WATER RESOURCE MONITORING USING REMOTE SENSING

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ABSTRACT

The natural system and the advancement of civilization depend on water resources. Water is essential for maintaining human health and supporting a variety of human activities, such as daily life, agriculture, and industrial production. Particularly in coastal lake regions, remote sensing offers a practical and economical way to identify and track water bodies as well as important information about how climatic events affect water structures. Delineating surface water bodies, estimating meteorological variables like temperature and precipitation, estimating hydrological condition variables like soil moisture and land surface characteristics, and estimating fluxes like evapotranspiration have all been accomplished with the use of remote sensing techniques. High-resolution satellite data now makes it feasible to monitor flood, drought, and irrigation management events in near real time. We will talk about it in this paper. Using remote sensing to monitor water resources.

Keywords: *Water Resource; Monitoring; Remote Sensing; Ecological System; Human Activities; Flood; Drought Events; High-Resolution Satellite; Mapping; Managing; Water-Related Issues; Wetlands; Freshwater*

INTRODUCTION

Remote Sensing

Modern technology known as remote sensing, which collects data from a distance, has amazing uses in many different domains. The management of water resources is one of its most important uses. An essential component of water monitoring is the use of remote sensing in water resources, as well as the investigation of its importance in mapping, monitoring, and handling water-related problems. [1]

Water is the most important resource for maintaining health since it is essential to the ecological system and the advancement of civilization. Streams, reservoirs, lakes, ponds, and freshwater wetlands are examples of water resources that are vital to daily life, agriculture, and industrial output. Water resources include lakes, ponds, streams, reservoirs, and freshwater wetlands.

These days, remote sensing data is widely used for water mapping, which is essential for locating and effectively monitoring water resources—a key tactic in averting related problems. Most optical pictures have high spatial and spectral resolution, which makes it possible to identify water bodies. Since water bodies have different radiance and reflection characteristics than other types of terrain, remote sensing imagery is primarily used to map them. This allows for high accuracy and speedy mapping using a variety of indices that are defined as straightforward mathematical functions. Conventional surveying and mapping techniques can be used to harvest surface water, but they are costly, time-consuming, specialized, and dependent on topography. Furthermore, employing traditional surveying techniques to gather and track real-time water data over a long period of time and on a wide scale is not a rational or feasible course of action. [2]

Application of Remote Sensing in Water Resources

Life on Earth depends on water resources, and both human and environmental well-being depend on their appropriate management. Data on water resources can now be gathered effectively using remote sensing, a method of gathering information from a distance.

1. Assessing Water Availability

The evaluation of water availability, a crucial component of sustainable water resource management, is greatly aided by remote sensing. Lakes, rivers, and reservoirs are just a few of the aquatic bodies for which satellite-based sensors offer thorough data.

2. Monitoring Water Quality

Maintaining the quality of water resources is crucial for both the environment and human health. By measuring variables like temperature, chlorophyll concentration, and turbidity, remote sensing systems can monitor the quality of water.

3. Detecting Water Pollution

One efficient way to identify the causes of water pollution and track its spread is using remote sensing.

4. Mapping Watershed Boundaries

For sustainable management of water resources, it is essential to comprehend the borders and features of watersheds. Delineating drainage patterns and mapping watershed borders are made possible by remote sensing. This data ensures optimal water usage throughout each watershed by facilitating land use management, flood risk assessment, and water resource planning.

5. Measuring Surface Water Flow

River and stream surface water flow can be measured thanks to remote sensing technology. Scientists can monitor water bodies' volume and flow velocity by using optical and radar sensors.

6. Remote sensing for harmful algal blooms:

Water quality and human health are seriously threatened by harmful algal blooms (HABs). Our capacity to identify and track HABs in rivers has significantly increased thanks to remote sensing technologies. Changes in water color and chlorophyll-a concentrations, which signify the presence of toxic algae, can be detected using satellite-based sensors.

7. Real-time sensors: Online spectrophotometers, conductivity sensors, pH sensors, dissolved oxygen (DO) sensors, conductivity sensors, turbidity sensors, and other real-time sensors are essential for maintaining the prompt and precise evaluation of water conditions. These sensors offer real-time input and continuously measure a variety of parameters, enabling proactive management and timely interventions.

8. Flood Monitoring and Prediction

Floods pose serious risks to ecosystems, property, and human life. By measuring water levels and the degree of inundation during rainstorm events, remote sensing technology enables real-time flood monitoring. Authorities and emergency responders use this information to prepare for floods, evacuate vulnerable areas, and carry out flood control measures. [3]

9. Drought Assessment and Prediction

Droughts can have disastrous effects on the environment, water supplies, and agriculture. By tracking soil moisture, vegetation health, and reservoir water levels, remote sensing helps determine drought. In order to lessen the effects of drought occurrences, officials can use this knowledge to forecast them and put water conservation measures into place. [4]

REVIEW OF LITERATURE

One of the major worldwide challenges is water resources management, or WRM. Water is crucial to the provision of food, energy, and health and is necessary for life through drinking water and sanitation. Floods and droughts are examples of water cycle extremes that can significantly affect all human activities, particularly for populations that are already at risk. As a result, water is crucial to development and is one of the Sustainable Development Goals of the United Nations (UN): SDG 6: Sanitation and clean water. In particular, food security (SDG2: Zero hunger), public health (SDG3: Global health and well-being), and poverty alleviation (SDG1: No poverty; Grey and Sadoff, 2007) will all benefit from addressing water challenges related to the provision of clean water and protection from water hazards. From simple storage, abstractions, and diversions to massive engineering projects for reservoir storage (such as the Grand Inga Dam in the Democratic Republic of the Congo) and water transfer (such as the China North-South transfer project), water management has undergone a revolution since the early civilizations when it was first managed for the public good. Nonetheless, there are still many obstacles in the way of providing water in a fair, effective, and sustainable manner. [5]

Enhancing groundwater-surface quality, non-point source pollination, and the water supply solves problems with water management resources. Understanding the basic characteristics of the physical, biological, social, and economic components as well as improved knowledge about how these components work together within the watershed are necessary for several of these sources. Rivers, wetlands, groundwater, and other watershed components are all connected to water management resources. Methods for assessing land use and watershed management operating procedures are needed for this system, and watershed simulation models are needed to lower decision-making uncertainty. [6]

According to the study, remote sensing technologies offer useful updates to the spatial information on natural resources as well as the meteorological and geographical conditions of the remote location, allowing for the interrelation of information about a particular global area. In addition to integrating and analyzing multi-layered spatial data, GIS offers a range of specialized formats for efficient watershed development planning, as well as recommendations and decision criteria for Integrated Sustainable Development. Planning and development of water resources depend on the enhanced data collection capabilities of Linear Imaging Self scanner (LISS-III) satellites, which are based on land cover hydrogeomorphology. GIS evaluates geographic data integration based on environmental factors. (VM Chowdary, 2009) [7]

Objectives

- Review role of satellite remote sensing to assess water security.
- To Study the Water Resource Monitoring using Remote Sensing
- Water quality, quantity, and extremes are the three aspects considered.

RESEARCH METHODOLOGY

The terms "water quality evaluation" and "remote sensing" were used to search for published papers on remote sensing-based water quality evaluation in English across various sources, including Web of Science and Scopus. Papers on the evaluation of water quality using remote sensing methods were then gathered, and a thorough review was conducted by scanning the papers that were gathered. Following that, a selection of papers is used to identify the water quality metrics. The information gathered is then used to tabulate the types of sensors, retrieval algorithms, and selected water quality parameters.

RESULT AND DISCUSSION

Mountain glaciers, snow, surface water bodies (lakes, rivers, and reservoirs), soil moisture, and ground water are the main freshwater resources that humans can use. Pressures on water resources are growing globally as a result of their very uneven distribution in space and time. However, people might not be aware of the location and quantity of regional water resources, particularly with regard to deep-confined groundwater and distant mountain glaciers and snow. Severe drought and torrential flooding may occur in extreme situations if there is either too little or too much water in a given time frame and territory. These events can have disastrous effects and damages on the local and regional community. As a result, it is crucial to accurately map and manage water resources, drought, and flooding risk utilizing state-of-the-art technologies such as hydrologic models, remote sensing, geographic information systems (GIS), and geo-statistics (Table 1). [8]

Table 1 ***lists the most recent sensors and remote sensing technologies for mapping floods, droughts, hydrological fluxes, and water resources.***

Application Fields	Specific Contents	Examples of Sensors or Satellites
Water resources	Snow	AVHRR, Terra/Aqua MODIS, Landsat, SSM/I, AMSR-E, Cryosat etc.
	Glaciers	Landsat, ASTER, SPOT, ICESat, SRTM, etc.
	Soil moisture	SSM/I, AMSR-E, SMAP, SMOS, etc.
	Groundwater	GRACE
	Lakes, reservoirs, rivers, and wetlands	MODIS, Landsat, SPOT, ICESat, GRACE, SRTM etc.
Hydrological fluxes	Precipitation	NEXRAD, TRMM, GPM, etc.
	Evapotranspiration	MODIS, Landsat, GRACE, etc.
	River, reservoir or lake discharge	MODIS, ENVISAT, Landsat, SRTM, ICESat, etc.
Drought and flooding	Drought and flooding	MODIS, Landsat, GRACE, UAV, AMSR-E, SMAP, SMOS, ENVISAT, ASAR, Sentinel-1A/2A, etc.

Data from remote sensing is essential for mapping water resources (Table 1). Depending on their orbital characteristics, satellite remote sensing systems can provide continuous, current measurements with worldwide coverage, but they rely on ground observations to create and validate their algorithms. [9]

The Value of Remote Sensing in Assessing Water Quality:

Water remote sensing tools (sensors) enable scientists to record the color of a body of water, revealing the existence and abundance of optically active natural water components. The water color spectrum as viewed by a satellite sensor is referred to as the water's apparent optical property (AOP). This indicates that the color of the water is controlled by the angular distribution of the light field as well as the nature and quantity of the substances in the medium, which in this case is water. As a result, the values of distant sensing reflectance, or AOP, will vary with changes in the optical characteristics and concentrations of optically active chemicals in the water. The qualities and quantities of chemicals in water are referred to as intrinsic optical properties, or IOPs. IOPs are unaffected by the angular distribution of light (the "light field"), but they are affected by the type and quantity of chemicals present in the water. For example, the diffuse attenuation coefficient of downwelling irradiance, K_d (commonly employed as an indication of water clarity or ocean turbidity), is described as an AOP (or quasi-AOP), whereas the absorption and scattering coefficients of the water are characterized as IOPs. The concentration of optically active water components can be determined in two ways: by studying spectra, which are light energy distributions over a variety of wavelengths or colors. The first technique uses empirical algorithms based on statistical relationships. The second technique employs analytical algorithms based on the inversion of calibrated bio-optical models. [10, 11].

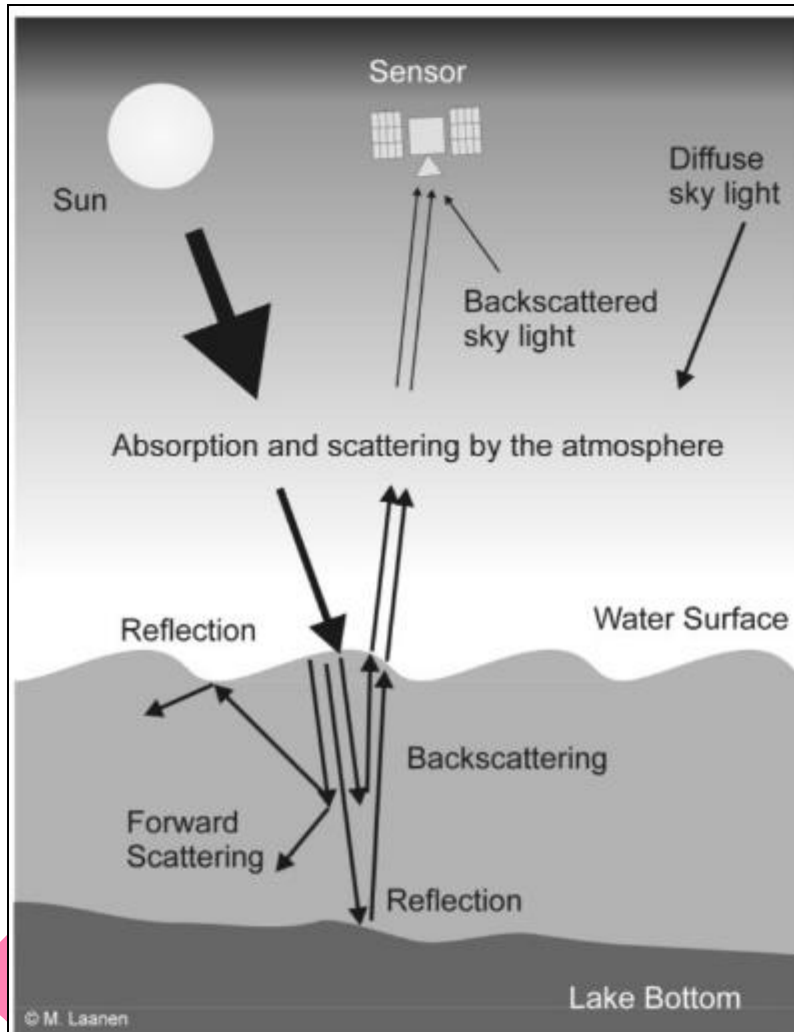

Figure 1: The path covered by light from the Sun through the water body to the remote sensing sensor

The light energy emitted from water bodies is measured using optical close-range instruments (such as spectrometers and radiometers), aircraft or helicopters (airborne remote sensing), and satellites (space-borne remote sensing). For example, algorithms are employed to extract values like secchi depth, the absorption by colored dissolved organic matter at 440 nm (aCDOM), and the concentration of suspended particulate matter (SPM) and chlorophyll-a (Chl-a). The water quality of the water body under study will be inferred from the measurement of these values. An algal bloom, for instance, brought on by eutrophication processes, may be indicated by an extremely high concentration of green pigments like chlorophyll. Therefore, the concentration of chlorophyll may serve as a stand-in or signal for a water body's trophic state. Similarly, water quality can be monitored using additional optical quality metrics such colored dissolved organic matter (CDOM), transparency (Kd), suspended particles or suspended particulate matter (SPM), and chlorophyll-a (Chl-a). [12]

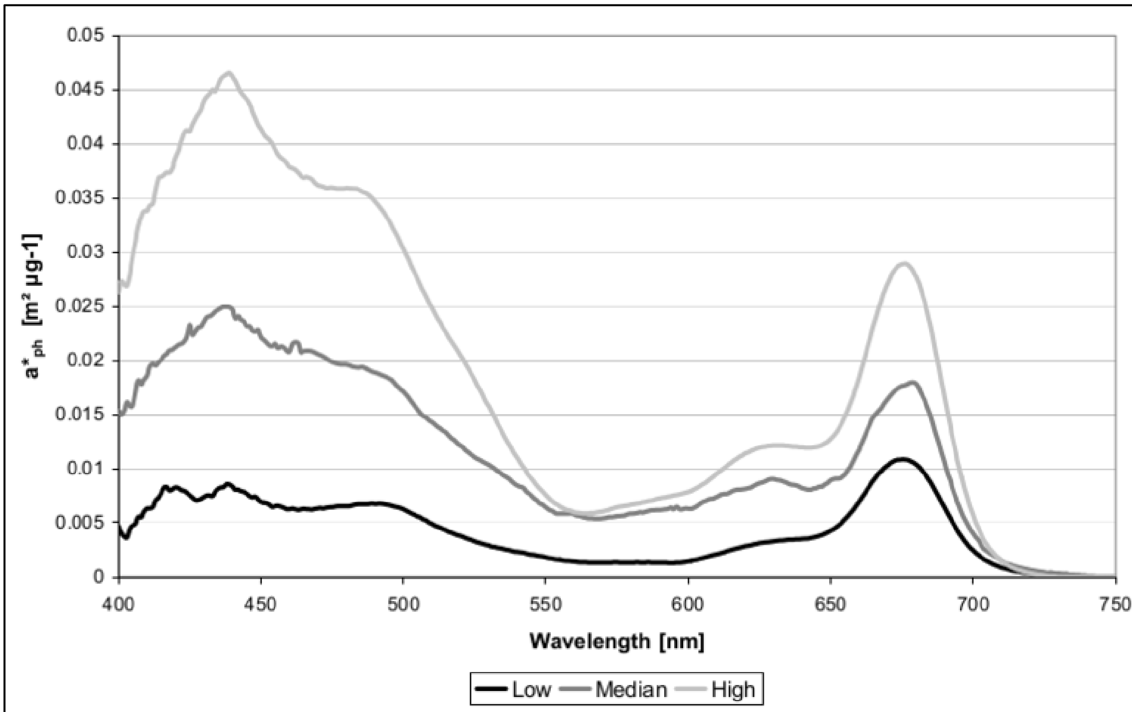

Figure 2: Illustration of a particular absorption spectrum for phytoplankton. The distinctive red and blue Ch-a peaks at 438 and 676 nm are visible in this graph. The Cyanophicocianin absorption maximum at 624 nm is another peak that can be seen. [13]

Water Resources Mapping

In water resources studies, one of the most straightforward and straightforward uses of remote sensing has been the identification and mapping of surface water boundaries. The difference in spectral reflectance between land and water is the basis for optical remote sensing of water resources. The reflectance curves of dry soil, plant, and water at various wavelengths are displayed in Figure 3. While flora and soil have a higher reflectivity in NIR and MIR wavelengths, water absorbs the majority of these wavelengths. Water absorbs most of the energy in NIR and MIR wavelengths, whereas vegetation and soil have a higher reflectance in these wavelengths. Thus, in a multi-spectral image, water appears in darker tone in the IR bands, and can be easily differentiated from the land and vegetation. Figure 4 shows images of a part of the Krishna River basin in different bands of the Landsat ETM+. In the VIS bands (bands 1, 2 and 3) the contrast between water and other features are not very significant. On the other hand, the IR bands (bands 4 and 5) show a sharp contrast between them due to the poor reflectance of water in the IR region of the EMR spectrum. [14]

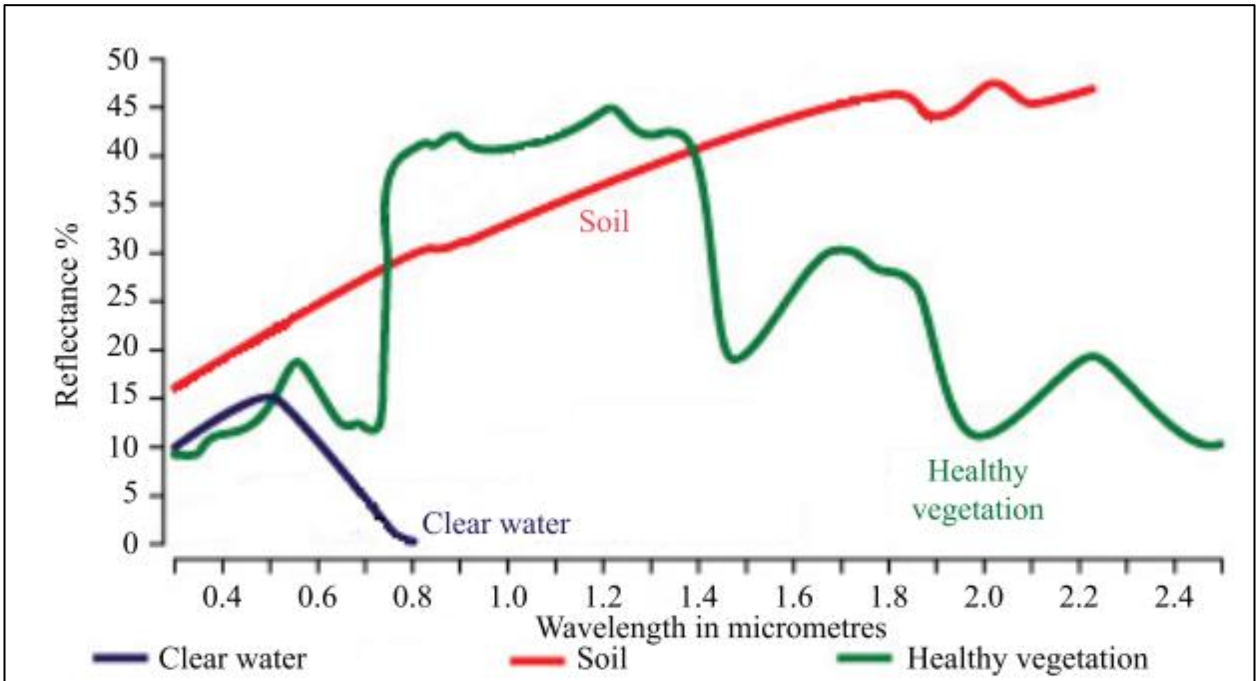

Figure 3: Spectral reflectance curves of different land cover types (Modified from http://www.rsacl.co.uk/ rs.html).

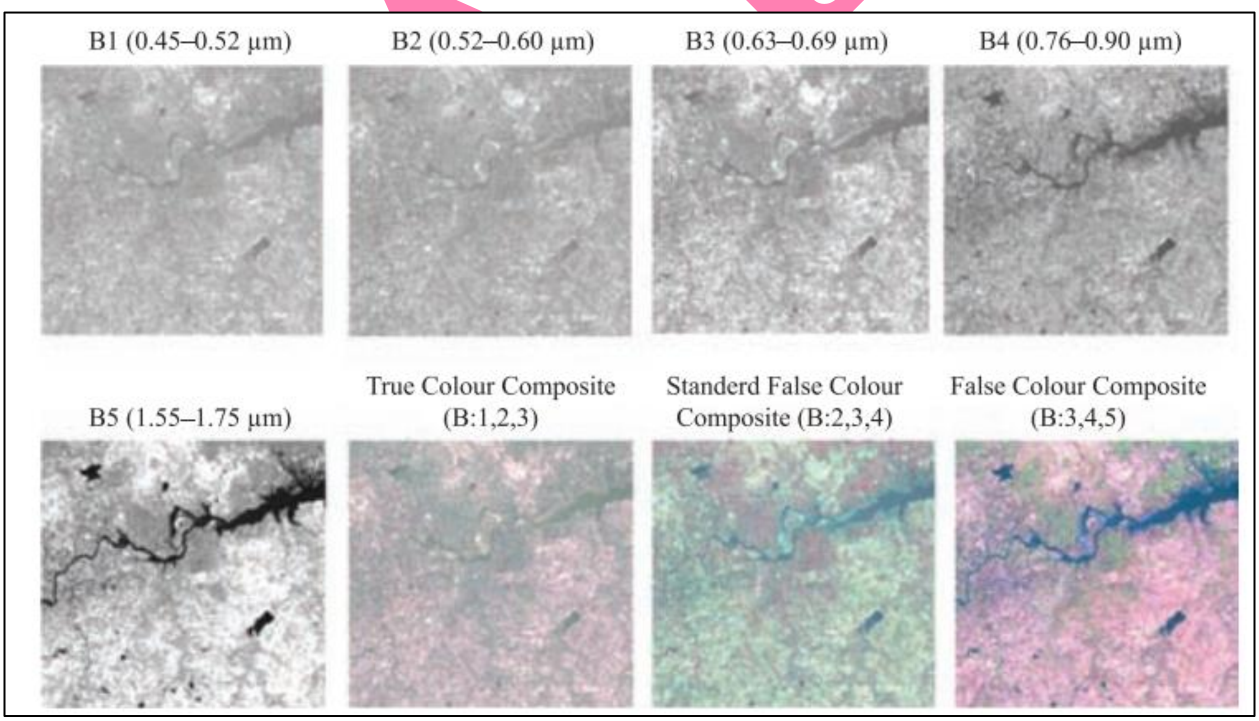

Figure 4: Landsat ETM+ images of a part of the Krishna River basin in different spectral bands.

An excellent illustration of the use of satellite remote sensing for water resources mapping is the mapping of surface water resources in India's Jodhpur District, where water bodies up to 0.9 ha in surface area have been mapped using Landsat TM pictures with a spatial resolution of 30 m.18 More precise mapping of the water resources can be accomplished with the aid of extremely fine resolution photographs, such as IKONOS and SPOT photos, which have a spatial resolution of less than 1 m. Despite offering extremely fine spatial resolution, optical remote sensing methods have limited use in inclement weather due to their reduced ability to penetrate clouds. Because of the frequent cloud cover in the tropical zones, this is especially problematic. Additionally, as floods are typically linked to unfavorable weather, this restricts the use of optical remote sensing in flood monitoring. The inability of optical remote sensing to map water resources under dense vegetation cover is another significant drawback.

Using an active microwave sensor greatly aids in getting over these restrictions. Depending on the signal's wavelength and the plant's structure, radar waves can pass through clouds and vegetation. Compared to other land features, very little energy is scattered back because the water's surface produces a specular reflection of the microwave radiation. Water body boundaries are marked and distinctions are made using the difference in energy returned to the radar sensor. Surface water bodies and flooded regions under dense forest have been successfully marked using radar remote sensing. [15]

CONCLUSION

Monitoring, mapping, and managing water-related issues has been completely transformed by the use of remote sensing in water resources management. Remote sensing offers useful information for making well-informed decisions for sustainable water resource management, from determining water availability to tracking water quality and identifying pollution sources. Our comprehension and forecasting of water quality dynamics are further improved by combining remote sensing with water quality models. By enabling more effective and efficient methods of managing water resources, these technical developments help to maintain the sustainability and well-being of river ecosystems and the communities that depend on them. We should expect additional advancements in monitoring capabilities and the creation of more reliable and thorough instruments for evaluating the quality of water as remote sensing technologies advance.

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