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A REVIEW ON: INTEGRATED WATERSHED MANAGEMENT USING REMOTE SENSING AND GIS

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Abstract

A watershed is a geographical area with a well-defined boundary that collects and drains rainwater into a single outlet. Within its borders, a watershed includes a range of natural resources, including soil, water, and biomass. For the planning and management of land and water resources at watersheds area, watershed models supported by remote sensing data and a geographic information system (GIS) have proven to be essential research tools. Understanding how human and natural events interact and relate to one another is crucial. With reference to the evaluation of watershed management and land use land cover, remote sensing and geographic information, systems (GIS) can yield reliable data. In this review, paper shows the study of watershed development and land changes. A geographic information system is one that is made to collect, store, and process, evaluate, organize, and display any kind of geographic data. The aim of this research is to study issues related to watershed management and LULC. Morphometric analysis using RS and GIS has been very beneficial for the exploration and management of the watershed and it can handle hydrological problems, such as soil erosion, drought, and floods.

Keywords:*LULC, GEE, Landsat-8/9, Morphometric Analysis, DEM, Remote Sensing and GIS.*

1. Introduction

The sustainable management of land and water resources depends heavily on watersheds which are vital hydrological units that gather, store, and direct precipitation to downstream of water bodies (Jha *et.al.*,2007). The Agricultural productivity is supported, the ecological balance is preserved and also flood and drought risks are reduced with the aid of the efficient watershed management (Gashaw *et.al*., 2017). Whereas a combination of growing anthropogenic pressures like deforestation, unplanned urbanization, and intensive agriculture, as well as climate-induced effects like unpredictable rainfall and temperature changes, have harmed watershed health and function (Sharma *et. al*., 2021).Due to these difficulties, conventional field-based techniques for assessing watersheds are frequently labor intensive, time-consuming, and geographically constrained.

Watershed analysis and planning can undergo a paradigm shift in this regard thanks to the integration of Geographic Information Systems (GIS) and Remote Sensing (RS). According to Srivastava *et.al* .(2002), RS offers affordable, multi-temporal satellite imagery that facilitates the monitoring of vegetation health, surface water dynamics, and land use/land cover (LULC). GIS is an effective tool for watershed delineation, hydrological modeling, soil erosion estimation, and resource prioritization because it makes it possible to store, visualize, model, and analyze layers of spatial data (Jothimani,1997). Soil erosion is one of the major environmental drawbacks, which lead to the destruction of fertile topsoil, low land output, and more sediments in rivers and reservoirs. It has a negative impact on the sustainability of agriculture and water resources quality, especially in developing countries. Knowledge of soil erosion spatial distribution is important in watershed management and conservation planning. Therefore, there is a need to have dependable and spatially explicit erosion evaluation techniques to enable making sustainable land-use decisions (Ashiagbor, G et al 2013).

Due to their ability to provide high-resolution data, real-time monitoring capabilities, and scalable applications across a variety of terrains and climatic zones, RS and GIS have thus become essential tools in contemporary watershed management.

Water is a precious resource without which life cannot exist. There are now significant issues due to the constant rise in water demand for different uses brought on by population expansion, agricultural and commercial development, and rising water supply pollution.Therefore, available water should be utilized as efficiently as possible and in accordance with the requirements. To guarantee the water resources 'balanced and sensible use, an integrated and complementary management approach is essential. A review of community needs and availability, which change over time and space, is one of the most essential requirements for the development and management of water resources. Watershed based water management is being recommended as the best technique since it emphasizes using available resources to meet the watershed's overall water demand (Singh, S. *et. al.* 1997).

Watersheds are being viewed as a component of overall sustainable rural development. The evaluation of watershed impact is a task that requires the use of advanced instruments, surveys, and social analytical techniques (Kumar, G., Sena *et.al.* 2014). Any system designed to gather, store, process, analyze, arrange, and present any type of geographic data is referred to as a geographic information system.(Das, D. B., & Kumar, D. D. *et. al.* 2015).

A watershed represents a complex ecological, social, and political system, transcending its basic function as a hydrological unit. It delivers crucial services to rural populations and is fundamental to maintaining foodsecurity, social stability, and economic resilience. Its development requires detailed steps, including characterization, assessment, and prioritization, designing development concepts, monitoring implementation, and analyzing impacts. For this reason, Remote Sensing and GIS technology has been increasingly utilized recently (Singh,P., Gupta,A., & Singh, M. *et.al.*2014) & (Srivas,S., & Khot, P.G. *et.al.*2018).

In the function of watershed management Multi-temporal satellite images from remote sensing is helpful for mapping erosion risk, hydrological modeling, and classifying land use and land cover (LULC). For the purposes of hydrological modeling, watershed delineation, soil and water conservation planning, and decision support systems,GIS makesit easier to integrate, manipulate, and analyze spatial data. In the technological foundation for watershed management analysis, it commonly used satellite platforms (e.g.,Landsat,Sentinel, MODIS), sensor types (e.g., multispectral, radar), and derived products such as Digital Elevation Models (DEMs) (e.g., SRTM, ASTER) that are vital for hydrological modeling and topographic analysis (Jha *et al.*, 2007;

Gashaw *et al.*, 2017). Also highlights the software tools like (ArcGIS, QGIS, ERDAS, ILWIS) that facilitate data integration, visualization, and spatial modeling (Meena & Singh *et. al*., 2018).

The main objectives of this review paper are,

1. To evaluate how remote sensing and GIS technologies contribute to data collection, analysis, modeling, and decision support, among other areas of watershed management.
2. In watershed-related fields such land use / land cover analysis, hydrological modeling, soil erosion assessment, flood and drought risk mapping, and water store management, it describes the primary uses of RS with GIS.
3. To utilize geospatial technologies in watershed management in order to improve sustainability and effectiveness.
4. To discuss the different tool and techniques used for watershed management.

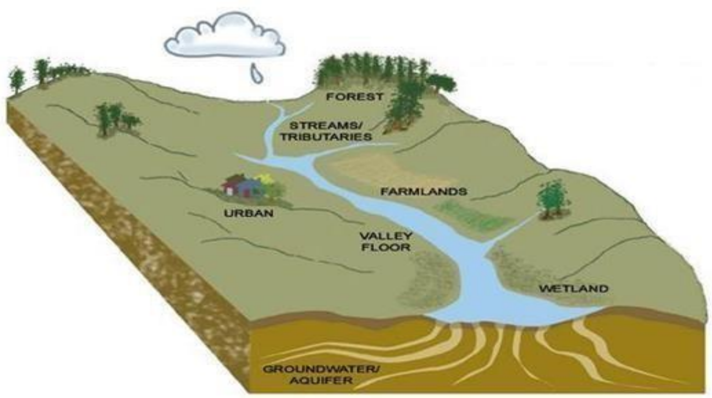

Figure1: Image show the characteristics of watershed.

2. Literature review

The application of Geographic Information Systems (GIS) and Remote Sensing (RS) for watershed management has advanced significantly, but there are still a number of issues that prevent them from reaching their full potential. A significant shortcoming is the poor integration of real time satellite data as the majority of research still relies on intermittent images from platforms like Landsat images or Sentinel images. Despite the fact that cloud based tools such as Google Earth Engine (GEE) offer near real time imagery and robust geospatial processing their application in watershed monitoring remains unexplored (Gorelick *et. al.*, 2017; Mutanga & Kumar, 2019). In addition, there another problem is inadequate ground truth runoff simulations and it erosion projections are less accurate when GIS based models like RUSLE or SWAT are used without sufficient field validation. It has been demonstrated in the past that Remote Sensing and GIS combined with erosion models like the Revised Universal Soil Loss Equation (RUSLE) are a useful method of assessing soil erosion. RUSLE modeling with the help of GIS allows using rainfall, soil properties, topography and land use/land cover data to determine the erosion prone regions. A number of authors indicated a slope gradient and vegetation cover are the most influential factors in the degree of erosion. The literature highlights that erosion risk mapping is the most appropriate compared with absolute soil loss estimation as a tool to prioritize the vulnerable areas and use in watershed management strategies (Jha *et. al.*, 2007;Ashiagbor, G et al 2013).

Furthermore, even if AI and ML are effective in improving classification accuracy and capturing intricate, nonlinear environmental patterns, they are hardly used in watershed studies (Belgiu& Dragun, 2016; Li *et. al.*, 2021). As the land use, land cover (LULC) classification is made use of machine learning. It is an incorporation into hydrological modeling, flood forecasting, and sediment transport studies and it is still in its infancy. There are problems with generalizability and scalability in this paper as well as models that are calibrated for one area frequently perform poorly in other topographical or climatic zones and it's highlighting the need for more robust and modular modeling frameworks (Mandal & Pradhan, 2020).The further more use of RS and GIS is in reliable and practical watershed management solutions and these gaps must be filled.

Hydrological modeling, watershed prioritizing, flood-risk analysis, and LULC change detection have been greatly improved as a result of recent research combining remote sensing, GIS, and machine learning techniques. Ali and (Ahmed *et. al*.,2022) conducted flood-risk mapping employing SVM classification and thresholding with 2017 IRS-1D (10 m) data from MIKE SHE, yielding a precise flood-zone forecast. So similar to this, (Sharma *et. al*., 2018) achieved extremely accurate LULC mapping by using Random Forest and Change Vector Analysis (CVA) on ASTER GDEM (90 m, 2012) for MIKE SHE simulations. In this study work, (Bhandari *et. al*., 2024) discovered key LULC variations influencing runoff utilizing thresholding and Random Forest on Landsat-8 (90 m, 2019) within HEC-HMS in hydrological modeling.

For flood-risk applications, Mehta (2014) used CVA and unsupervised classification on Landsat-8 (23.5 m, 2013) within MIKE SHE for flood-risk applications, identifying significant LULC changes in ecological areas. Similar to this research paper (Patel *et. al*., 2024) in that they supported efficient erosion-risk management in RUSLE by using CVA and unsupervised techniques with ASTER GDEM (23.5 m, 2023). (Deshmukh *et. al*., 2015) used thresholds and unsupervised classification in RUSLE to process IRS-1D (30m, 2023) for watershed prioritization and producing an accurate ranking of erosion-vulnerable sub-watersheds.

(Kulkarni *et. al.*, 2021) achieved high-precision watershed prioritization by combining OBIA and image differencing on ASTER GDEM (30 m, 2021) within SWAT using object-based methods. In a different watershed analysis, (Chaudhary *et. al*., 2020) used OBIA and thresholding on Landsat-8 (250 m, 2014) in MIKE SHE to find important LULC changes that affected hydrology.

Hydrological modeling made excellent use of vegetation-based indices. They are used ASTER GDEM (23.5 m, 2020) and Similarly, (Singh *et. al*., 2010) demonstrated efficient watershed management by applying NDVI technique and Random Forest on IRS-1D (10 m, 2015) within SWAT. In the meantime, this paper (Dey *et. al*., 2011) produced precise flood-risk forecasts for RUSLE using thresholding and Random Forest on ASTER (30 m, 2015).

(Reddy *et. al*., 2013) used image differencing and SVM on Landsat-8 (30 m, 2019) for MIKE SHE in order to successfully identify high-erosion zones. (Pawar *et. al*., 2015) found significant LULC shifts, particularly plant losses, in MIKE SHE using SAVI and SVM with ASTER GDEM (23.5 m, 2020).

(Varma *et. al*., 2019) used CVA and OBIA on Sentinel-2A (10 m, 2017) to provide high-accuracy LULC detection for efficient landscape management. In this paper, (Yadav *et. al*., 2013) used SAVI and Random Forest on Landsat-8 (10 m, 2014) in HEC-HMS to precisely identify flood-prone watersheds is one example of a watershed prioritization study. Similar to this (Desai *et. al*., 2015) article paper produced distinct flood-susceptibility maps using thresholding and MLC on ASTER (90 m, 2023). In order to help large-scale resource management, (Ghosh *et. al*., 2017) used CVA and SVM using MODIS Terra (30 m, 2019) for MIKE SHE.

Some studies have been in a position to establish the effectiveness of vegetation indexes and image classification technique in hydrological and watershed modeling. Study by (Pillai *et. al*., 2010) enabled determination of high-erosion-prone in MIKE SHE hydrological model by taking advantage of the NDVI and maximum likelihood classification (MLC) of data retrieved through the application of the MODIS Terra instrumentation and therefore a more accurate assessment of the erosion processes was made possible. Subsequently, (Kulshrestha *et. al*., 2011) went ahead to thresholding and Object-Based Image Analysis (OBIA) of the MODIS Terra imagery to determine how land-use/ land-cover (LULC) changes have led to watershed prioritization. Recently, (Naik *et. al*., 2025) employed the Soil Adjusted Vegetation Index (SAVI) and the unsupervised classification techniques based on Sentinel-2A data combined with MIKE SHE model, which resulted in the correct prediction of the hydrological responses, along with the improved understanding of the watershed behavior.

(Verma *et. al*., 2021) used NDVI method and SVM classification in hydrological modeling applications using ASTER GDEM (10 m, 2012) within SWAT to accurately identify flood-prone zones. Similarly,Basu (2021) found significant LULC changes influencing watershed stability using thresholding and SVM on ASTER GDEM (250 m, 2011) within MIKE SHE.

In above review peer-reviewed studies revealed the widespread and diverse application of Remote Sensing (RS) and Geographic Information Systems (GIS) in watershed management. Flood risk mapping, hydrological models, land use/land cover (LULC) monitoring, watershed prioritization are some of the studies that have been carried out on watershed related issues using remote sensing and GIS techniques. (Ali & Ahmed, *et. al*., 2022). Spatial datasets have been used in hydrological modeling studies to simulate watershed responses and runoff to different climatic and land-use conditions (Sharma et al., 2021). In addition, LULC monitoring plays a significant role in training of landscape processes and their applications in the hydrological processes which are considered in both the old and new research (Jothimani, 1997; Yadav & Dutta *et. al*.,2013). Moreover, the thematic-based- and morphmetric-based watershed prioritization methods have been actively used to tackle the key sub-watersheds to the management of the sustainable resources (Srivastava et al., 2002; Borah & Bhattacharjya, 2020).

To provide significant landscape and hydrological insights detection techniques such NDVI technique, thresholding, Change Vector Analysis (CVA), and image differencing were frequently employed (Gashaw et al., 2017; Mandal & Pradhan, 2020).

The methods used for classification differed between investigations. While in more recent studies the researchers have used sophisticated machine learning techniques like Random Forest (RF), Support Vector Machines (SVM), and object-based classification to improve accuracy and adaptability. Earlier works used traditional methods like Supervised Maximum Likelihood Classification (MLC) and unsupervised classification (Jothimani, 1997). (Belgiu & Drăguň, 2016; Li et al., 2021). In Landsat-8, ASTER GDEM, IRS-1D, MODIS Terra, and Sentinel-2A were the main sources of spatial data with resolutions ranging from 10 m to 250 m and suggesting a trend toward higher-resolution images in more recent investigations.

The Various watershed models are like SWAT, RUSLE, HEC-HMS, and MIKE SHE they were integrated with GIS software like ArcGIS, QGIS 3.40.7 version, ENVI, and ERDAS Imagine to simulate runoff, sediment yield, flood risks, and conservation scenarios (Jha et al., 2007). Most of these models are implemented within small to medium scale watersheds across India and Africa, including the Teesta, Nagavali, and Andassa watersheds representing a wide range of topographic and climatic settings.

There are still certain limits even if the results consistently highlighted the usefulness of RS-GIS techniques in aiding resource planning, prioritizing sub-watersheds, and showing spatial patterns. Few research used real time cloud based platforms such as Google Earth Engine or multi-sensor data fusion (Gorelick et al., 2017). Additionally machine learning was mostly restricted to categorization tasks rather than integrated hydrological modeling and ground validation. These limitations indicate that in order to improve the resilience, flexibility, and transfer ability of watershed models future research must incorporate AI driven analytics, real time monitoring, and multi-source data processing.A combined overview of 25 chosen studies shown in this part to highlight the various ways that RS and GIS techniques have been applied. It contains information about study fields, software, data sources, satellite platforms, detection/classification techniques, and application types. This can be used as a guide to spot trends, assess advancements, and discover areas of technical innovation.

3. Proposed Methodology for Integrated Watershed Management Using Remote Sensing and GIS

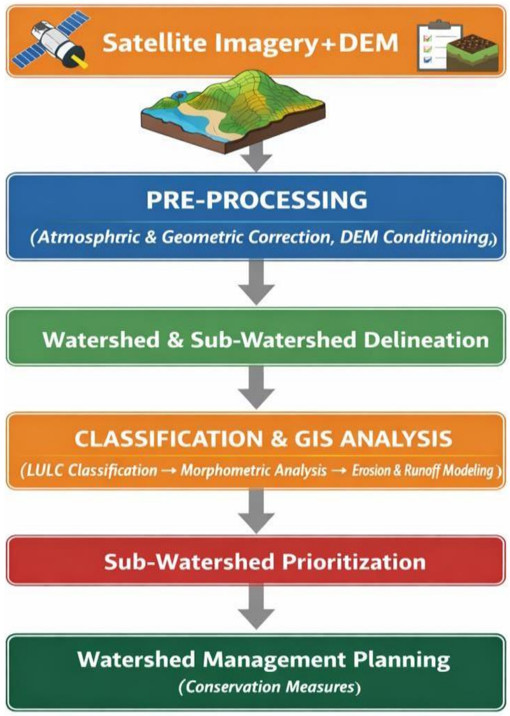

Fig 2: Workflow Diagram of Sub watershed using remote sensing and GIS

The methodology integrates remote sensing with GIS based on data preparation. The data obtained from the remote sensing images used for watershed characterization which helps in the delineation of watershed and sub watersheds. Based on the watershed characteristics the prioritization is done and it is followed by planning and implementation of soil, water and biomass conservation measures. It supported by the categorization and spatial analysis. In this framework, it places emphasis on the regions' applicability, scalability, and reproducibility.This section compares classification methods (e.g., Random Forest, SVM, Maximum Likelihood), and pre-processing techniques such as cloud masking, geometric correction, and terrain reconditioning (Ali & Ahmed, *et. al.*, 2022).

3.1 Preprocessing of Remote Sensing and Spatial Data

In this order to ensure the geometric, radiometric, and thematic consistency of multi-source datasets before watershed analysis pre-processing is an essential step. These are the Digital Elevation Models (DEMs) such as SRTM, ALOS PALSAR and Carto DEM they are utilized for topography and hydrological analysis while multi-temporal satellite data such as Landsat-8/9, Sentinel-2, or IRS LISS-III are obtained to record land surface dynamics. To reduce sensor and atmospheric impacts, initial pre-processing involves radiometric calibration, atmospheric correction, and cloud masking (Chavez, 1996; Song et al., 2001). To guarantee spatial alignment of satellite imagery DEMs, soil maps, and rainfall data within a similar coordinate system and geometric correction and reprojection are used. To eliminate artificial depressions and maintain hydrological continuity, DEM conditioning methods such sink filling are used (Jenson &Domingue, *et. al.*, 1988).

In the Watershed and sub watershed, delineation is based on the flow direction, flow accumulation, and drainage networks. It generated by GIS-based hydrological tools using the corrected DEM. For further study ancillary datasets such soil maps, rainfall records, geomorphology and lineament layers are combined and standardized and the results of satellite imagery pre-processing, hydrologically corrected DEM, watershed and sub-watershed borders, theme layers, etc.

3.2 Classification of Watershed Analysis based GIS

After the pre-processing watershed characteristics and management priorities are determined through spatial modeling and thematic classification. Due to their resilience in diverse environments, supervised or machine-learning algorithms like Support Vector Machine (SVM) or Random Forest (RF) are used for Land Use/Land Cover (LULC) categorization (Pal & Mather, 2005; Belgiu & Drăguň, *et. al.*, 2016). The Multi-temporal LULC datasets that show how land degradation, deforestation, and agricultural development affect watershed hydrology enable the Change detection analysis. The DEM data is used to extract morphometric parameters such as linear, areal and relief features. In Runoff behavior erosion susceptibility and watershed response to rainfall are evaluated using parameters such drainage density, bifurcation ratio, elongation ratio, and relief ratio (Horton, 1945 & Strahler, *et. al.*, 1964). To assess moisture distribution and erosion is potential terrain and hydrological indices such as slope, Topographic Wetness Index (TWI), and Stream Power Index (SPI) are calculated. The Revised Universal Soil Loss Equation (RUSLE) which is incorporates rainfall erosivity soil erodibility slope length steepness cover management and conservation practice parameters is used in a GIS setting to quantify the risk of soil erosion (Renard et al., 1997). The Geology geomorphology are all integrated to identify groundwater potential and recharge zones. This are layers slope drainage density, lineament density, soil, and LULC layers each parameter is given a relative value using Multi-Criteria Decision Analysis (MCDA) methodologies such the Analytical Hierarchy Process (AHP) (Saaty *et. al*., 2008). The process of sub watershed prioritizing is involves the combination of land degradation indicators runoff potential, erosion risk and morphometric indices. It mediate soil and water conservation measures such contour, check dams, percolation tanks and afforestation are advised for higher priority sub watersheds. For the field observations GPS data and existing watershed project records are used to validate final findings and the results of satellite imagery Classification LULC maps are erosion risk maps, groundwater potential zones, sub-watershed priority ranking, and watershed management action plans.

3.3 Geospatial Technologies in Sustainable Watershed Management:

Preservation and utilization of natural resources land and water have become paramount, given its increasing demand. In this respect, watershed has gained growing popularity all over the world to address environmental issues and implement various development activities. These development projects, which include management of rainfall, soil erosion control, reduction of runoff and increasing productivity, also focus on the social and economic development of the watershed community. GIS and GPS are increasingly being used to address aspects of watershed development programs such as creation of base maps, inventory of natural resources at various scales, identification of critical issues related to soils, water and crops, creation of action plans and impacts assessment. A number of studies have been conducted on planning of agricultural systems and natural resources. During recent years, with the development of communication technology, techniques have emerged for real time field data Collection and transmission, which will be very useful for real-time monitoring of watershed activities. A Digital Elevation Model (DEM) is in essence a representation of the height data that is thus collected. Hydrological DEM can be created when combined with drainage data, which is helpful for both hydrological modeling of watersheds and automatically defining watersheds. Additionally, high spatial resolution data are being used more and more to evaluate watershed performance and track different soil conservation initiatives. To make the data available in the web in almost real time, a large network of Automatic Weather Stations (AWS) is being set up across India using state-of-the-art communication technologies. By adding machine intelligence, these networks can perform important field decisions automatically. Recent developments of micro/nano satellites and networking with ground-based sensors enable the data to be used for realtime applications for watershed management. Secondly, geoinformatics and web GIS technologies have the potential to have a great influence on the management of watersheds.

3.4 Different tools and techniques for Watershed Management

Watershed management is defined as "the integrated use of land, vegetation and water for the benefit of its residents within a geographically discrete drainage area. Watersheds are today being used as a pragmatic planning unit for the dissemination of rain-fed agricultural technology from lab to land to improve crop production, maintain soil and water resources, and minimize land degradation. Land and water resources work hand-in-hand, so the watershed concept is more appropriate. For the effective management of watersheds and the availability of basic information, technological improvements like remote sensing, GIS, portable devices, equipment and communication devices are crucial.

3.5 Remote Sensing

Improvements in satellite remote sensing sensors spatial, spectral, temporal and radiometric resolutions have been significant since the early 1970s. In the 1970s, the resolution was 80m and in the mid 1980s it ranged from 0-36m (Landsat-MSS, SPOT-MLA) to 0.68-5.8m (Landsat-TM, IRS-LISS II, Catosat-1,2, Quick bird, PAN, Landsat-MSS, MLA and IRS-PAN and LISS-IV. Along with these developments, the use of satellite data has been extended from watershed to sub-watershed and micro-watershed (Table 1).

Table 1. shows which IRS sensors are appropriate for use in watershed research.

Sr. No.	Level of study	Suitable spatial resolutions	sensors	Application potential
1	Basin level (1:250000 scale)	50 to 150m	IRS-WiFs,AWiFS,LISS-1	Deriving overall base information on natural resources and land cover; large scale monitoring of changes.
2	Watershed level (1:50000 scale)	20 to 50m	IRS-LISS- III, SPOT-MLA,TM,ETM,	Deriving natural resources information for watershed prioritization, Planning, monitoring
3	Sub / micro-watershed level	0.5 to 20m	IRS-LISS-IV, SPOT-PLA, Cartosat-1 /2,	Execution planning, monitoring watershed

	(1:10000 or larger)		IKONOS, Quick Bird, Worldview-2.	developmental activities, detailed account on changes happened. Stereo data for DEM generation.

Moreover, the concurrent availability of stereo-satellite data from IRS-LISS-IV, SPOT-PLA, IRS 1C/1D-PAN, IKONOS and Cartosat1-2. They made it possible to create digital elevation (DEM) models for the watersheds, which include essential topographic feature extraction, runoff analysis, slope stability analysis, landscape analysis, and more. The spatial resolution and base-height ratio of the sensor are usually the determining factors of the accuracy of the DEM. SPOT DEM accuracies generated from HRS imagery are absolute planimetric accuracy 15 to 30 m and absolute elevation accuracy 10 to 0 m (Annon.004). In Cartosat-1 DEM an accuracy of 3-4 m in height was achieved where spatial resolution is .5 m (Srivastava et al.2002). CartoDEM can be used as input for planning the development of watersheds. The geometric accuracy and information content of ortho-images and DEM provided by the CartoSAT-1 Mission can be used for delineation of watershed boundaries at scale of 1:25,000 to 1:50,000 scales, generation of contour maps at 10 m interval and generating thematic maps at 1:10,000 scale (Krishna Murthy *et.al.* 2008)

3.6 Geographic Information System (GIS)

Watershed level planning requires a host of inter-related information to be generated and studied in relation to one another. The data from remote sensing provides valuable and up-to-date geographic information about the physical terrain features and the natural resource. A geographic information system (GIS) is a great way to organize and store tabular and spatial data in an organized format. When planning and developing watersheds that take into account all natural and socioeconomic aspects, this is a highly helpful and crucial tool. GIS has been applied to aid and assess various resource management options, to develop digital databases and to assess state and trends of local resources. Apart from being made efficient and cost-effective, GIS is a revolution in its own right, and with that, it has become a necessary technology for creating sustainable development plans for the management of both land and water resources. GIS was used extensively during early development, mainly for data conversion and digitalizing paper maps, for data storage, and for printing maps. Limited spatial analysis was used. Over time, things changed drastically and spatial analysis was essential component in watershed planning. By combining spatial and non-spatial data, such as thematic layers and socioeconomic data, GIS also makes modeling to arrive at location-specific solutions easier. Communication networks came into existence simultaneously with the boundaries of data storage being removed, while new fields such as web map services and collaborative mapping have emerged. Now with today's GIS technologies, "map anywhere, serve anywhere" is possible.

modelling techniques, as well as advances in data display and visualization. Among these applications, watershed planning proved to be effective in planning land resources, water resources, watershed prioritization and monitoring.

Public outreach is a crucial aspect of this information in addition to data creation and spatial analysis. This spatial information used to be in the knowledge of a few people in their cabinets. Serving of data is now faster due to the RAID/BLADE servers, gigabit data transfer rates, and Mbps internet connection speeds. Outreach to the outside world has significantly enhanced. Today, spatial data is being delivered via the Internet and has real-time spatial analysis capabilities. One such NRSC/ISRO programme is Bhoosampada which gives Natural resources information, base information and latest theme area information through an online GIS. It provides spatial analysis of the data available without the need to use a separate GIS program. Moreover, the output can be downloaded in an appropriate output format. The purpose of this is to get the material out to the public before it becomes irrelevant.

3.7 Field Sensors and Data Communication Devices

The collection, collation and analysis of field data or ground information is an important aspect of watershed management; analysis of real-time spatial data will help in timely decisions making and the implementation of appropriate remedial measures. The collected field data is representative of the ground situation in real time and time. Common elements of field data collecting include geographical location, photos of the area in the sample locations, notes on soils, crops and land use, and general notes on a ground truth performance. The data collection activity and the use of the data are generally done sequentially and the ground truth data collection activity is allowed to complete before the data is used, therefore there is usually a time delay between the two activities. There have been several advances in the way field data is collected, ranging from hardcopy field notes on paper to the more modern laptop and palmtop. However, combining some of the most current technological developments promises to provide far improved solutions in this field, which would be advantageous to a variety of users.

3.8 Global Positioning System

Location awareness is a critical feature for any application which is provided by GPS. In any case when collecting and using real time field data, where the data is collected is significant. Most tech-literate people these days know what GPS is, and how it's become an integral part of the technology for locating position. Many location-aware, location-based applications are underway, especially in the utility, service and emergency management sectors. With standard code receivers, the latest developments and relaxations have enhanced the accuracy of location to over 15 metres. Differential accuracy is possible to the extent of centimeters.

3.9 Automatic Weather Station

Meteorological data must be extremely accurate and be recorded and delivered at the watershed level in a real-time basis, so as to manage resources and boost crop productivity. The Automatic Weather Station (AWS) is an affordable resource to provide wide-ranging weather data in the area of interest. AWS collects data such as rainfall, wind direction and speed, humidity, temperature and more. Also, other sensors with special interests can be integrated to AWS for measuring soil temperature, leaf moisture, etc. The application examples of the AWS data in the agricultural monitoring and crop management, disaster management, flood forecasting, drought/crop condition assessment, and other industries such as transportation are widely known.

4. Challenges and Limitations

RS and GIS face several constraints in watershed management. Low-resolution satellite data (e.g., MODIS at 250m) may miss fine-scale features, while high- resolution alternatives (e.g., Sentinel-2 at 10m) are costly. Ground truth, essential for validating RS data, is resource-intensive and often minimal. Local institutions frequently lack technical expertise and funding to implement these technologies. Additionally, integrating socio-economic data and real- time satellite imagery remains limited, reducing model reliability and applicability. Scalability problems also occur because models that have been calibrated for a particular region might not be able to generalize across different climate zones.

5. Conclusion

In today's watershed management, remote sensing and GIS technologies are essential instruments that provide effective, economical, and accurate methods for data collection, analysis, and decision-making. Through the integration of multi-temporal satellite imagery, spatial analysis, and modeling, these technologies enable comprehensive assessment of watershed characteristics, land use/land cover changes, hydrological modeling, soil erosion risk, flood risk mapping and water resource distribution. The review highlights that RS and GIS not only support better understanding of watershed dynamics but also facilitate the planning and implementation of sustainable management strategies. As technological advancements continue, the incorporation of higher-resolution datasets, real-time monitoring, and machine learning will further enhance the effectiveness of watershed management practices. Over the past decades, the integration of RS and GIS has transformed traditional approaches by enabling precise spatial and temporal analysis of watershed parameters. The review reveals that RS and GIS significantly improve the accuracy of watershed delineation, resource inventory, and impact assessment, supporting data-driven decision-making and sustainable resource planning.

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