover, encompassing factors such as plant growth, stress, and nutrient insufficiencies [27].			
Canopy Chlorophyll Content Index (CCCI) [38–42]	Canopy	N Status/ Chlorophyll	$\frac{NDRE-NDRE_{min}}{NDRE_{max}-NDRE_{min}}$
CCCI is widely employed for estimating the chlorophyll concentration in plant canopies. CCCI exhibits sensitivity toward variations in leaf chlorophyll concentrations and structural changes in leaves. CCCI values ranges from 0 to 1, where higher values are indicative of higher levels of chlorophyll content [43].			
Ratio Vegetation Index (RVI) [44–47]	Leaf	Biomass	$\frac{NIR}{Red}$
RVI is widely used to assess the health and growth of vegetation for the purpose of evaluating crop productivity and identifying nutrient insufficiencies. RVI values ranges from 0 to 1 where higher VHI values are indicator of healthier vegetation [48].			
Enhanced Vegetation Index (EVI) [49–52]	Canopy/ Regional	Biomass/Vegetation Cover	$2.5 * \frac{NIR-Red}{NIR+C1*Red-C2*Blue+L}$ C1 = 6; C2 = 7.5; L = 1
EVI is a vegetation index that enables the assessment of vegetation density, cover, and health and frequently utilized in land-use and ecological studies. EVI values ranges from −1 to 1 where elevated values are indicator of more robust and healthier vegetation [53].			
Visible Atmospherically Resistant Index (VARIgreen) [53, 54]	Canopy/ Regional	Vegetation Fraction/ LAI	$\frac{Green-Red}{Green+Red+Blue}$
VARIgreen is utilized to assess vegetation cover and health and primarily used in regions where atmospheric interference is of significant concern. VARIgreen index values ranges from −1 to 1, with higher values indicating a greater degree of vegetation health [48].			

Table 1.
Shot description of frequently used vegetation indices (VIs).

policymaking for food security and the prediction of agricultural economic return should include monitoring the conditions under which agricultural crops grow as well as making projections about the potential crop yield [14, 15, 19]. This could include the development of policies for increasing the efficiency of agricultural production and maintaining its sustainable development [15]. To provide food for a growing population in low- and middle-income countries (LMICs), agricultural production systems need to work toward closing the yield gap that exists between the yields that farmers currently accomplish and the yields that may be conceivably easily achievable in a rainfed basic sustenance agricultural system. In order to evaluate and map crop yield gaps, Hochman et al. [21] created a simulation that consolidated numerical yield and crop varieties area data, remotely sensed data, cropping information processing paradigm, and GIS mapping. The purpose of this model was to address the discrepancy between the two sets of data.

There exist multiple approaches for predicting crop yield; some of the approaches are given in **Figure 3**. The conventional approach to predicting crop yield involves the assessment of crop condition by professionals. Throughout the crop-growing season, various observations and measurements are conducted, including but not limited to tiller number, spikelet number and fertility percentage, pest and fungal damage percentage, and weed infestation percentage, among others. The data obtained through this method can be utilized to make predictions about yield through the application of regression techniques or by drawing upon the insights of local experts [22]. Two additional techniques employed for predicting crop production are remote sensing and crop simulation models. The aim of the yield forecast is to provide accurate, scientifically sound, and impartial predictions of crop yield at the earliest possible stage in the growing season, considering the impact of weather and climate. The

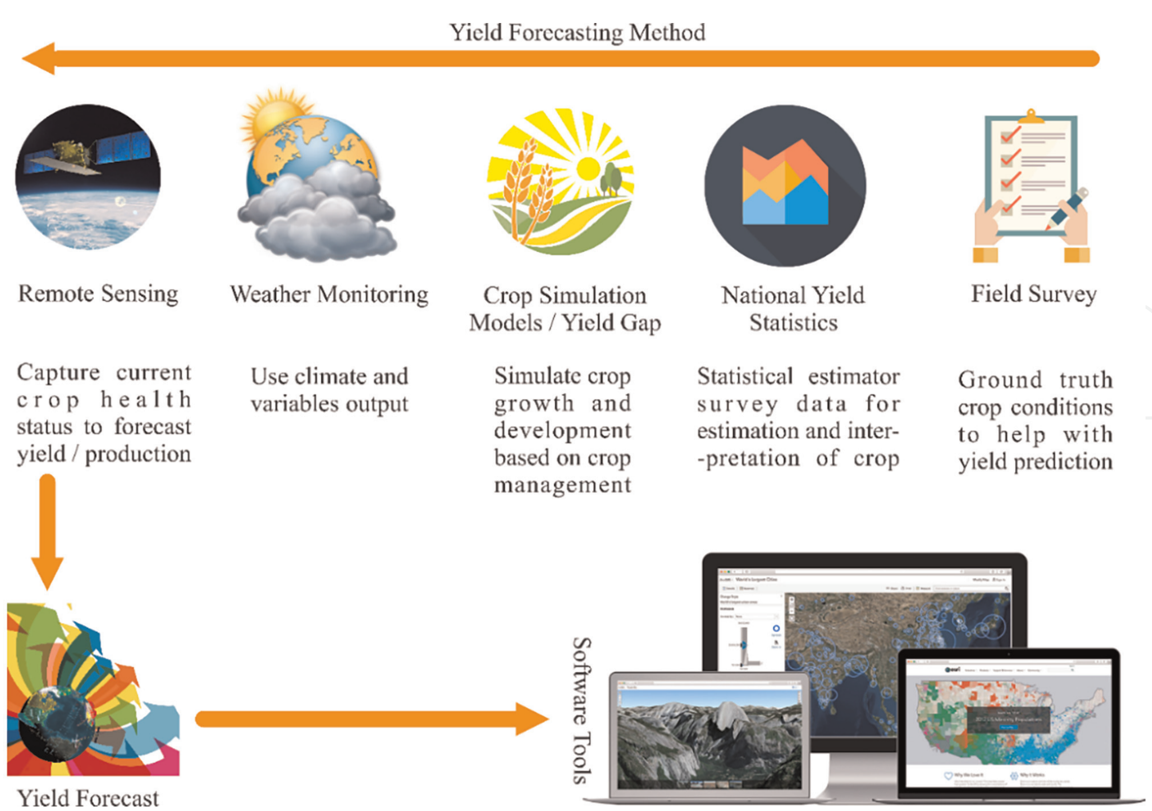

Figure 3.
Approaches used for yield forecasting include field survey, national yield statistics, crop simulation, weather monitoring, and remote sensing.

disparities between forecasts and final estimates lie in the temporal aspect of their dissemination. Predictions are generated prior to the complete harvest of the crop, whereas evaluations are conducted after the harvest of the crop. The outcomes are derived from the implementation of a statistical estimator on the survey data, and the subsequent point estimates are analyzed by commodity.

Throughout history, farmers have consistently engaged in the practice of making predictions as a means of strategizing their agricultural methods. The selection of a cultivar, the optimal planting timeframe, and the appropriate quantity of fertilizer to utilize are contingent upon the prevailing climatic conditions. If farmers are aware of a high probability of rainfall in the upcoming week, they will promptly proceed to sow their seeds in the field [23, 24]. The accurate prediction of crop yield necessitates the concurrent prediction or knowledge of other significant parameters. An instance of this would be the measurement of the land that was sown at the commencement of the cultivation period and the measurement of the land that was reaped. The utilization of geospatial methodologies in the prediction of crop development and yield has numerous advantages, such as the capacity to furnish farmers, policymakers, and other interested parties with precise and prompt information. The utilization of this information can aid in the process of decision making, specifically in tasks such as identifying the most favorable periods for planting, choosing suitable crop types, and optimizing the management of resources, such as water and fertilizer, for greater efficiency.

3. Crop disease and pest infestation

It is essential that there should be no instance of hunger or malnutrition among the population if the nation is to experience long-term economic expansion and environmental sustainability. Malnutrition is the only cause of one-third of deaths and underweight, with retarded growth among children less than 5 years of age in poor nations. Food insecurity, poor maternal and childcare practices, a lack of access to safe drinking water, and insufficient quality sanitation and health services are all contributors to malnutrition, which is caused by a deficiency in both macronutrients and micronutrients, as well as an imbalance in nutritional intake and disease [25]. Over the past few centuries, the mismatch between the increasing food demand of the world's booming population and the amount of agricultural supply has made the issue worse [26]. The main limiting variables that can influence agricultural productivity, growth, and eventually food security are both biotic and abiotic constraints. These include unfavorable and harsh temperatures, a lack of water, bad soil, insect infestation, illnesses, and weeds. In addition, changes in temperature or climatic disruption have a significant and deleterious effect on agricultural output and productivity around the globe, particularly in tropical regions [27]. As the world's climate continues to shift, experts predict that agricultural output will drop by 20 percent by 2080 and that the situation would be even direr in developing nations like India. Droughts, floods, and other weather extremes are just a few examples of how climate change is affecting crop production. Insect pests and disease epidemics have become more common because of these shifts and disruptions [28]. Exports and imports of agricultural products have increased worldwide since the liberalization that followed the founding of the World Trade Organization (WTO) in 1995. The spread of invading alien species, which threaten native and introduced plant communities worldwide, has been accelerated by the globalization of trade. As a result of global warming and trade liberalization, more infectious diseases and insect pest outbreaks have appeared. Furthermore, new tools have made it possible to reduce the impact on agricultural yield as much as possible [28]. Now, more than ever, GIS and remote sensing are being used extensively for precise data collection and analysis when it comes to crops as shown in **Figure 4**. In this section, it will look at how geospatial technology has played an admirable part in the detection and mitigation of plant/crop diseases and insect pests. This section may also illustrate the supplementary understanding of how geospatial technologies would be utilized in agriculture to lessen the impact of the disease and insect-pest attack.

The term "healthy" is used to describe a plant that is fully realizing its genetic potential in terms of physiological effects. When insects or diseases cause havoc on plant life, normal physiological processes are thrown off [29]. The plant's health, biomass, and output are all negatively impacted by pests and illnesses carried by insects. Typically, the effects of insect pests and diseases on yield and quality are not immediately apparent throughout the growing season. Forest diseases and pests can have a massive effect on ecological services, altering natural landscaping and its cultural value, hindering wildlife habitat and biodiversity, and limiting the forest's

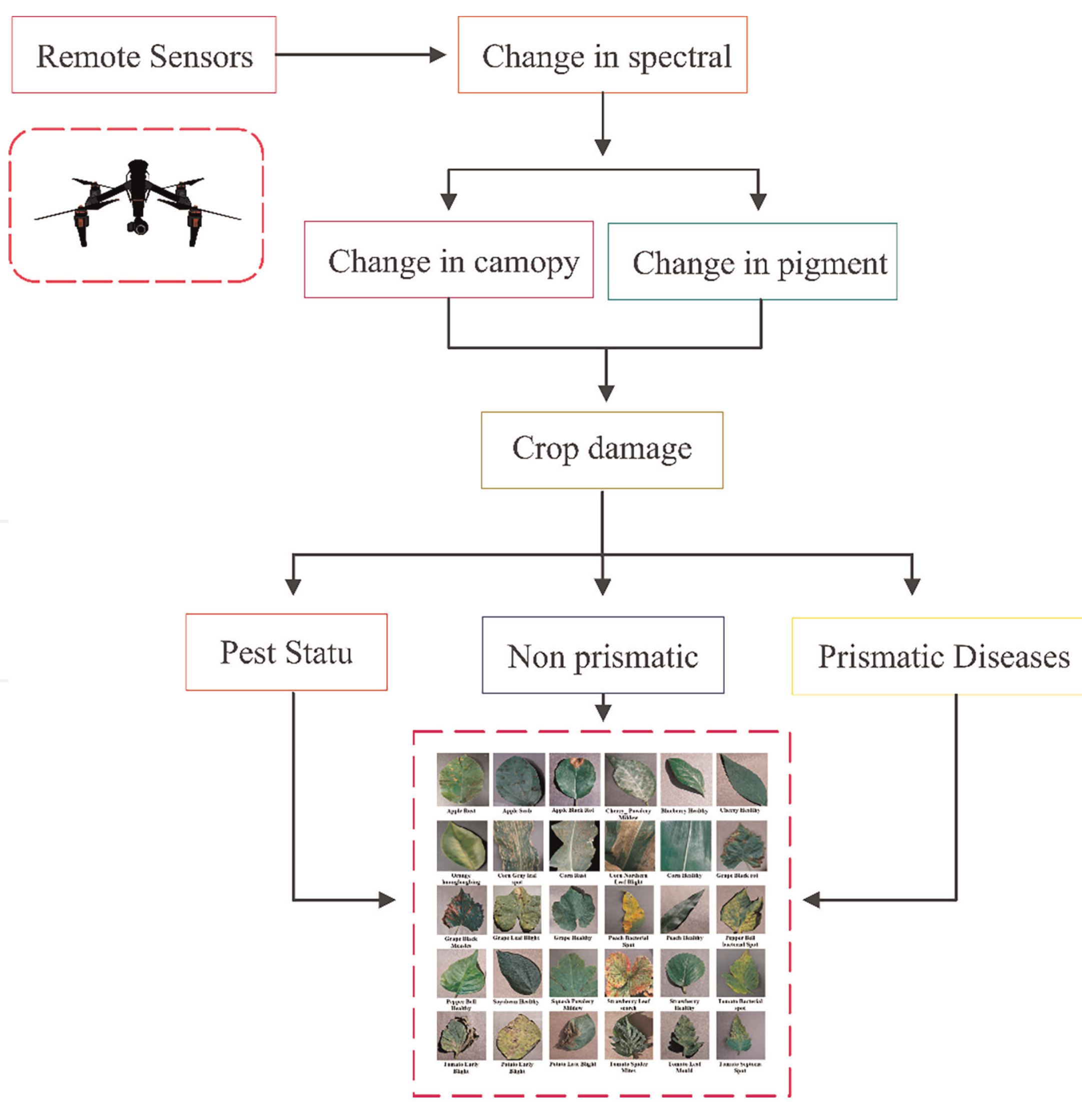

Figure 4.
The emergence of crop-damaging diseases and pests, and the use of remote sensing.

capacity for carbon sequestration, all of which harm agricultural output. GIS stores, captures, analyzes, and displays data that describes an area of the earth's surface. Most common GIS features include data storage and retrieval, presentation and querying, evaluation (geometric and thematically), conversion, and others. Information gathering, processing, administration, and display are the four pillars upon which a GIS is built [30]. The proliferation of data-capture methods is proportional to the variety of technological tools at our disposal. As a result of advancements in geospatial techniques like GPS, geodetic surveys, laser scanners, aerial photography, and satellite-based remote sensing, and so on, it is now much simpler to keep tabs on plant health. Arizona, Northern California, Idaho, Washington, and Oregon used GIS/GPS technology to analyze semi-automated data [31].

Using a unified strategy, we geo-referenced weather data, plant growth data, and satellite imagery in a GIS to assess the potential for pests and diseases as well as the optimal growing conditions for our crops. Using elevation, weather, and satellite data projections, projections for both favorable growing conditions and the spread of illness were developed for agricultural regions. Models for six insect pests and twelve crop diseases were computed and displayed daily in geo-referenced maps for agricultural survey regions. Dates and yields of grape harvests were also forecasted with remarkable precision. Information was disseminated daily via the Internet as regional weather, insect, and disease risk maps based on data derived from GIS [30]. Difficulties associated with plant nourishment, insect identification, crop forecasting, water requirements, and weed management are just some of the many areas where remote sensing has been utilized. Changes in plant characteristics are indicators of disease and pest attack, which can be detected by remote sensing. Typical ground-based optical scouting techniques may miss tiny variations in vegetation, but a remote sensor's capacity to do so makes it a helpful tool for assessing within-field variability, evaluating crop development, and managing fields based on present conditions [30].

Nowadays, precision agriculture relies on geospatial technologies like GPS integration with GIS for Insect-Pest Management (IPM). Crop management planning benefits further from the utilization of remote sensing and spatial analysis, as well as other technologies such as the Global Navigation Satellite System (GNSS) [32]. However, there are also some drawbacks to these techniques. For example, high spatial resolution imaging is not easily accessible for all locations, especially rural ones. While hyper-spectral photography is essential, consultancies and end-users/farmers often lack specialist knowledge of geospatial techniques, and timely mapping and near-real-time picture collection and delivery processes are crucial to the success of this field of study. Despite these difficulties, geospatial technology can also provide useful data in an IPM setting by facilitating a thorough comprehension of the relative spatial of the abiotic and biotic characteristics of a field and its crop, as well as giving information on the populations of diseases and pests that are either already present or likely to appear [30]. In a field where reports of pest and disease outbreaks on a massive scale are on the rise, this technology is proving invaluable. Improved production, pest and disease control, and other facets of forestry management are all possible thanks to geospatial technologies. These tools are now used mostly in academic settings, but with improved access to data and technology, this is likely to change. Increased yields and lessened concerns over food insecurity are two of the many benefits that have resulted from the widespread adoption of geospatial data and technology.

Crop output must rise along with population growth to guarantee that everyone, no matter where they live, has access to adequate food and water. Agricultural sustainability is achieved via the employment of a variety of technologies and strategies that make production safer and reduce negative effects on the environment. Successful agriculture relies heavily on the use of precision agriculture tools. Using data gathered by geospatial technologies, precision farming is a method of micromanagement that improves agricultural and territorial management decisions. Pests and diseases have a significant impact on crop yields, which in turn affects the ability to feed the world's population. But the development of geospatial technology has facilitated the operations of controlling many pests and illnesses affecting plant health.

4. Land use/land cover (LU/LC) mapping

The terms "land cover" and "land use" are sometimes used indiscriminately; nevertheless, the true connotations of these concepts are significantly different from one another. The covering surface on the earth is referred to as land cover, and it might include things like flora, urban development, waterways, fallow land, or other things. To effectively carry out global monitoring investigations, resource planning endeavors, and development endeavors, it is essential to recognize, delineate, and map land cover [8, 33, 34]. The establishment of a benchmark from which monitored operations, such as change detection, can be carried out and the provision of ground cover data for baseline thematic layers are both accomplished through the process of identifying land cover [35]. However, the term "land use" relates to the use that the land is put to, such as for agricultural purposes, for the goal of providing an environment for wildlife, or for other recreational activities. Because it is necessary to have up-to-date data to determine what percentage of land is now being put to what kind of use and what kinds of changes occur in land utilization throughout the year; approaches for land use need both mappings as a baseline and ongoing monitoring [33, 36, 37]. The dynamic characterization of the world's LU/LC has been summarized in **Table 2**. Having this knowledge aids in the process of formulating plans to strike a balance among preservation efforts, competing uses, and the demands of development. Land use studies are being conducted because of several issues including the loss of forested land, the reduction in the amount of fertile land, and creeping urbanization [11].

Resource planning and control, preservation of wildlife habitats, baseline modeling for GIS inputs, urban expansion and encroaching, route and logistical planning for

LULC - Objects	Characteristics
Water bodies	Possesses very minimal to almost no sparse vegetation, no rock outcrops, and no man-made structures such as docks [44]
Trees	Any considerable concentration of thick vegetation is usually characterized by a covered or thick canopy [35]
Grass	Uniform regions of grass-like flora, sometimes known as blade-type leaves, provide the impression of being distinct from tree cover and sparse vegetation. Grasslands that grow naturally in the environment without any visible human planning [36]
Waterlogged vegetation	Regions with any kind of flora where water and soil are visibly mixed. Regions that are flooded periodically consist of a combination of grass, shrubs, trees, and barren land [55]
Crops	Cereal grains, grasslands, and crops were all seeded and plotted by humans [19]

LULC - Objects	Characteristics
Shrubs and scrub	Landscaping with uncovered rock and soil should have either isolated pockets of vegetation or isolated plants distributed across the terrain. Obstacles that prevent that are populated by shrubs among dense forests that are obviously not higher than the trees. Look grayer and browner because of a less dense layer of leaves [34]
Built-up area	Commercial, business, and private buildings along with the parking areas constructed by humans that are enclosed together with a variety of housing developments, including structures, roads, gardens, and trees, as well as domestic constructions or housing developments that are separated and bordered by land covered with vegetation [48]
Fallow land	Stretches of rock or dirt that are covered in very little or no flora at all having vast tracts of land consist primarily of sand and desert, with little or no wildlife [56]
Snow and ice	Large, evenly distributed expanses of snow or ice are often only seen in mountainous regions or at the highest latitude and evenly distributed across a wide area [57]

Table 2.
Dynamic categorization of the world's land use and land cover (LULC).

geophysical investigation, resource exploitation operations, disaster characterization (storms, inundation, volcano, earthquake, and fires), legislative borders for taxation and asset appraisal, object tracking (identifying landing fields, highways, hillsides, and crossings), and delineating of the land/water boundary are the important tasks that can be performed using LU/LC data gathered using geospatial techniques. However, in agricultural resource management, LU/LC refers to the physical characteristics and use of land in a particular area, including vegetation cover, soil type, water availability, and land use activities as shown in **Figure 5**.

Understanding LU/LC is crucial for sustainable agricultural management, as it provides information on land use change, crop suitability, and environmental impacts. In agriculture resource management, LU/LC data is used in various ways, including:

Crop Suitability Analysis: LU/LC data can be used to identify areas suitable for specific crops. For example, if a farmer is interested in planting a particular crop, they can use LU/LC data to identify areas with suitable soil types, water availability, and

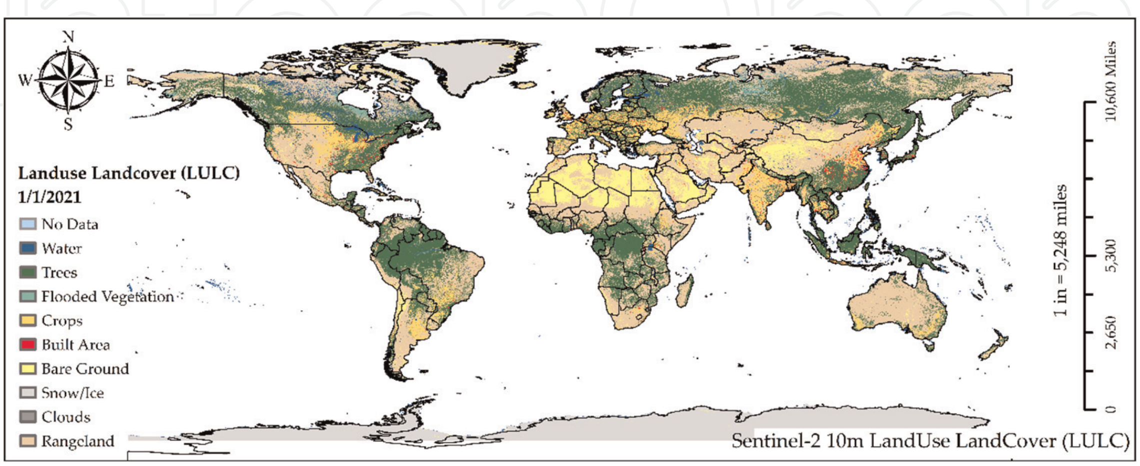

Figure 5.
Global 10 m land use/ land cover (LU/LC) map for 2021 using geospatial technologies [source: ESRI website (https://www.esri.com/partners/impact-observatory-a2T5x0000084pJXEAY/land-use-land-cover–a2d5x000005juReAAI)].

vegetation cover for that crop. This analysis helps to optimize crop production, leading to higher yields and better resource management.

Land Use Planning and Management: LU/LC data are also used in land use planning and management. By understanding the current and past use of land, farmers and land managers can develop land use plans that maximize productivity while minimizing environmental impacts. For example, if a particular area has a history of intensive agriculture, land managers may decide to rotate crops to avoid soil degradation and nutrient depletion.

Environmental Monitoring: LU/LC data are also essential for environmental monitoring. By tracking changes in land use and vegetation cover, environmental impacts such as deforestation, soil erosion, and habitat loss can be identified and addressed. This information is crucial for developing effective conservation strategies and ensuring sustainable resource management.

Natural Resource Management: LU/LC data are also used to manage natural resources such as water and soil. By understanding the characteristics of the land, farmers can implement practices such as soil conservation, water harvesting, and irrigation that optimize resource use and minimize waste.

Disaster Management: LU/LC data are also essential for disaster management. By identifying areas at risk of natural disasters such as floods, landslides, and droughts, farmers and land managers can implement measures to mitigate the impact of these events. For example, farmers may decide to plant crops that are more resistant to drought or implement soil conservation practices to reduce soil erosion during floods. So, LU/LC data are essential in agriculture resource management and provide crucial information on crop suitability, land use planning and management, environmental monitoring, natural resource management, and disaster management. By using LU/LC data, farmers and land managers can optimize resource use, minimize environmental impacts, and ensure sustainable agricultural practices. The efficacy of remote sensing (RS) data in facilitating land use and land cover (LU/LC) mapping has been substantiated by scientific literature. The use of RS data has been shown to provide precise and current data on land use changes, thereby aiding sustainable land management practices.

5. Flood monitoring

Floods are one of the most destructive environmental disasters worldwide, contributing to more substantial economic and social consequences compared to any other natural event. Because of their widespread distribution, floods cause more death and destruction than any other natural calamities [38]. When it rains heavily in a place, downstream areas frequently become inundated because of the excess water. Whenever water flows overland and into low-lying areas, this can cause flooding [39]. Floods and other environmental disasters wreak havoc on both human and natural resources and generate significant amounts of destruction [40, 41]. Flooding has an adverse impact on the lives of around 140 million citizens each year on average. Assessment of extensive flooding is of the utmost significance regarding the repercussions on society, the economy, and the environment [42]. Flood control and mitigation efforts are essential to minimize the damage that can be caused to environmental assets, agricultural land, and other infrastructures, among other things [43, 44]. As a result, doing a study of the likelihood that an area will be flooded is a crucial responsibility for advance warning systems and emergency responders as they work toward developing management plans for preventing and mitigating future flood disasters [45]. For instance, HAZUS is a GIS-based natural hazard assessment tool formulated for evaluating flood hazards; HEC-FDA is a computer program to facilitate agricultural engineers across vulnerability assessment of flooding-risk-reduction strategy. These are just two examples of the many comprehensive techniques that are currently available and utilized by many data analysis organizations around the world. GIS is a computer-based system that handles georeferenced data by providing the capability for inputs, information management (data management and access), modification and evaluation, and dissemination. GIS offers a wide variety of techniques that may be used to determine the region that has been impacted by floods and to make predictions on the areas that are expected to be inundated because of high-water levels in rivers [41]. GIS will be utilized to a significant degree to compile material obtained from a variety of maps, aerial pictures, satellite images, and digital elevation models (DEM) [44]. The vulnerability assessment also will appropriate utilization of the data from the census as well as any other appropriate statistical abstracts to better cater to the requirements of the native population. The research and technique of collecting data (spectrum, geographical, and temporally) about a region or material thing without making direct physical touch with the entity or region under inquiry are known as remote sensing [42–44].

In recent years, remote sensing technology and geographic information systems have emerged as the two most important tools for flood inundation mapping [43]. The demarcation of flood zones and the creation of flood danger and flood risk mapping for places that are prone to flooding are the two primary focuses of attention in this sector of industry [42]. Any endeavor at flood evaluation or hazard modeling in this region is hampered by the limited availability of high-resolution DEMs, even though river flooding in developing countries is very severe because of their overreliance on agriculture. However, the accessibility of high-resolution DEMs is limited. In places prone to flooding, flood hazard mapping is an integral part of carrying out the necessary planning for land use [45]. It generates charts and maps that are simple to understand and can be accessed quickly, which makes it easier for administrators and planners to identify areas of risk and prioritize their activities to mitigate or respond to such risks [46]. Worldwide natural disasters due to flood hazard, the hotspot areas, flood frequency, distribution and deciles using geospatial technologies are illustrated in **Figure 6.**

The traditional methodologies of predicting floods were not trustworthy enough to make a precise forecast. The techniques used for flood monitoring are illustrated in **Figure 7**. But usage of remote sensing and GIS technologies is extremely helpful in determining and evaluating flood-related consequences caused by excessive rainfall in a catchment area or by ocean wave surges in coastal areas. During the previous year, numerous researchers and engineers put various models to use in order to estimate flood levels [46]. At the present time, geospatial approaches offer a diverse selection of data sources that can be utilized for the modeling of floods. In the field of disaster modeling, including flood inundation mapping, cartography, and the analysis of complicated problems, the analytic hierarchy process, abbreviated as AHP, is among the most well-known and successful methodologies [40, 43]. In addition to the Analytic Hierarchy Process (AHP), other recognized and appropriate models for hazard assessment include the Multi-Criteria Decision Support Approach (MCDA), the Weights of Evidence (WoE), the logistic regression (LR) model, the responsive neuro-fuzzy interface system, artificial neural networks (ANN), and the FR model [47, 48]. Researchers attempted to demonstrate a connection between the predictor variables and the

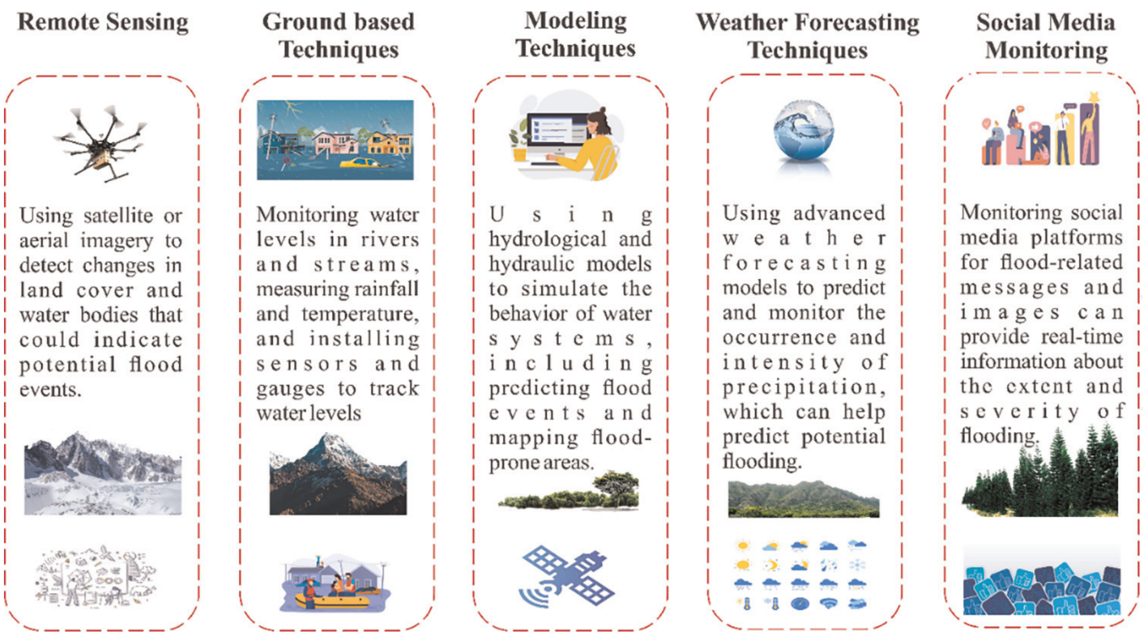

Figure 6.
Global natural disaster hotspots for flood hazard frequency and distribution using geospatial technologies.

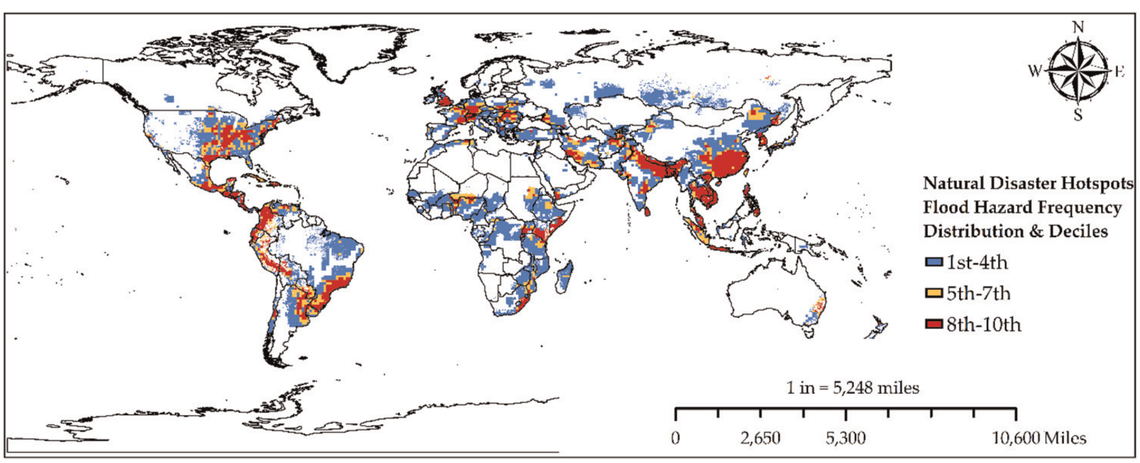

Figure 7.
Geospatial techniques and global map for flood hazard [58] [online source: SEDAC website (https://sedac.ciesin.columbia.edu/data/set/ndh-flood-hazard-frequency-distribution/maps)].

occurrence of the flood by using the ANN approach, which was used in the forecasting of flood [48]. It has been stated that the ANN approach can deal with all inputs that are unpredictable to derive useful information. The employment of MCDA, RS, and GIS techniques is particularly helpful in the study and mapping of possible flood-prone regions because these techniques are dependable and precise [48]. The MCDA method is applicable for flood assessment and mapping in areas with insufficient or no available data, and it may be of use to local authorities in the process of flood mitigation. In China, the AHP model was used for the purpose of flood deflection [47, 48].

The modeling of floods is a complicated process that requires considering a great number of different parameters. The application of the RS approach makes a substantial contribution to the mapping and evaluation of flood risks. Because they are rapid and more effective, RS and GIS offer the greatest opportunity to catch, preserve, integrate, alter, access, analyze, and present information for the assessment of prospective risk regions. This is especially useful in situations where time is of the essence. This study is an example of an ensemble method that demonstrates how effective GIS-based flood modeling can be. The frequency ratio (FR) method, GIS, and remote sensing were all utilized in the process of estimating the likelihood of flooding.

6. Water resource management

Water is a fundamental element of nature's resources and can be found in many different varieties, including underground aquifers, rivers, streams, lakes, glaciers, and so on. The capability of water to keep humans alive, transport nutrition to agricultural production, neutralize pollutants and hazardous substances, and regulate the hydrological regime are the primary reasons for the significance of water [46]. Consequently, the management of water resources is an important problem for us to address now to lessen the likelihood of water shortages for coming generations. Substantial oscillations in the hydrological system are currently causing degradation or water contamination supplies, as illustrated in **Table 3**. These high variations are a direct result of the significant economic and demographic shifts that have occurred in recent times [45]. As a direct consequence of this, this invaluable asset is currently subject to competition and requires both protection and management for conservation. In this section, we have presented the critical issue of gaining knowledge of water resources through the application of geo-informatics by utilizing different types of intelligence, including classic, enhanced, composite, and artificial [49].

Water Resources Management	Hydrological management
	Modeling of groundwater
	Quality analysis of water
	Water supply management
	Sewer system management
	Storm water control
	Flood disaster management

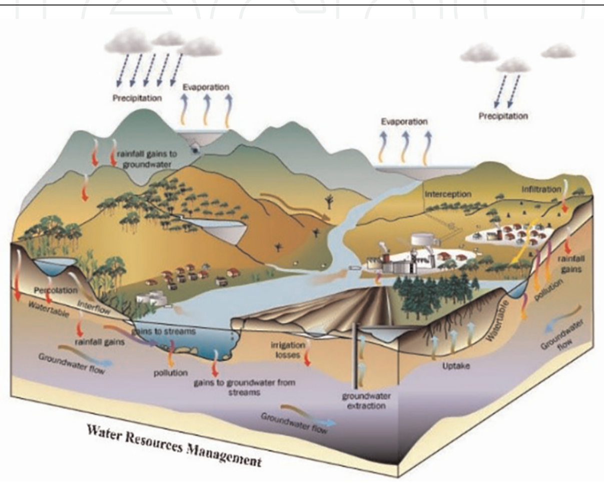

Table 3.
Water resources management strategies.

The primary purpose of water resource management is to comprehend and manage water resources, whereas geospatial approaches make use of remote sensing, geographic information systems, and global positioning system to make this process more efficient. In addition to its function as a factor in maintaining life, water also plays a part in the generation of potentially lethal risks in the manner of floods and droughts [11, 43, 48]. GIS databases document and catalog water supply information. There are servers located all around the world where the data accumulated on water resources are kept. Some of the details are generally the product of GIS data acquisition [11]. So, with the aid of GIS, researchers can store and distribute massive amounts of information about water resources. Large geospatial satellites launched from outside the Earth's atmosphere are interconnected with GIS and utilized to aid in the global dissemination of data/ information. When a base station needs to obtain geographical data, the satellite makes it available to them wirelessly. Fortunately, cloud-based deployment options are available for most GIS systems today. This allows information stored in any GIS server to be accessed by geospatial centers located anywhere in the world. The widespread availability and adaptability of data and information access are features of GIS applications [50].

Research published on water has revealed that water alters both its condition and pressure throughout the course of time [1, 45, 51]. When it is necessary to keep monitoring various water circumstances, GIS becomes an extremely useful tool. Therefore, hydrologists are among the professionals who stand to benefit the most from geographic information systems. Using a GIS that has been carefully constructed, one can do a variety of studies on water. For instance, hydrogeology is a field of study that analyzes groundwater along with its preservation, incidence, and mobility properties. The nature and properties of water that is either stored deep inside the earth or that is on the surface and is either motionless or moving can be entered into GIS as data, stored there, and retrieved for use in the system's subsequent processing. This can be done for water that is either underground or on the surface. The process of modeling groundwater entails hydrologists trying to comprehend the behavior and features of groundwater. Keeping in mind the limited supply of water, there is a lot of research that can be done to safeguard water catchment zones [52]. In addition to this, GIS can assist in the production of models and designs that can assist in the responsible utilization of underground water. When conducting investigations and case studies, the application of geospatial techniques can allow the creation of digital photographs of groundwater [53]. On this planet, there are many kinds of water, and not all of them are fit for human or animal consumption. Studies on aspects such as slope, drainage features, and patterns of land exploitation can all be analyzed with GIS to determine whether the water in a certain region is suitable for consumption by humans. Sample data can be analyzed, saved, and used to report generation thanks to the capacity of GIS to manage vast volumes of data sets. GIS also has the capability to handle the generation of maps [54]. These studies can be utilized by the relevant organization, or even by the authorities, to make future studies and laws on water, as well as to assess whether the water is suitable for human consumption.

7. Conclusion

The present chapter aims at highlighting the importance and usage of geospatial techniques (remote sensing together with GIS technologies) in agricultural resource management, including monitoring and mapping of crop growth and production forecasting, crop disease and pest infestation, land use and land cover mapping, flood monitoring, and water resource management. Literature suggests that the use of remote sensing (RS) and geographic information systems (GIS) in agriculture has been increasing rapidly over the past few decades due to advancement of digital technologies that have leveraged GIS as a vital alliance technology for evaluating crops, soils, and their environments. In this chapter, we discussed various analyses and methodologies involved in using remotely sensed satellite data for management of agriculture resources. Based on the scientific literature, it can be concluded that geospatial techniques have been effectively utilized for digital mapping of agricultural resources and play a crucial role in ensuring sustainable agricultural production. It has been observed that multispectral satellite sensors are preferably used in mapping and monitoring of agricultural resources because of their low cost but have limited application, which is linked with their low spatial and spectral resolution. However, hyperspectral satellite sensors with fine spatial and spectral resolution allow more promising results with greater accuracy and provide exceptional abilities to address enormous challenges associated with regular monitoring and mapping of agricultural resources at large areas. This book chapter will be helpful to develop cost-effective and accurate monitoring solutions for agriculture resource management at fine spatial resolution for decision making especially in land use issues in agriculture crop production.

Acknowledgements

We acknowledge the funding provided by Higher Education Commission (HEC) Pakistan for the establishment of Agricultural Remote Sensing Lab at University of Agriculture, Faisalabad. We also acknowledge the support of Vice Chancellor, UAF, for providing us with infrastructure facilities at University of Agriculture, Faisalabad.

Conflict of interest

All the authors and co-authors declare that there is no conflict of interest.

Author details

Syeda Mishal Zahra[1,2,3], Muhammad Adnan Shahid[1,2], Zahid Maqbool[1]*, Rehan Mahmood Sabir[1,2], Muhammad Safdar[1,2], Muhammad Danish Majeed[1,2] and Aneela Sarwar[4]

1 Agricultural Remote Sensing Lab (ARSL), National Center for GIS and Space Applications, University of Agriculture, Faisalabad, Pakistan

2 Faculty of Agricultural Engineering and Technology, Department of Irrigation and Drainage, University of Agriculture, Faisalabad, Pakistan

3 International Water Management Institute (IWMI), Lahore, Pakistan

4 Department of Agricultural Engineering, Bahauddin Zakariya University, Multan, Pakistan

*Address all correspondence to: zahid.maqbool@uaf.edu.pk

References

[1] Ghosh P, Kumpatla SP. GIS applications in agriculture. In: Zhang Y, Cheng Q, editors. Geographic Information Systems and Applications in Coastal Studies. London, UK: IntechOpen; 2012. pp. 1-27

[2] FAO. The Future of Food and Agriculture: Trends and Challenges. Rome: FAO Publishing; 2017;**4**:1951-1960

[3] Gomiero T. Soil degradation, land scarcity and food security: Reviewing a complex challenge. Sustainability. 2016; **8**(3):1-41

[4] Delgado JA, Short NM, Roberts DP, Vandenberg B. Big data analysis for sustainable agriculture on a geospatial cloud framework. Frontiers in Sustainable Food Systems. 2019;**3**:54-59

[5] Delgado JA, Vandenberg B, Neer D, D'Adamo R. Emerging nutrient management databases and networks of networks will have broad applicability in future machine learning and artificial intelligence applications in soil and water conservation. Journal of Soil and Water Conservation. 2019;**74**(6): 113A-118A

[6] Gomiero T. Alternative land management strategies and their impact on soil conservation. Agriculture. 2013; **3**(3):464-483

[7] Koroleva EV, Nikitin YY. U-max-statistics and limit theorems for perimeters and areas of random polygons. Journal of Multivariate Analysis. 2014;**127**:98-111

[8] Mathenge M, Sonneveld BGJS, Broerse JEW. Application of GIS in agriculture in promoting evidence-informed decision making for improving agriculture: A systematic review. Sustainability. 2022;**14**(16):9974-9999

[9] Kingra PK, Majumder D, Singh SP. Application of remote sensing and GIS in agriculture and natural resource management under changing climatic conditions. Agricultural Research Journal. 2016;**53**(3):295

[10] Kazemi H, Akinci H. A land use suitability model for rainfed farming by multi-criteria decision-making analysis (MCDA) and geographic information system (GIS). Ecological Engineering. 2018;**116**:1-6

[11] Gebeyehu MN. Remote sensing and GIS application in agriculture and natural resource management. International Journal of Environmental Sciences & Natural Resources. 2019; **19**(2):45-49

[12] Kumar S, Karaliya SK, Chaudhary S. Precision farming technologies towards enhancing productivity and sustainability of Rice-wheat cropping system. International Journal of Current Microbiology and Applied Sciences. 2017;**6**(3):142-151

[13] Sishodia RP, Ray RL, Singh SK. Applications of remote sensing in precision agriculture: A review. Remote Sensing. 2020;**12**:3136-3167

[14] Houshyar E, Smith P, Mahmoodi-Eshkaftaki M, Azadi H. Sustainability of wheat production in Southwest Iran: A fuzzy-GIS based evaluation by ANFIS. Cogent Food & Agriculture. 2017;**3**(1): 1327682. DOI: 10.1080/23311932.2017.1327682

[15] Mann ML, Warner JM. Ethiopian wheat yield and yield gap estimation: A

spatially explicit small area integrated data approach. Field Crops Research. 2017;**201**:60-74

[16] Al-Gaadi KA, Hassaballa AA, Tola E, Kayad AG, Madugundu R, Alblewi B, et al. Prediction of potato crop yield using precision agriculture techniques. PLoS One. 2016;**11**(9):1-16

[17] Memon MS, Jun Z, Sun C, Jiang C, Xu W, Hu Q, et al. Assessment of wheat straw cover and yield performance in a rice-wheat cropping system by using Landsat satellite data. Sustainability. 2019;**11**(19):5369-5390

[18] Hassan SS, Goheer MA. Modeling and monitoring wheat crop yield using geospatial techniques: A case study of Potohar region, Pakistan. Journal of the Indian Society of Remote Sensing. 2021;**49**(6):1331-1342

[19] Muslim M, Romshoo SA, Rather AQ. Paddy crop yield estimation in Kashmir Himalayan rice bowl using remote sensing and simulation model. Environmental Monitoring and Assessment. 2015;**187**(6):1-12

[20] Wang M, Tao FL, Shi WJ. Corn yield forecasting in Northeast China using remotely sensed spectral indices and crop phenology metrics. Journal of Integrative Agriculture. 2014;**13**(7):1538-1545

[21] Hochman Z, Gobbett D, Holzworth D, McClelland T, van Rees H, Marinoni O, et al. Reprint of quantifying yield gaps in rainfed cropping systems: A case study of wheat in Australia. Field Crops Research. 2013;**143**:65-75

[22] Basso B, Cammarano D, Carfagna E. Review of crop yield forecasting methods and early warning systems. In: Proceedings of the First Meeting of the Scientific Advisory Committee of the Global Strategy to Improve Agricultural and Rural Statistics. July 2013; FAO Headquarters, Rome, Italy: Scientific Research Publishing; 2013. p. 19

[23] USDA. The Yield Forecasting Program of NASS the Statistical Methods Branch. Washington, D.C.: Statistics Division, National Agricultural Statistics Service, U.S. Department of Agriculture; 2012. p. 104

[24] Lobell DB, Burke MB. On the use of statistical models to predict crop yield responses to climate change. Agricultural and Forest Meteorology. 2010;**150**(11):1443-1452

[25] Tirado MC, Crahay P, Mahy L, Zanev C, Neira M, Msangi S, et al. Climate change and nutrition: Creating a climate for nutrition security. Food and Nutrition Bulletin. 2013;**34**(4):533-547

[26] Savary S, Ficke A, Aubertot JN, Hollier C. Crop losses due to diseases and their implications for global food production losses and food security. Food Security. 2012;**4**(4):519-537

[27] Säre M. Climate change and agricultural production. Culture and Environment. 2019;**4**:201-208

[28] Masters G, Norgrove L. Climate change and invasive alien species. CABI Working Paper. 2010;**1**:1-30

[29] Sabtu NM, Idris NH, Ishak MHI. The role of geospatial in plant pests and diseases: An overview. In IOP Conference Series: Earth and Environmental Science. 2018;**169**(1):012013

[30] Anwer A, Singh G. Geo-spatial technology for plant disease and insect pest management. Bulletin of Environment, Pharmacology and Life Sciences. 2019;**8**:1-12

[31] Thomas CS, Skinner PW, Fox AD, Greer CA, Gubler WD. Utilization of GIS/GPS-based information technology in commercial crop decision making in California, Washington, Oregon, Idaho, and Arizona. Journal of Nematology. 2002;**34**(3):200-206

[32] Qu Y, Tao B. The constitution of vegetable traceability system in agricultural IOT. Journal of Chemical and Pharmaceutical Research. 2014;**6**(7): 2580-2583

[33] Mishra PK, Rai A, Rai SC. Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. Egyptian Journal of Remote Sensing and Space Science. 2020;**23**(2):133-143

[34] Souza CM, Shimbo JZ, Rosa MR, Parente LL, Alencar AA, Rudorff BFT, et al. Reconstructing three decades of land use and land cover changes in brazilian biomes with Landsat archive and earth engine. Remote Sensing. 2020; **12**(17):2735-2762

[35] Naikoo MW, Rihan M, Shahfahad PAH, Talukdar S, Mallick J, Ishtiaq M, et al. Analysis of peri-urban land use/land cover change and its drivers using geospatial techniques and geographically weighted regression. Environmental Science and Pollution Research. 2022;**29**:1-9. DOI: 10.1007/ s11356-022-18853-4

[36] Jin S, Yang L, Zhu Z, Homer C. A land cover change detection and classification protocol for updating Alaska NLCD 2001 to 2011. Remote Sensing of Environment. 2017;**195**:44-55

[37] Phiri D, Morgenroth J. Developments in Landsat land cover classification methods: A review. Remote Sensing. 2017;**9**(9):1-10

[38] Wood HM. The use of earth observing satellites for hazard support. International Geoscience and Remote Sensing Symposium (IGARSS). 2001;**1**: 135-137

[39] Merz B, Kreibich H, Schwarze R, Thieken A. Review article "assessment of economic flood damage." Natural Hazards and Earth System Science. 2010; 10(8):1697–1724.

[40] Du J, Fang J, Xu W, Shi P. Analysis of dry/wet conditions using the standardized precipitation index and its potential usefulness for drought/flood monitoring in Hunan Province, China. Stochastic Environmental Research and Risk Assessment. 2013;**27**(2):377-387

[41] Youssef AM, Pradhan B, Hassan AM. Flash flood risk estimation along the St. Katherine road, southern Sinai, Egypt using GIS based morphometry and satellite imagery. Environmental Earth Sciences. 2011;**62**(3):611-623

[42] Markantonis V, Meyer V, Lienhoop N. Evaluation of the environmental impacts of extreme floods in the Evros River basin using contingent valuation method. Natural Hazards. 2013;**69**(3):1535-1549

[43] Billa L, Shattri M, Mahmud AR, Ghazali AH. Comprehensive planning and the role of SDSS in flood disaster management in Malaysia. Disaster Prevention and Management: An International Journal. 2006;**15**(2): 233-240

[44] Huang X, Tan H, Zhou J, Yang T, Benjamin A, Wen SW, et al. Flood hazard in Hunan province of China: An economic loss analysis. Natural Hazards. 2008;**47**(1):65-73

[45] Tehrany MS, Pradhan B, Jebur MN. Flood susceptibility mapping using a

novel ensemble weights-of-evidence and support vector machine models in GIS. Journal of Hydrology. 2014;**512**:332-343

[46] Kisi O, Nia AM, Gosheh MG, Tajabadi MRJ, Ahmadi A. Intermittent streamflow forecasting by using several data driven techniques. Water Resources Management. 2012;**26**(2):457-474

[47] Setiawati MD, Miura F, Aryastana P. Validation of Hourly GSMAP and Ground Base Estimate of Precipitation for Flood Monitoring in Kumamoto, Japan. In: Geospatial Technology for Water Resource Applications. Boca Raton: CRC Press Taylor & Francis Group; 2016. pp. 130-143

[48] Ahansal Y, Bouziani M, Yaagoubi R, Sebari I, Sebari K, Kenny L. Towards smart irrigation: A literature review on the use of geospatial technologies and machine learning in the Management of Water Resources in arboriculture. Agronomy. 2022;**12**(2):297

[49] Thakur PK, Aggarwal SP, Nikam BR, Garg V, Chouksey A, Dhote PR. Training, education, research and capacity building needs and future requirements in applications of geospatial technology for water resources management. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives. 2018;**42**(5): 29-36

[50] Hathout S. The use of GIS for monitoring and predicting urban growth in east and west St Paul, Winnipeg, Manitoba. Canada. Journal of Environmental Management. 2002; **66**(3):229-238

[51] Wang HB, Wu SR, Shi JS, Li B. Qualitative hazard and risk assessment of landslides: A practical framework for a case study in China. Natural Hazards. 2013;**69**(3):1281-1294

[52] Ingole NA, Ram RN, Ranjan R, Shankhwar AK. Advance application of geospatial technology for fisheries perspective in Tarai region of Himalayan state of Uttarakhand. Sustainable Water Resources Management. 2015;**1**(2): 181-187

[53] Jayakrishnan R, Srinivasan R, Santhi C, Arnold JG. Advances in the application of the SWAT model for water resources management. Hydrological Processes: An International Journal. 2005;**19**(3):749-762

[54] Pourghasemi HR, Moradi HR, Fatemi Aghda SM, Gokceoglu C, Pradhan B. GIS-based landslide susceptibility mapping with probabilistic likelihood ratio and spatial multi-criteria evaluation models (north of Tehran, Iran). Arabian Journal of Geosciences. 2014;**7**(5):1857-1878

[55] Moisa MB, Dejene IN, Merga BB, Gemeda DO. Impacts of land use/land cover dynamics on land surface temperature using geospatial techniques in Anger River sub-basin. Western Ethiopia. Environmental Earth Sciences. 2022;**81**(3):1-14

[56] Chen J, Chen J, Liao A, Cao X, Chen L, Chen X, et al. Global land cover mapping at 30 m resolution: A POK-based operational approach. ISPRS Journal of Photogrammetry and Remote Sensing. 2015;**103**:7-27

[57] James E. A land use and land cover classification system for use with remote sensor data. Remote Sensing. 2001;**2**:1-12

[58] Dilley M, Chen RS, Deichmann U, Lerner-Lam AL, Arnold M. Natural Disaster Hotspots: A Global Risk Analysis. Washington, DC: World Bank Publications; 2005