A REVIEW ON ADVANCES IN AGRICULTURE AND AGROFORESTRY WITH GPS AND GIS

ABSTRACT

Various researchers, agronomists, scientists, and engineers utilize a variety of technologies every year to boost agricultural productivity at a low cost, but this has a negative influence on the environment. Precision agriculture is the study of the use of technology to enhance agricultural operations in comparison to conventional agricultural methods and lessen negative environmental impacts. Precision agriculture depends heavily on remote sensing technology, and this technology's use in precision agriculture opens up new possibilities for raising agricultural standards. The global positioning system (GPS) enables the geographic Latitude and Longitude data of field data (slope, aspect, nutrients, and yield). Since it has the ability to continuously determine and record the right position, it can build a bigger database for the user. A geographic information system (GIS) that can handle and store these data is needed for further investigation. Despite agroforestry's limited spatial extent, isolation, and higher functional and structural complexity, recent advancements in geospatial technologies, as well as the free accessibility of spatial information and software, can provide additional insight into assessing tools, making the decisions, and developing policies. This review has covered the current uses of geospatial technology, along with their restrictions and limits, as well as prospective future uses for agroforestry. This review discusses GPS, GIS, and remote sensing technology and explains how they might be used in precision agriculture and agroforestry.

Keywords: Precision agriculture, Environment, Agroforestry, Remote Sensing, GIS and GPS

1. INTRODUCTION

The world population is expected to reach 10.0 billion people in 2050 as it continues to grow [1]. Everyone cares about the production of agricultural products, and each farmer, agricultural manager on a big scale, and regional agricultural agency strives to produce food as cheaply as possible. A farmer needs to be well-informed in order to be effective, and this includes having the information and understanding necessary to create a workable plan for farming operations. These tools will allow farmers to gain a better understanding of the crop's condition, the extent of insect damage or stress, the anticipated yield, and the properties of the soil. Commodity brokers are also highly interested in how well farms are producing since yield estimates for all products—both quantity and quality—control pricing and worldwide trade. Precision agriculture is the study of the use of technology to produce agricultural products that meet global food demand more efficiently than conventional agricultural methods while also having a lower negative environmental impact. The global positioning system, geographic information systems, and remote sensing are just a few of the technological elements that make up the integrated information and agricultural management system known as precision agriculture. It attempts to boost overall agricultural output efficiency while reducing the harmful effects of chemical loading on the environment. By gathering and analysing data on the different types of soil and crop status, it also aims to maximize the effectiveness of agricultural inputs within constrained areas of the farm field. The variability within the field must be under control if we are to achieve this efficiency goal. In order to make informed crop management decisions, precision farming involves gathering timely and accurate information on soil and crop status. The perception of the land from which farmers and agribusinesses derive their income is currently changing as a result of precision agriculture. Precision agriculture entails acquiring timely geospatial data on the requirements of the soil, plants, and animals as well as prescribing and applying treatments for specific sites in order to maximize agricultural productivity and save the environment. Remote sensing technologies are extensively used in precision agriculture, and their importance is growing all the time. Remote sensing with space-based sensors is the most effective technique to gather repeated (from seconds to several days) and comprehensive (specific to provincial covering) measurements on crop spectral behaviour as well as their growing environment, such as soil and atmosphere. This data may be utilised for a variety of purposes, including crop inventory, crop production projections, drought and flood damage assessment, and range and irrigated land monitoring and management. The use of RS data for crop inventory in India is covered in this review. Before discussing the Indian experience, a quick summary of the traditional methods of agricultural acreage/estimation in India and the justification for using RS for crop inventory is made. According to Sharma et al.,[2] the agroforestry system (AFS) is a well-known land use system that unites agriculture and forestry by generating a more integrated, diverse, productive, profitable, healthy, and sustainable land use system than the agriculture system. It has the potential to significantly improve a variety of social, environmental, and economic issues, including farm productivity and incomes [3], livelihood security [4], soil fertility decline [5], water conservation [6], climate change risk and variability [7], maintaining the atmospheric environment, and water quality [8], severe weather, greenhouse gas emissions [9], improvement of the microclimate [10], weed management [11], and provision of environmental values [12].

Excluding this widespread land use effectively limits landscape improvements, especially in degraded and wastelands with significant potential for climate change prevention and mitigation, which in turn restrains their economic growth [13]. Additionally, these databases are underutilized in SDSS and suitability assessment even though computer-based AFS tree selection database research started before 1991 [14]. Furthermore, nothing is known about the data sources and processing employed to determine the scope and organisation of AFS as well as a number of other applications. Additionally, there hasn't been much research done on how geospatial technologies are used in AFS, covering their current status and future prospects. With the help of IRS III digital data [15], prepared a Rabi (winter) crop inventory for a portion of the Solani River basin (parts of Haridwar and Saharanpur districts, Uttar Pradesh, India). Many academics and agronomists have made significant contributions to the field of crop inventory, such as [16], who forecasted wheat crop yield and production for the 1998–1999 Rabi season using remote sensing and agrometeorological data. Three different varieties of wheat crops, namely wheat-1 (high vigor-normal sown), wheat-2 (mid vigor-late sown), and wheat-3 (low vigor-very late sown), have been found and distinguished from one another using supervised maximum likelihood classification. Based on trend analysis of historical crop yield (actual yield), spectral vegetation indices (Ratio Vegetation Index (RVI) and Normalised Difference Vegetation Index (NDVI)), agrometeorological parameters, and historical crop yield (actual yield) data, linear and multiple linear regression models were used to forecast wheat crop production in this study. Singh et al., [17] evaluated the classification and accuracy of wheat crops over central India using digital data from four multi-spectral sensors with different spatial resolutions and spectral channels: LISS-III, LISS-II, LISS-I, and WiFS. These sensors were acquired from two Indian remote sensing satellite platforms (IRS- 1B, IRS-IC). For crop production and corn monitoring [18], used optical and RADARSAT-2 satellite pictures. The main goal of the paper was to establish indicators of crop condition and generate estimates for crop yield using RADARSAT-2 data and optical data to identify cultivated areas and monitor crop condition. From RADARSAT-2 data, corn polarisation signatures were obtained and connected to leaf area index (LAI), photosynthetic active radiation (PAR), crop characteristics, and vegetation indices. In order to anticipate agricultural production for the province of Hubei [19], built crop yield estimation models utilising remote sensing data. First, the productivity zoning approach was used to choose the simulated counties, and then the historical trend was examined to determine the fluctuated yield. Second, the correlation coefficient between the remote sensing index and the fluctuating yield was determined. Then, to construct basic linear regression models to estimate crop yield, the indicator with the highest correlation coefficient was chosen as the important factor. By contrasting the actual crop yield from statistic data with that from the outcomes of the modelling, the error analysis was finally processed. The precision error ranges from -14.38% to 11.31%, according to the results, and the R2 coefficient of determination is 0.872. In the majority of Hubei Province, the findings computed using this method are accurate enough to be used for agricultural yield estimation. With the help of synchronized Landsat and SPOT reflectance data for spring wheat, barley, and oats [20], recently worked on modelling cereal yield in Finland using optical and radar remote sensing. Their study's specific objective was to calibrate optical VGI models (Models I–IV) and validate baseline yield estimates (yb) by comparing them to yield statistics from the MAFF inventory, reflectance data from Landsat, SPOT, NOAA, and the official crop model of MTT Agrifood Research Finland, the CropWatN dynamic crop model. As a starting point, data from trials with an average yield between 1996 and 2006 were used. Finally, employing VGI models to calculate cereal nonpotential baseline yield levels (yb) in growth zones (I-IV) as a yield inventory tool for the annual MAFF inventory statistic.

2. GEOGRAPHIC INFORMATION SYSTEM IN AGRICULTURE

A powerful collection of tools, known as GIS, may be used to collect, save, access at any time, modify, and display geographical data from the actual world for a different purpose [21]. The use of Geographic Information System in agriculture is revolutionizing management and planning. Geographic information system (GIS) technology has substantially broadened the applications of remote sensing-based analysis. GIS allows for the overlay of human pressure indices, actual physiognomy, and environmental conditions. In developed and developing countries agriculture plays a vital role in enhancing their economics. Using satellite-based earth observation data, crop inventory was estimated and examined in this study. The grain market became less unpredictable as harvest estimates became more accurate and reliable. The potential of Geographic Information System to assess and visualize agricultural landscapes and work processes has shown to be highly benefited for anyone working in the agriculture business. A farm's production and profitability depend on keeping its inputs and outputs in balance. Topography or other environmental elements are typically represented as layers of spatial data. By combining various map and satellite data sources, GIS technology is increasingly being used to create models that simulate the dynamics of complicated biological ecosystems. [22]. In addition to maps, GIS enables for the development of visuals, animations, and other cartographic outputs. Geographic Information System plays much more bigger role in agricultural production all over the globe, from mobile GIS in the field to scientific production data analysis at the farm manager's office, in order to assist farmers in increasing output, lowering expenses, and managing their property more effectively [23]. While it is hard to completely regulate natural inputs in agriculture, GIS applications such as agricultural yield estimations, soil supplement evaluations, and runoff detection and remedying may be capable of helping us better understand and manage them.

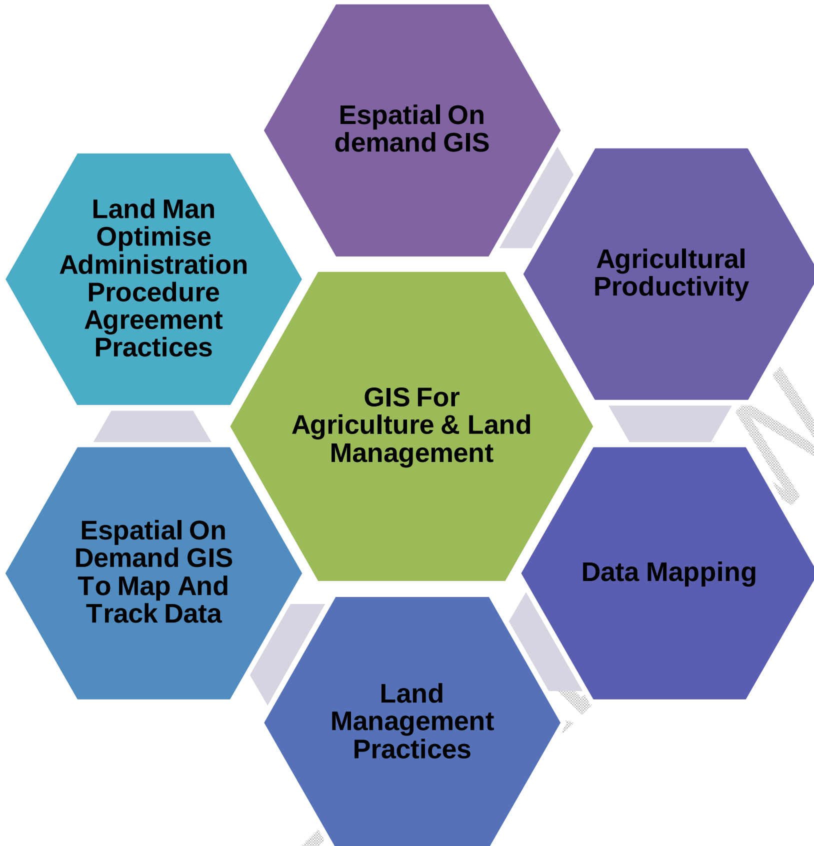

Fig. 1. Uses of GIS For Agriculture and Land Management.

3. GLOBAL POSITIONING SYSTEM IN AGRICULTURE

The GPS has the ability to document the in-field variances as regionally embedded information (GPS). The correct position may be found and continually recorded. This technology allows the user access to a larger database by taking agricultural fields and locations into account in more detail than in the past. Only in locations where GPS position tracking has been done can accurate yield statistics be supplied. GPS receivers working with them provide the geographical coordinates for the yield monitor data. Using this, yield maps for each field may be produced. Field effective strategies for fertilizer application, growing, and harvesting may be developed by merging data from several satellites and correlating it with GPS [24].

Precision agriculture, often known as site-specific agriculture, was made possible by combining GPS with geographic information systems (GIS). Large volumes of geographic data may be handled and assessed rapidly thanks to these technologies' ability to integrate real-time data collecting with exact location data.

GPS-based technologies are used in precision farming for farm planning, field mapping, soil sampling, tractor navigation, crop scouting, variable rate applications, and yield mapping. Farmers may now operate machinery safely in low visibility field situations such as rain, dust, fog, and darkness, due to GPS.

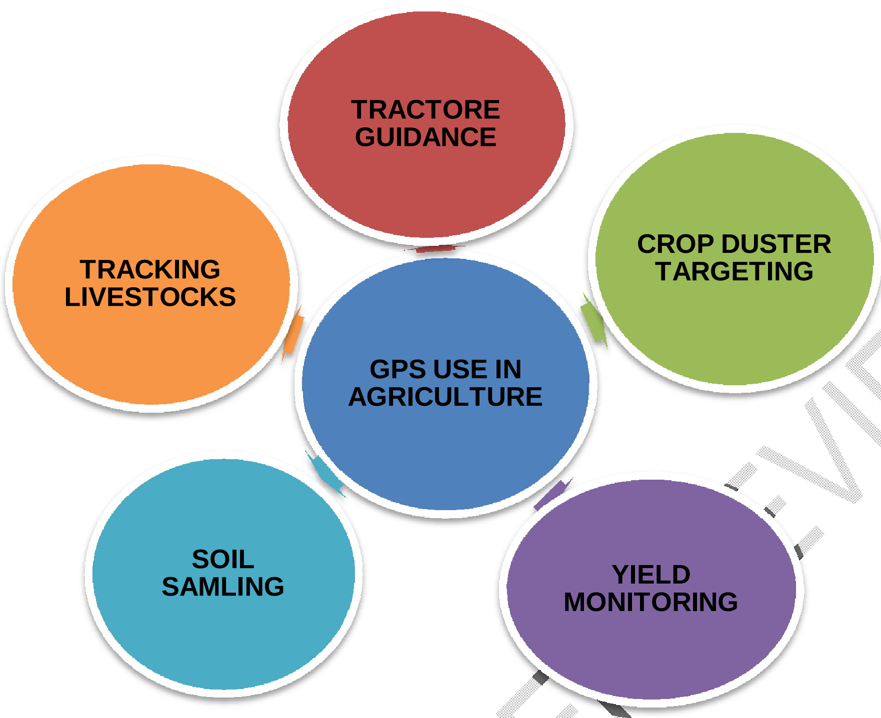

Fig. 2. Uses of Global Positioning System (GPS) in agriculture.

4. REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN AGROFORESTRY

Natural resource management heavily relies on mapping and resource inventory, and the need for current geospatial data for management, research, and almost real-time decision-making is growing exponentially. This is largely due to the free accessibility and availability of satellite data products as well as geospatial advancement. Geospatial technologies are crucial for AFS and have a lot of promise to offer new perspectives and opportunities for scaling up AFS interventions [25]. AFS characterization, including species distribution and density patterns, and change in land use patterns at any landscape-level with regard to location, altitude, and topography, are all part of the initial use of the RS-GIS in AFS. For the future development of supporting policies, planning [26], management strategy [27], An accurate and impartial estimation of the magnitude, geographic distribution patterns, and characterization of AFS are crucial for maximising its contribution to the nation's climate change goals or intended nationally determined contributions (INDCs) under the UNFCCC. [28]. In addition, the AFS extent offers the chance to pinpoint agricultural yield variations [29]. Only if the AFS region is there will even the CS potential of the AFS have any significance [30]. RS is a brand-new, useful, and affordable approach for evaluating and tracking biomass, carbon stock, CS, and related changes of AFS [31];[32] while reducing the uncertainty.

In addition, GIS is crucial for understanding the relationships between physical, biological, and biochemical components as well as for development [33]. It is also crucial for evaluating, monitoring, mapping, and quantifying the socioeconomic value of AFS services [34]. Through the AFS suitability analysis or spatial decision support system, there are potential to adopt various AFS practises in the regions lacking in AFS practises [26]. (SDSS). However, despite the fact that computer-based AFS tree selection database research had started before 1991 [14], SDSS and suitability analyses do not frequently use these databases. A crucial step in helping policymakers decide whether and where to promote AFS is the large-scale scientific evaluation of the land for AFS that combines spatial information from various parameters using GIS [35]. Another important step is the planning of various AFS projects at various scales to achieve the goal of the National AFS policy 2014 [36]. In particular, the spatial decision support system (SDSS) connects the gap and offers a trustworthy resource for wise species choice and subsequent planning [33]. Unmanned aerial vehicle (UAV) platforms have just entered the mainstream and help with extensive mapping and monitoring of systems, particularly complex systems like AFS [37].

5. APPLICATIONS IN PRECISION AGRICULTURE

5.1. Crop inventory

In order to identify crops and locations where cropping patterns are changing, remote sensing (RS) and geographic information systems (GIS) are essential tools for conducting crop surveys and mapping. [38]. For a government in a nation where agriculture is the main industry, accurate and timely information on the types of crops planted, their area, and estimated output is crucial. The spectral data is a crucial component of remote sensing data for crop modelling, and it is closely related to canopy parameters, which are indicators of the health and stage of growth of the crop. Crop-specific maps, which are useful to agribusinesses like seed and fertiliser companies, are produced by combining satellite images, survey data, and information on the layout of the land and its owners (farmers). The study of remote sensing can be very helpful in compiling information on various crops. In the literature, several investigations utilising aerial photography and digital image processing methods have been described. It helps to decrease the amount of field data that must be gathered and increases the estimate's precision. [39]. In rain-fed locations, agricultural damage, especially to rice-growing regions, is a typical occurrence. Crop yield, damaged crop region, and anticipating moisture stress and flood are common occurrences. A crucial component of production estimation is various crop yield information. Every crop genotype has a specific yield potential that can be met in an experimental field under ideal circumstances. Yet, in the actual world, factors like soil, weather, and cultivation techniques including planting date, irrigation, and fertiliser affect crop output. Moreover, biotic stressors like disease and pests have an impact on crop output. Given that it delivers a rapid, precise, synoptic, and objective estimation of numerous crop characteristics, satellite-based remote sensing is an appropriate substitute for assessing and forecasting crop condition and yield. One crucial tool for yield modelling is data from remote sensing. [40]. Crop yield can be predicted by crop vigour. Using vegetation indices collected from various wavelengths, it can be evaluated. Models for simulating plant growth have been used to monitor crop growth, health, and production. Because the majority of plant development models were created at the field scales, however, their use in vast areas has been restricted. Using crop modelling and synthetic aperture radar technology, estimate and forecast yield [41]. By estimating the loss of leaf area, remote sensing data can be used to identify and assess the health of a crop. Chlorophyll usually breaks down as a result of pest attacks, and remote sensing can be used to detect the decrease in chlorophyll levels in plants.

Nutrient and water stress

For healthy growth and vitality, plants require sufficient amounts of nutrients, sunlight, and water. Macronutrients are more important than micronutrients as fundamental components in the development of plant cell and tissue. Nutrient and water stress management is one of the most significant domains where we can choose to apply remote sensing and GIS through the application of precision farming. Remote sensing and geographic information systems (GIS) are crucial for site-specific nutrient management, which can lower crop costs and boost fertiliser usage efficiency. [42]. By using precise technologies, it may be able to use water wisely in arid areas. Drip irrigation, for instance, can be used in conjunction with data from remotely sensed data, such as the temperature difference between the canopy, to improve water use efficiency by lowering runoff and percolation losses. Nutrient deficit is identified by using multispectral and hyperspectral image analysis. Selecting wavelengths sensitive to various types of nutrients and water stress can be aided by spectral reflectance measurements. [43]For effective irrigation water management, crop water stress detection is crucial. In order to assure that crops won't suffer from water stress and will produce yield under limited water conditions, precision agriculture must monitor vegetation water stress using satellite technology. The regional and temporal dynamics of crop development under water stress and its effects on production may be provided through satellite data.

Flood monitoring

The use of remote sensing technology enables measurements, particularly from space, to be made at spatial scales that are far larger than those that can be reached by field-based tools and techniques. To learn more about floods on various temporal and spatial scales, especially in the form of flooded areas, satellite data of inundation have been used. The amount of time it takes to detect and respond to flood emergencies has been cut in half because to automated spacecraft technology. Using satellite images of floods is crucial to show their potential, advance our knowledge of flood dynamics, and even speculate on their potential utility. [44]. Using a remote sensing approach, it is possible to increase the spatial coverage of river discharge estimates on a global scale. Several surface water hydraulic characteristics of large rivers, such as average river width over a specific reach length, water surface slope, water surface elevation, and channel morphology, can be measured or evaluated from remote-sensing data. [45]. For flood forecasting and other water resource management concerns, river flow measurements and hydrological data assimilation are crucial. Early warning systems can be improved by including observations of rivers, precipitation, and surface topography. Satellite microwave sensors can be used to measure changes in river width and river discharge to quantify river discharge. [46]. In order to predict river discharge, optimization techniques were also utilised to reduce differences between flood extent simulations and observations. It is possible to estimate the spatial variability in evapo-transpiration over a large area utilising remotely sensed data in conjunction with surface energy balance methods. Most plant leaves generate energy when they are warm in a cropped region, and this energy is mediated by soil moisture and crop evapo-transpiration.

5.2. Land use and land cover

The identification of surface features at different sizes and their hierarchical classification are involved in land use/land cover mapping, which is important in the study of worldwide change. Environmental challenges caused by human activity, such as deforestation, biodiversity loss, and global warming, have a considerable impact on land use and land cover. As a result, the data on land use and land cover that is currently available can offer important input for decisions regarding environmental management and future planning. Growing socioeconomic status and population have an unplanned and uncontrollable impact on how land is used and covered. Poor management of agricultural, range, and forest areas often causes land use and cover changes, resulting in major environmental challenges such as floods and landslides. To identify changes, satellite imagery maps of land use and land cover were pixel by pixel compared. [47]. Land cover refers to naturally occurring surface features (such as trees, hills, rivers, and so on), whereas land usage refers to features that have been altered by humans (urban, rural settlement, canal, orchards, etc.). In all geographical research, mapping of land use and land cover has always been crucial since it contains the fundamental details of features already present on the surface, including their area, location, shape, and pattern. In geo-registered multi-temporal remote sensing data, digital detection is crucial for identifying variations related to land use and land cover properties. [45]. Information on the land usage and land cover of an area has been prepared using remote sensing and GIS extensively. As a result, it is superior to manual surveys of vast regions in terms of price, accuracy, and human error. Additionally, imagery or aerial photographs capture a synoptic view of an area, so nothing can go unnoticed while surveys have a high likelihood of overlooking some features. Additionally, since surveys can't be carried out frequently or over a short period of time, satellite imagery can be acquired at irregular intervals, making it easier and more cost-effective to monitor surface features or phenomena (such as floods, deforestation, forest fires, etc.). With relation to geo-registered multitemporal remote sensing data, digital detection refers to changes in land use and land cover attributes. Cooperation of field observations with remotely sensed data can result in more rapid and cost-effective land cover categorization and outlier detection than each strategy alone. [48].

5.3. Agro metrological application

Strong climatic and metrological effects on agriculture. The metrological data are gathered using various point station observation networks in space. The ability of conventional agrometrological techniques to use their data for forecasting yields and real-time agricultural monitoring is severely constrained. The use of satellite metrology has made it possible to measure evapotranspiration, solar radiation, and rainfall accurately and frequently. The main inputs for the agrometeorology model included minimum and maximum temperatures, considerable rainfall occurring at biweekly intervals, and so on. The use of geostationary satellites for weather and climate remote sensing is regarded as the single most important development in the last 25 years for tracking the Earth's vegetation, weather, and climate. These satellites measure ocean temperatures and terrestrial vegetation.Knowledge on meteorology and vegetation are the two key important inputs for agricultural meteorology. Two broad meteorological satellite types are in common usage [38]. The first is a polar orbiting satellite that is positioned in a low Earth orbit of 750 kilometres, and the second is the Geosynchronous Meteorological Satellite (GMS), which orbits at an altitude of about 36 000 kilometres.

5.4. Pest infestation

Uses of remote sensing technologies are a crucial and efficient way to spot diseased, infested, and invader-infested areas. The analysis of biological invasion trends is challenged by regional variability, but due to its broad scope, remote sensing can give the essential information. [49]. Applications for remote sensing include data that is crucial for identifying and mapping defoliation, characterising pattern disruptions, and more. If these changes can be connected, categorised, and interpreted, the remote sensing application in monitoring and analysing insect defoliation has been utilised to relate variation in spectral responses to chlorosis, yellowing of leaves, and foliage decrease during a specific time period. Different flying altitudes can produce varying spatial resolutions for airborne remote sensing. Ground-based platforms provide useful information for management planning and decision-making and are frequently utilised in pest management, agricultural disease detection, insect damage to crops, and weed infestation. [50]. Aerial colour infrared photography with a standard camera has proved helpful in identifying damage caused by a variety of harmful pests. [51].

5.5. Water resource management

Recent decades have seen a global and regional decrease in the availability of water resources, which calls for judicious management using cutting-edge technology. Remote sensing is one of the most effective tools for analysing and tracking water resources. Hyperspectral remote sensing is emerging as a more comprehensive method of examining spatial, spectral, and temporal variations in order to generate more precise estimations of information needed for water resource applications. With the advent of microwave remote sensing, it is now possible to measure soil moisture availability using distant sensing data. Groundwater is a significant natural resource that promotes human health, ecological variety, and economic development. Our ecosystems and the survival of future generations are in danger due to the excessive use of this essential resource. The use of RS and GIS technology in groundwater hydrology has received less attention. Watersheds, watershed sources, terrain surfaces, land uses, land covers, rainfall, temperature, humidity, soil conditions and composition, geology, atmospheric conditions, human activities, environmental data, and so on all necessitate a thorough understanding of the physical world and the spatial data that surrounds it. Groundwater and freshwater challenges, relevance, and sustainable management are also described utilising geographic information system (GIS) and remote sensing (RS) technologies. As long as resource materials and database construction have been carefully considered, the integration of geographic information systems and remote sensing techniques has allowed assessments of aquatic vegetation growth, salt marsh quality, and floodplain disturbances to be made throughout time. [52].

6. CONCLUSION

Accurate production tracking and modification are possible with precision farming. Farm planning becomes more challenging as a result of precision farming. Many additional map data sets are available for use in long-term crop planning, erosion management, salinity control, and tillage technique evaluation. Yet, as the volume of data increases, so does the amount of labour necessary to analyse it, raising the danger of inaccurate interpretation. Precision farmers are likely to collaborate more closely with a variety of computer, GPS, and agriculture expertise. Hence, the three main technologies used in precision agriculture are GIS, GPS and remote sensing. A number of platforms (satellites and UAVs) and sensor alternatives for collecting AFS data became available as RS and GIS technology evolved through time.

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