Chapter 1
Overview of Geospatial Technologies for Land and Water Resources Management

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Abstract Land and water resources management are essential for the future sustainability of the environment. The studies on land and water resources require basic geo-referenced data, such as land use-land cover (LULC), soil maps, and digital elevation models (DEMs) for capturing the spatio-temporal variations of thematic layers. These data can be easily obtained from remote sensing images and limited ground truth. Hydro-meteorological data, such as precipitation, air, land surface temperature, solar radiation, evapotranspiration, soil moisture, river and lakes water levels, river discharge, and terrestrial water storage, can also be derived from remote sensing as well as from point-based ground instruments. Then, studies can be carried out at various spatio-temporal scales.

1.1 Introduction to Geospatial Technology

Remote Sensing, Geographic Information Systems (GIS), and Global Positioning System (GPS) form a revolutionary combination often referred to as Geospatial Technologies. Geospatial Technologies is the most powerful and transformational modern-day technologies used extensively to address real-time problems on the

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earth's surface. The conjunctive use of remote sensing and GIS has proved to be highly effective to analyze diverse phenomena on the earth's surface (Davis et al. 1991; Lo et al. 1997; Huggel et al. 2003; Kaab et al. 2005; Pandey et al. 2007; Patel and Srivastava, 2013; Calera et al. 2017; Chae et al. 2017; Borrelli et al. 2017). The capability of satellites and sensors for earth observations through numerous spectral bands has enhanced the umbrella of applications manifold. Analysis of land and water resources using vast volumes of data demands a robust database management system. GIS serves as a perfect platform for storing, managing, and analyzing voluminous spatial and non-spatial data (Chang 2008). It provides a robust computing environment and platform for re-scaling models and supports handling complex data-method relationships (Pandey et al. 2016b). Groot (1989) defined geospatial technology or geoinformatics as "the science and technology dealing with the structure and character of spatial information, its capture, its classification and qualification, its storage, processing, portrayal, and dissemination, including the infrastructure necessary to secure optimal use of this information." Various applications of this technology can be broadly categorized into two significant domains, namely land resources and water resources. These two domains cover many applications in natural resources management, where geospatial technology serves as a very effective decision-making tool in these applications. This technology is being extensively used for effective and sustainable planning, management, and development of natural resources (Verbyla 1995).

Land resources form the core of sustainable existence and development in critical challenges, like agriculture, food production, poverty, and climate change impacts (Muller and Munroe 2014). Issues like improving agricultural production, soil conservation, deforestation, land degradation, and climate change require repeated observations of the nature, extent, and spatial variations of the earth surface with a high spatial resolution (Buchanan et al. 2008; Pandey et al. 2011; Yang et al. 2013; Calvao and Pessoa 2015; Huang et al. 2018; Pandey and Palmate 2018; Pandey et al. 2021a). Rapid geospatial technology advancements have revolutionized land resources mapping, monitoring, and management (Velmurugan and Carlos 2009). This technology also facilitates the generation of time-series databases enabling the scientists and researchers to derive meaningful results, recommendations, and action plans for the decision-makers at various implementation levels.

Water, the most precious natural resource, experiences immense pressure due to overexploitation to satisfy the ever-growing population's needs (Wang et al. 2021). Moreover, factors like urbanization, globalization, infrastructural developments, and climate change have posed a massive threat to the limited freshwater resources available on earth (Chapagain and Hoekstra 2008; Giacomoni et al. 2013; Nair et al. 2013). Geospatial technology plays an instrumental role in analyzing, modeling, and simulating water quality, water availability, water supply management, floods, and droughts under various climate change scenarios. There are numerous applications of this technology addressing sustainable water resources management viz. assessment of groundwater recharge potential; integrated watershed management and development (Pandey et al. 2004); design flood estimation (Sharma et al. 2021);

flood modeling (Patro et al. 2009); flood inundation and hazard mapping (Singh and Pandey 2021); sediment dynamic modeling (Pandey et al. 2016b).

Remote sensing forms the most integral component of the geospatial technology serving the purpose of a data source. Remote sensing has a unique capability of observing the earth's surface in numerous spectral bands covering different wavelength ranges (Lillesand et al. 2015). Optical remote sensing uses visible, near-infrared, and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground (Lillesand et al. 2015). Different materials reflect and absorb differently at different wavelengths. Thus, the targets can be differentiated by their spectral reflectance signatures in remotely sensed images.

There are few open source satellites that provide solutions to geospatial technologies with easier access to the user. Remote sensing satellite sensors gather information from space and generate a large number of datasets that are difficult to manage and analyze using software packages or applications that may require significant time and labor. The cloud computing systems, such as Amazon Web Services (AWS) and Google Earth Engine (GEE), have been developed to address this issue. Although cloud computing platforms and other emerging technologies have demonstrated their significant potential for monitoring land and water resources management, they have not been appropriately examined and deployed for RS applications until recently. Users can access various data sets on those platforms without having to download anything. Both GEE and AWS offer similar features, such as automatic parallel processing and a fast computational platform for successfully dealing with substantial data processing or time-series analysis in a quick interval.

1.2 Cutting Edge—Techniques and Applications of Geospatial Technologies in Land and Water Resources Management

Various types of geospatial technologies have been made accessible to end users in recent years for use in a variety of applications in land and water and other emerging applications.

1. **Remote Sensing**—High-resolution satellite imagery is acquired from space using a camera or sensor platforms mounted to the spacecraft. There were fewer high-resolution satellite images with centimeter resolution accuracy needed for monitoring in many applications, to meet human requirements and study the earth's climate.
2. **Geographic Information Systems (GIS)**—An application or software package for analyzing or mapping satellite data and performing additional operations, such as geo-referencing and geocoding, if the particular location of the earth's surface is known. The model can then be used to do various analyses through the use of different techniques.

3. **Global Positioning System (GPS)**—The discipline of earth monitoring has grown significantly in recent years. It has three basic components: the space segment, the control segment, and the user segment. It is a cutting edge technology capable of providing greater accuracy, less than a millimeter or meter. In the application to land and water resources, the most important requirement is to gather the geographical coordinates of any object present on the earth's surface and gain information from the object features with geographical data, which was acquired in real time and directly from the field at a reasonable cost.
4. **Internet Mapping Technologies**—Cloud computing platforms, such as Google Earth Engine, Microsoft Virtual Earth, Amazon Web Services, as well as other web features, are gradually improving how geographical data is analyzed and disseminated. With the availability of many modern technologies to users and other agencies, began analyzing data for satellite photos without prior experience or any pre-processing processes. By comparison, traditional GIS procedures are limited to highly skilled individuals for analyzing satellite data and mapping data for a variety of applications. As a result, internet mapping offers more opportunities to users who are willing to invest efforts in complex algorithms.

There are numerous uses for land and water resources, such as rainfall, land cover, snow cover extent, surface water extent, soil moisture, and hydrological cycle. All of these application parameters are quantified using various approaches including satellite data. Surface water bodies can be identified using remote sensing techniques; meteorological variables, such as temperature and precipitation can be estimated; hydrological state variables, such as soil moisture and land surface features can be estimated; and fluxes, such as evapotranspiration can be estimated. Availability of different sensors which directly gather information from land water bodies provides significant information in modeling algorithms. Moreover, it can be applied to crop inventory and forecasts; drought and flood damage assessment; and land use monitoring and management. Today, India is one of the major providers of earth observation data in the world in a variety of spatial, spectral, and temporal resolutions, meeting the needs of many applications of relevance to national development.

Based on multiple spectral bands used in the imaging process, optical remote sensing systems are categorized into three basic groups viz. panchromatic (single band), multispectral and hyperspectral systems. Table 1.1 offers many Indian and global panchromatic and multispectral satellite data products extensively utilized to address land and water resources management challenges. Table 1.2 shows a list of hyperspectral satellite data products.

Microwave remote sensing is very popular in the research community to map and monitor water resources primarily because of the capability of microwaves to accurately detect water (Ulaby 1977; Engman 1991) due to its all-weather ability. Synthetic Aperture Radar (SAR) has been one of the most prominently used microwave remote sensing data products to address water-related applications. Table 1.3 presents a list of SAR and other satellite data products available in the microwave region of the electromagnetic spectrum (Brisco et al. 2013; Singh and Pandey 2021).

Table 1.1 List of optical remote sensing (panchromatic and multispectral) data products

S. No.	Satellite mission	Sensor	Spatial resolution (m)	Temporal resolution	Manufacturer	Data available from
1	Cartosat-3	Pan	0.28	5 days revisit	ISRO	15-Feb-2020
2	Cartosat-3	MX	1.12	4/5 days	ISRO	15-Feb-2020
3	Cartosat-2 series	Pan	0.65	4/5 days	ISRO	01-Aug-2016
4	Cartosat-2 series	MX	1.6	4/5 days	ISRO	01-Aug-2016
5	Cartosat-2B	PAN	1	4/5 days	ISRO	13-Jul-2010
6	Cartosat-2A	PAN	1	4/5 days	ISRO	29-Apr-2008
7	Cartosat-2	PAN	1	4 days	ISRO	14-Apr-2007
8	Cartosat-1	PAN-F	2.5	5 days	ISRO	08-May-2005 to 31-Jan-2019
9	Cartosat-1	PAN-A	2.5	5 days	ISRO	08-May-2005 to 31-Jan-2019
10	Cartosat-1	Stereo	2.5	5 days	ISRO	08-May-2005 to 31-Jan-2019
11	Cartosat-1	Widemono	2.5	5 days	ISRO	27-May-2005 to 31-Jan-2019
12	Resourcesat-2A	AWIFS	56	2–3 days	ISRO	06-Jan-2017
13	Resourcesat-2A	Liss-3	23.5	12–13 days	ISRO	06-Jan-2017
14	Resourcesat-2A	Liss-4-FMX	5.8	25–26 days	ISRO	06-Jan-2017
15	Resourcesat-2A	Liss-4-SMX	5.8	2–3 days	ISRO	15-Dec-2016 to 17-May-2017
16	Resourcesat-2	AWiFS	56	2–3 days	ISRO	30-Sep-2011
17	Resourcesat-2	Liss-3	23.5	2–3 days	ISRO	30-Sep-2011
18	Resourcesat-2	Liss-4-FMX	5.8	2–3 days	ISRO	30-Sep-2011
19	Resourcesat-2	Liss-4-SMX	5.8	2–3 days	ISRO	28-Sep-2017
20	Resourcesat-1	AWiFS	56	5 days	ISRO	07-Dec-2003
21	Resourcesat-1	Liss-3	23.5	5 days	ISRO	07-Dec-2003
22	Resourcesat-1	Liss4-SMX	5.8	5 days	ISRO	11-Dec-2003
23	Oceansat-2	OCM	360	2 days	ISRO	01-Jan-2010
24	Landsat 7	ETM+	30	16-day	NASA/USGS	1999 to present
25	Landsat 8	OLI/TIRS	30	16-day	NASA/USGS	2013 to present

(continued)

Table 1.1 (continued)

S. No.	Satellite mission	Sensor	Spatial resolution (m)	Temporal resolution	Manufacturer	Data available from
26	Sentinel-2A and 2B	MSI	10, 20, 60	10 and 5 days	ESA	2015 to present

Dataset source for downloading, Cartosat series: https://bhoonidhi.nrsc.gov.in/ Resourcesat series: https://bhoonidhi.nrsc.gov.in/ and https://glovis.usgs.gov/ Landsat series: https://earthexplorer.usgs.gov/ Sentinel Series: https://scihub.copernicus.eu/

Table 1.2 List of optical remote sensing (hyperspectral) data products

S. No.	Satellite	Sensor type	Resolution		Organization
			Spectral (nm)	Temporal (day)	
1	EO-1	Hyperion	10	16–30	NASA
2	Shenzhou-8	Tiangong-1 hyperspectral imager (HSI)	10 (VNIR) 23 (SWIR)	–	Chinese academy of science physics
3	PRISMA	PRISMA	10	14–7	Agenzia Spaziale Italiana
4	HISUI	HISUI	30	2–60	Japanese ministry of economy, trade, and industry
5	EnMAP HSI	EnMAP	30	27 (VZA $\geq$ 5°)	GFZ-DLR
6	SHALOM	Improved multi-purpose satellite-II	10	4 (VZA $\geq$ 30°)	ASI-ISA
7	HyspIRI	HyspIRI	30 (60)	5–16	JPL-NASA

Dataset source for downloading, S. No. 1—http://earthexplorer.usgs.gov/ 2—http://www.msadc.cn/sy/ 3—http://prisma-i.it/index.php/en/ 4—https://oceancolor.gsfc.nasa.gov/data/hico/ 5—https://earth.esa.int/eogateway/catalog/proba-chris-level-1a 6—https://www.nrsc.gov.in/EOP_irsdata_Products_Hyperspectral

1.3 Methodology Development in Land Resources Management

Geospatial technologies play a pivotal role in monitoring and managing land resources. One of the most widely exploited applications is Digital Terrain Modeling (DTM), which characterizes the topography of any area using digital elevation models (DEMs) (Zhou et al. 2007). DEM products of different spatial resolutions are extensively used for topographic mapping, relief mapping, and terrain analysis (Yang et al. 2011). They also serve as a preliminary input in various hydrological studies (Nagaveni et al. 2019; Himanshu et al. 2015). A list of several DEM products available for use is presented in Table 1.4.

Table 1.3 List of microwave remote sensing data products

S. No.	Satellite	Sensor	Resolution	Data available from	Organization
1	Risat-1 C-band SAR	FRS 1	3 m	01-Jul-2012 to 30-Sep-2016	ISRO
2	Oscar	Ku-band	50 km 25 km	09-Feb-2010 to 01-Mar-2014	AMSAT
3	Scatsat-1	Ku-band scatterometer	50 km 25 km	26-May-2017 onwards Release of SCATSAT-1 V1.1.4 data products	ISRO
4	SARAL	Ka-band radar altimeter	–	01-Nov-2014 onwards	CNES, ISRO
5	Sentinel-1	SAR C-band (center frequency: 5.405 GHz)	10 m		ESA
6	TerraSAR-X	X	HR (5–20 m) VHR (0–5 m)	2007 onwards	ISC Kosmotras
7	Radarsat-2	C	3–300 m	2007 onwards	MDA
8	ALOS-2	L	10 m	2014 onwards	JAXA

Dataset source for downloading, S. No. 1–4 https://bhoonidhi.nrsc.gov.in/ 5—https://scihub.copernicus.eu/ 6—https://earth.esa.int/ 7—https://tpm-ds.eo.esa.int/oads/access/collection/Radarsat-2 8—https://www.jaxa.jp/projects/sat/alos2/index_j.html

Table 1.4 List of DEM data products

S. No.	Product	Spatial resolution (m)	Developing agency	Accuracy
1	SRTM (shuttle radar topographic mission)	30, 90	NASA	RMSE ~10 m
2	CartoSAT	30	ISRO	Approx. 8 m
3	ASTER GDEM	30	NASA, METI	RMSE 2–3 m
4	ALOS PALSAR	12.5 and 30	JAXA and Japan resources observation system organization (JAROS)	RMSE of 4.6 m and 4.9 m
5	ESA—ACE-2	90, 270, 1 and 10	ESA	Extremely high

Dataset source for downloading, S. No. 1—https://dwtkns.com/srtm30m/ 2—https://search.earthdata.nasa.gov/search 3—https://search.earthdata.nasa.gov/search 4—https://search.asf.alaska.edu/#/ 5—https://sedac.ciesin.columbia.edu/data/set/dedc-ace-v2/data-download

DEMs are processed and analyzed in a GIS environment to derive numerous indices, which enable understanding various environmental processes (Gajbhiye et al. 2015; Rao et al. 2019). Additionally, DEMs are also extensively used in morphometric characterization of watersheds (Wang et al. 2010). Parameters like slope, aspect, contours, curvature are effectively derived from the DEMs (Gajbhiye et al. 2014).

Soil resources mapping is another major application under the gamut of land resources management powered by geospatial technologies. The satellite image interpretation and image classification techniques are employed to identify and map different land uses and vegetation types (Robertson and King 2011). Remote sensing and GIS are effectively used for crop mapping, inventory, and management (Wardlow et al. 2007). This domain features serve many purposes, such as crop acreage estimation, condition assessment, yield forecasting, cropping system analysis, and precision farming. Crop type mapping, acreage, and condition assessment are mainly carried out using image interpretation and digital image processing, wherein the spectral response of crop types is analyzed. The variations in the signatures of different wavelength bands help with discrimination among additional features (Foerster et al. 2012).

Additionally, image classification supported with ground truth information helps generate land use maps spatially. Medium and high-resolution time-series satellite data are beneficial for discriminating and monitoring various crops periodically. Assessment and monitoring of droughts are one of the most critical food security issues of concern globally (Swain et al. 2021). Significantly, agrarian countries are primarily dependent on their agricultural production, which is a significant economic driver. Climate change and water availability pose a substantial threat to the world's agricultural sector (Tarquis et al. 2010).

Geospatial technology has extensive scope for drought monitoring and assessment. Satellite remote sensing enables the monitoring of crops at various growth stages. Additionally, remote sensing data is used to compute spectral indices such as normalized difference vegetation index (NDVI) and normalized difference water index (NDWI), which provide essential inputs for drought assessment and monitoring (Pandey et al. 2010).

Soil erosion is a serious problem that poses a threat to agricultural land and infrastructure globally. One of the most popular methods used for soil erosion assessment and soil loss estimation is the Universal Soil Loss Equation (USLE) (Pandey et al. 2009b). This method involves the computation of rainfall erosivity factor (R), soil erodibility factor (K), topographic factor (LS), crop management factor (C), and conservation supporting practice factor (P). GIS provides a platform to prepare and analyze the spatial layers of each of these factors to estimate the average annual soil loss rate (Dabral et al. 2008). Subsequently, researchers across the globe have employed the Revised Universal Soil Loss Equation (RUSLE) to assess the soil loss status (Pandey et al. 2021b).

Land use/land cover data is a standard input used in sediment yield modeling (Pandey et al. 2007, 2009a, b). Satellite data is being very efficiently used in reservoir sedimentation assessment studies (Pandey et al. 2016a). The change in water spread area is assessed using satellite image processing at different times using indices like NDVI and NDWI, and deposition of sediments is evaluated. Consequently, loss in the live storage of reservoirs due to sedimentation is estimated (Jain et al. 2002).

1.4 Methodology Development in Water Resources Management

Water resources can be undoubtedly argued to be the most benefitted domain from the advent of geospatial technologies. These advanced technologies play a key role in conducting hydrological studies for rainfall estimation, soil moisture estimation and modeling, streamflow estimation, rainfall-runoff modeling, rainfall forecasting, water balance modeling, hydrological modeling, hydraulic and hydrodynamic modeling (Milewski et al. 2009; Singh et al. 2015, 2019; Himanshu et al. 2017, 2021; Jaiswal et al. 2020). Application of remote sensing and GIS in water resources also extends in identifying suitable sites for soil and water conservation structures, sediment yield modeling, reservoir sedimentation, watershed characterization, and management plan (Pandey et al. 2011; Pandey et al. 2016b; Dayal et al. 2021).

Satellite data for rainfall estimation has been one of the most popular applications, especially in the data-scarce regions or lack of adequate ground-based instrumentation for measuring rainfall. Numerous operational satellite-based rainfall products provide rainfall estimates at various spatial and temporal resolutions (Table 1.5). Numerous studies have been carried out to evaluate the performance of these data products before and after bias correction and were used in many hydrological studies (Behrangi et al. 2011; Himanshu et al. 2018).

Soil moisture estimation using remote sensing data is another rapidly evolving application in the water resources domain (Srivastava et al. 2009; Singh et al. 2015). Soil moisture is a crucial parameter used in various hydrological, land surface modeling, and meteorological studies (Albergel et al. 2013; Wanders et al. 2014). Interestingly, satellite-derived soil moisture products are also used to monitor and predict natural disaster events (Abelen et al. 2015). Additionally, these products also find application in climate variability studies (Loew et al. 2013).

The microwave band of the electromagnetic spectrum is exclusively used for soil moisture estimation. Table 1.6 presents a list of remote sensing-based soil moisture products available for use. Apart from the advantages of all-weather and day-night coverage, passive microwave sensors provide soil moisture estimation capability with good temporal resolution. In contrast, active microwave sensors provide finer, more satisfactory spatial resolutions (Singh et al. 2015).

The majority of the water resources management projects or research, especially at small and medium scales, are carried out at the watershed level (Sivapalan 2003). At this level, the analysis demands operational tools for simulating various processes

Table 1.5 List of satellite-based rainfall data products

S. No.	Product	Spatial resolution	Temporal resolution	Data available from	Developing agency
1	IMERG (early run, late run, and final run)	0.1	30 min, 1 day	2000–	NASA
2	GSMaP	0.1	1 h, 1 day, 1 month	2000–	JAXA
3	CHIRPS	0.05, 0.25	1 day, 5 day, 1 month	1981–	USAID, NASA, and NOAA
4	CMORPH	0.05, 0.25	30 min, 1 h, 1 day	1998–	National weather service climate prediction center (CPC)
5	PERSIANN	0.25	1 h, 1 day, 1 month, 1 year	1983–	Center for hydrometeorology and remote sensing (CHRS)
6	MSWEP	0.1	3 h	1979–2016	CMWF, NASA, and NOAA
7	SM2RAIN-ASCAT	0.1	1 day	2007–2020	–
8	SM2RAIN-CCI	0.25	1 day	1998–2015	–
9	GPM + SM2RAIN	0.25	1 day	2007–2018	–

Dataset source for downloading, S. No. 1—https://disc.gsfc.nasa.gov/dtasets/GPM_3IMERGHHE_06/summary?keywords=%22IMERG%20Early%22 2—ftp://hokusai.eorc.jaxa.jp/ 3—https://data.chc.ucsb.edu/products/CHIRPS-2.0/ 4—https://www.ncei.noaa.gov/data/cmorph-high-resolution-global-precipitation-estimates/access/ 5—https://chrsdata.eng.uci.edu/ 6—https://gwadi.org/multi-source-weighted-ensemble-precipitation-mswep 7–9 https://zenodo.org/record/3854817#.YC3BV3Uza5w

and interactions associated with water resources (Hingray et al. 2014). Therefore, watershed modeling becomes essential to understand and analyze the interactions between nature, climate, and human interventions. The distributed models employed for watershed modeling are data-intensive, and in data-scarce areas, geospatial technology plays a prominent role in addressing data gaps (Stisen et al. 2008). The topography data is one of the essential datasets in any watershed modeling assignment. The most widely available source of topographic data is open source DEMs. Advanced data capture techniques, such as Light Detection and Ranging (LiDAR), are being deployed to gather higher-accuracy terrain information. Table 1.7 lists a few LiDAR datasets exclusively available for the USA.

Climate data specifically, temperature, relative humidity, solar radiation, and wind speed, are the primary inputs required to analyze the hydrology of any watershed. All these parameters are being monitored repeatedly using various satellite sensors. Additionally, the National Center for Environmental Prediction (NCEP) provides

Table 1.6 List of satellite-based soil moisture data products

S. No.	Product	Spatial resolution	Temporal resolution	Data available from	Agency
1	ESA CCI soil moisture	0.25	1 day	1978–2020	European space agency's (ESA)
2	ASCAT soil moisture	12.5 km, 25 km	1–2 day	2007–	EUMETSAT H-SAF
3	SMAP L3	9 km, 36 km	1 day	2015–	NASA (NSIDC DAAC)
4	SMOS L2	15 km	1–3 days	2010–	ESA
5	SMOS CATDS soil moisture	25 km	1 day	2010–	ESA
6	SMOS BEC soil moisture	25 km	1 day	2010–	ESA
7	AMSR-2	50 km	1–3 days	2012–	Japan Aerospace Exploration Agency (JAXA)

Dataset source for downloading, S. No. 1—https://esa-soilmoisture-cci.org/data 2—https://hsaf.meteoam.it/Products/ProductsList?type=soil_moisture 3—https://smap.jpl.nasa.gov/data/ 4—http://www.catds.fr/Products/Available-products-from-CPDC 5—https://smos-diss.eo.esa.int/oads/access/ 6—http://bec.icm.csic.es/land-datasets/ 7—https://suzaku.eorc.jaxa.jp/GCOM_W/data/data_w_product-2.html

Table 1.7 List of LiDAR data products

S. No.	Product	Region	Accuracy
1	Open topography	USA	–
2	U.S. Interagency elevation inventory	USA	–
3	NOAA digital coast	USA	–
4	NEON open data portal	USA	–

Dataset source for downloading, S. No. 1–https://portal.opentopography.org/dataCatalog 2—https://coast.noaa.gov/digitalcoast/data/inventory.html 3—https://www.coast.noaa.gov/dataviewer/#/lidar/search/ 4—https://data.neonscience.org/data-products/explore

the Climate Forecast System Reanalysis (CFSR) data in a gridded format to be conveniently used for watershed modeling applications (Fadil and Bouchti 2020).

Satellite altimetry is a unique application of geospatial technology in water resources management. Altimetry provides a means to monitor the water level of rivers and reservoirs using satellite observations. Moreover, repeated observations allow evaluation of change in water storage in reservoirs and overcome the limitation of the spare in-situ network of gauge stations. The water levels from altimetry can also be used to calibrate and validate hydrological and hydrodynamic models (Thakur et al. 2021). Table 1.8 presents a list of some radar altimetry data products.

Table 1.8 List of basic characteristics of radar altimetry data products

S. no.	Mission	Equator track distance (km)	Band	Frequency (GHz)
1	GEOSAT	163	Ku	13.5
2	ERS-1/2	80	Ku	13.8
3	TOPEX/POSEIDON Jason-1/2/3 Sentinel-6	315	Ku/C	13.6/5.3
4	GFO	163	Ku	13.5
5	ENVISAT	163	Ku/S	13.6/3.2
6	CryoSat-2	7	Ku	13.6
7	HY-2A/2B	90	Ku/C	13.6/5.3
8	SARAL/ALTIKA	90	Ka	35
9	Sentinel -3A	104	Ku-band and C-bands	23.8
10	Sentinel- 3B	52	S band, X band	36.5

Dataset source for downloading, S. No. 1—https://science.nasa.gov/missions/geosat 2—https://aviso-data-center.cnes.fr/ 3—https://earth.esa.int/eogateway 4—https://aviso-data-center.cnes.fr/ 5—https://earth.esa.int/eogateway 6–8 https://aviso-data-center.cnes.fr/ 9,10—https://scihub.copernicus.eu

1.5 Conclusions

The application of geospatial technologies for land use-land cover analysis and mapping, digital terrain modeling, soil resource inventory, crop monitoring, and mapping, estimation of evapotranspiration, soil moisture measurement, morphometric parameter analysis, drought monitoring, soil erosion modeling, watershed management, agricultural land use planning, water quality assessment, reservoir sedimentation, flood mapping, monitoring reservoir/lake water levels, river discharge, and spatial modeling have revolutionized the assessment, mapping, and monitoring of land and water resources. The case studies provided in this book will serve as a valuable resource for scientists and researchers involved in planning and managing land and water resources sustainably.

This book offers an overview of geospatial technologies in land and water resources management. It consists of four main sections: land use land cover dynamics, agricultural water management, water resources assessment and modeling, and natural disasters. From leading institutions, such as the IITs and ISRO, the authors have shared their experiences and offered case studies to provide insights into the application of geospatial technologies for land and water resources management.

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