APPLICATION OF GIS (GEOGRAPHICAL INFORMATION SYSTEMS) AND REMOTE SENSING (RS)

INTRODUCTION

Now days, Remote Sensing and GIS became a key source to acquire the data. It emerged as a bloom for the acquiring the data of remote areas. GIS and Remote Sensing software is designed to store, retrieve, manage, display, and analyze all types of geographic and spatial data collected from satellite and airborne sensors. These tools allow users to efficiently handle large volumes of geospatial information and transform raw data into meaningful insights. By generating maps and graphical representations, the software supports spatial analysis and helps visualize geographic patterns and relationships. This is essential for a wide range of applications, including urban planning, environmental monitoring, agriculture, disaster management, and natural resource assessment. Ultimately, GIS and Remote Sensing software provides powerful capabilities for both the analysis and presentation of geographic information, supporting data-driven decision-making across various fields.

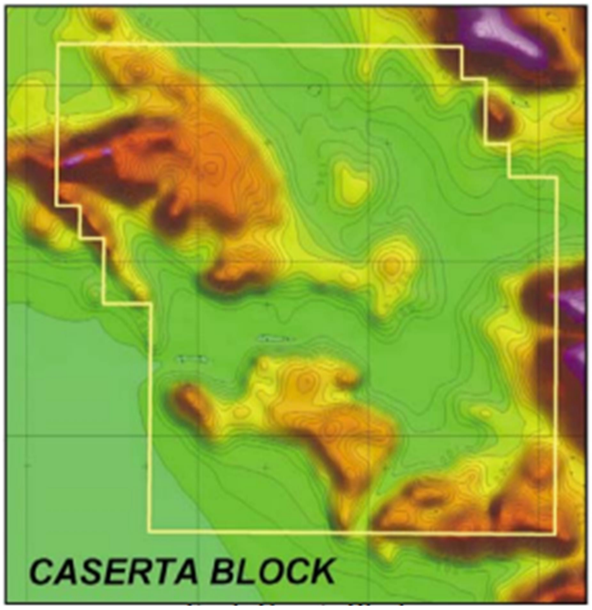
1. USE OF GIS AND RS IN GEOLOGICAL STUDY

a. Geological Mapping

Geological maps are essential tools in the mineral sector, offering a three-dimensional understanding of sediments, rocks, and soil units, along with their spatial distribution and age relationships. These maps are critical for mineral prospecting, geotechnical investigations, and geologic hazard assessment. For instance, they have been used to analyze the compositional features of granitic rocks.

With advancements in technology, a variety of remote sensing (RS) sensors—such as multispectral and hyperspectral sensors—are now widely used in geology and mining. These sensors, capturing data across numerous spectral bands, are crucial for mapping surface features through image classification.

Geological maps can also be generated using texture analysis of satellite imagery. Enhancing the visual interpretation of these images is key to improving the accuracy of geological mapping.



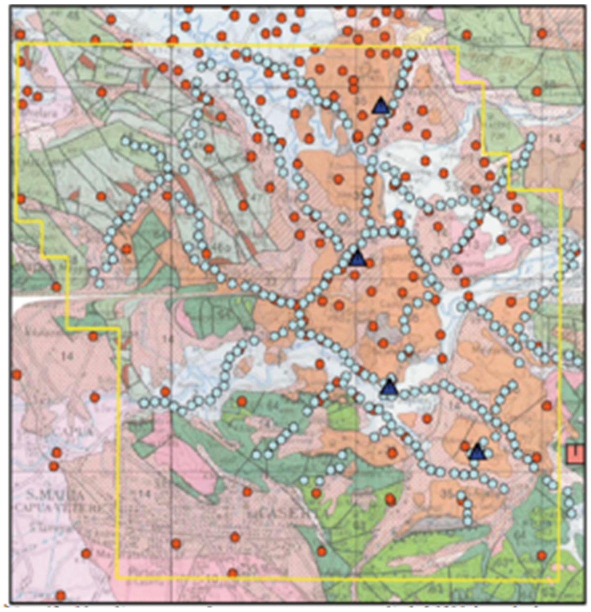


Fig 1: Caserta Block

Fig2. Surface geological map useful for GIS background

Source: AL-Shehab, et.al.. (2007).

Above figure demonstrates the utility of GIS's data-layering capability. In this figure, a surface geologic map has been used as the base layer and overlaid with other relevant datasets. This geologic backdrop ensures that all magnetotelluric (MT) survey sites are positioned on outcropping geologic units or features of interest. The four MT sites from the initial noise-test program are shown as dark blue triangles in Figure.

b. Structural Geology

Structural geology is fundamental in exploring mineral reserves and assessing geo-hazards such as landslides and volcanic activity. It focuses on identifying and analyzing geological structures—including faults, folds, and lineaments—which are essential in geological mapping and understanding subsurface rock geometry.

In recent years, structural geology has greatly benefited from remote sensing technologies. RS data provides valuable insights into the spatial distribution of structural features, significantly improving mapping precision and efficiency.

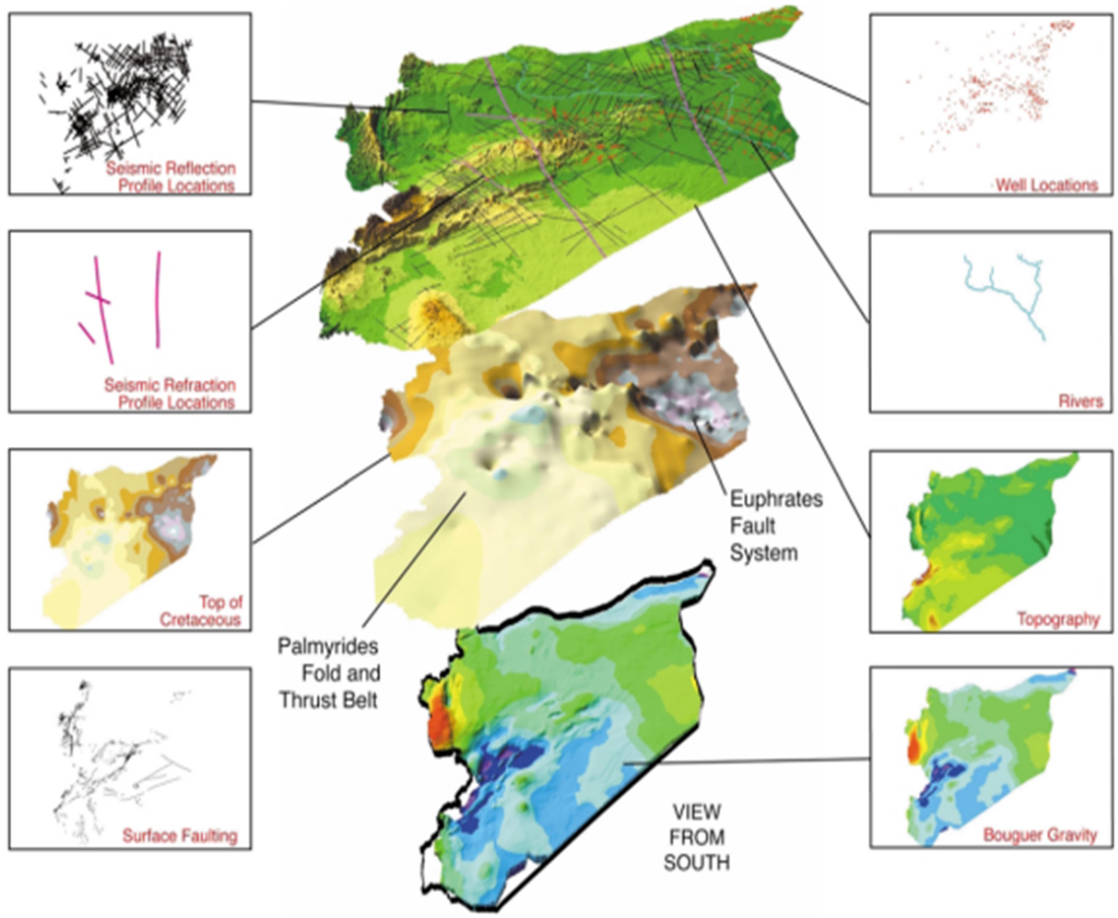


Fig 3. Composite image of selected layers imported into GIS for Sirya (Brew et.al., 2000)

Source: AL-Shehab, et.al.. (2007).

c. Lithological Classification

Detailed analysis of rock lithology and their relationships with outcrops enhances geological understanding. Lithological maps illustrate the spatial distribution of different rock types across the Earth's surface. Traditionally, lithological classification relied on ground-based surveys, which are time-consuming and labor-intensive.

Remote sensing offers a more efficient alternative. By analyzing color variations, weathering patterns, drainage features, and bedding thickness, RS can effectively classify rock types remotely, minimizing the need for extensive fieldwork while maintaining high accuracy.

d. Mineral Exploration and Remote Sensing

Mineral exploration seeks to define the size and value of deposits using advanced methods beyond basic prospecting. Traditional approaches—such as geochemistry, geophysics, and photogrammetry—require extensive data integration, often across multiple exploration phases.

Remote sensing (RS) and Geographic Information Systems (GIS) provide efficient solutions. Satellite imagery enables the extraction of critical geological information, including lithology, alteration zones, and structural features. Hyper spectral data enhances mineral discrimination, while both multispectral and hyper spectral sensors in the LWIR region are effective for mineral mapping.

ASTER's SWIR bands support surface mineralogy mapping, although limited spatial resolution and vegetation cover can affect accuracy. Despite this, VNIR bands remain useful for identifying iron oxide and hydroxide minerals in exposed regions.

GIS further supports mineral assessment by enabling spatial analysis, 3D visualization, and integration with geophysical and geochemical datasets—enhancing mineral targeting and resource evaluation.

e. Hydrothermal Alteration Mapping

Hydrothermal alteration results from chemical changes in host rocks due to interactions with ore-forming fluids along fractures and grain boundaries. Satellite imagery helps identify these alteration zones, which often appear as spectral anomalies in exposed terrains.

While alteration zones may signal mineralization, not all are economically viable, and not all deposits exhibit visible alteration. Therefore, remote sensing should be used alongside other exploration techniques to improve targeting accuracy.

f. Mineral Extraction and Monitoring

In developed countries, mineral extraction is supported by sophisticated technologies. Conversely, many underdeveloped nations still rely on inefficient methods, leading to underexploited mineral resources. For example, numerous mineral deposits in Nigeria remain untapped.

Mining operations involve large-scale excavation of earth materials. Monitoring these activities traditionally requires GPS and automated total stations to measure terrain changes—methods that are accurate but labor-intensive and limited in scope.

Remote sensing provides a more scalable solution through the generation of large-area Digital Elevation Models (DEMs), which are valuable for assessing terrain relief, environmental impacts, and hydrological changes in open-pit mining environments.

g. Environmental Impact of Mining

Mining is often associated with adverse environmental and health impacts at various scales. The extraction and processing of minerals—via open-pit or underground methods—can lead to deforestation, soil degradation, water pollution, and biodiversity loss. In many regions, these impacts threaten critical life-support systems, making environmental management a priority in mining activities.

2. DISASTER MONITORING USING REMOTE SENSING AND GIS

a. Earthquake Detection

Earthquakes are among the most devastating natural disasters, causing significant loss of life and property. In recent years, remote sensing (RS) and Geographic Information Systems (GIS) have become essential tools in earthquake monitoring and prediction. Remote sensors can detect early signs of seismic activity, offering valuable insights into potentially affected areas. Techniques such as optical imagery**,** Synthetic Aperture Radar (SAR)**,** and LiDAR provide complementary information for analyzing earthquake-prone zones. These tools improve understanding of earthquake behavior, enhance preparedness strategies, and support early warning systems.

b. Relief Operations

In disaster scenarios, timely and accurate information is crucial for effective response. GIS and RS technologies**,** including satellite imagery and UAVs, are now widely used for emergency logistics, staff safety, transportation planning, and establishing telecommunications or refugee camps. They enable relief agencies to assess ground conditions—even in inaccessible areas—supporting coordination and decision-making in humanitarian operations.

c. Wildfire Monitoring and Management

Wildfires are frequent and destructive natural disasters that threaten human health, ecosystems, and infrastructure while contributing to carbon emissions. Remote sensing and GIS are extensively used to detect, monitor, and model wildfires. High-resolution satellites equipped with visible, near-infrared (NIR), and shortwave infrared (SWIR) sensors can detect variations in vegetation health and burn severity. Healthy vegetation reflects strongly in the NIR spectrum, while burned areas emit more in the visible and SWIR bands. This spectral data supports forest management, risk mapping, and post-fire assessments.

d. Flood Management

While natural disasters like floods cannot be fully prevented, their impact can be minimized through early warning and planning. Remote sensing imagery**,** combined with GIS, plays a vital role in flood risk assessment, monitoring, and disaster management. Satellite data offers real-time, multi-temporal, and wide-area coverage, essential for both pre- and post-disaster activities.

Flood management involves three key phases:

- **Preparedness**: GIS supports evacuation planning, emergency center design, and disaster warning system development by integrating satellite data with other sources.
- **Response**: During floods, GIS combined with GPS aids in search and rescue operations, especially in inaccessible or devastated areas.

- **Recovery**: Post-disaster, GIS helps evaluate reconstruction sites and analyze damage and demographic changes for effective rehabilitation planning.

e. Drought Prediction and Monitoring

Drought is a complex phenomenon caused by prolonged precipitation deficits, often worsened by climate change and rising global temperatures. Satellite-based remote sensing can detect temperature anomalies by measuring reflected radiation from the Earth's surface and comparing it with historical data.

Drought is categorized into four types:

- **Meteorological drought**: Reduced rainfall over a period.
- **Agricultural drought**: Impacts on crops due to soil moisture deficits and evapotranspiration changes.
- **Hydrological drought**: Low water levels in rivers, lakes, and reservoirs.
- **Socioeconomic drought**: Effects on the availability and cost of water-related economic goods.

By tracking temperature patterns, precipitation deficits, and vegetation stress, RS tools can issue early warnings to vulnerable regions, enabling proactive drought mitigation efforts.

3. HYDROLOGICAL APPLICATIONS OF REMOTE SENSING AND GIS

a. Runoff Modeling from Snow-Covered Areas

Snow depth assessment is performed by analyzing the spectral signatures of snow-covered surfaces. Radiance values from satellite channels—particularly Channel 1—are categorized into zones based on pixel intensity variations. These zones (maximum, medium, and minimum snow coverage) are validated against ground truth data.

Remote sensing in visible (Band 3) and near-infrared (Band 4) wavelengths can differentiate between dry and wet snow, as their reflectance depends on snow grain size, depth, density, impurity content, and liquid water presence. For instance, soot concentrations as low as 0.1 ppm can significantly reduce snow reflectance. Reflectance in the near-infrared range decreases notably as snow begins to melt.

b. Flood Mapping

High-resolution remote sensing imagery enables large-scale flood extent mapping, including main rivers and tributaries. Flood stages derived from imagery are compared with field measurements or hydrodynamic models (e.g., HEC-2).

The process involves:

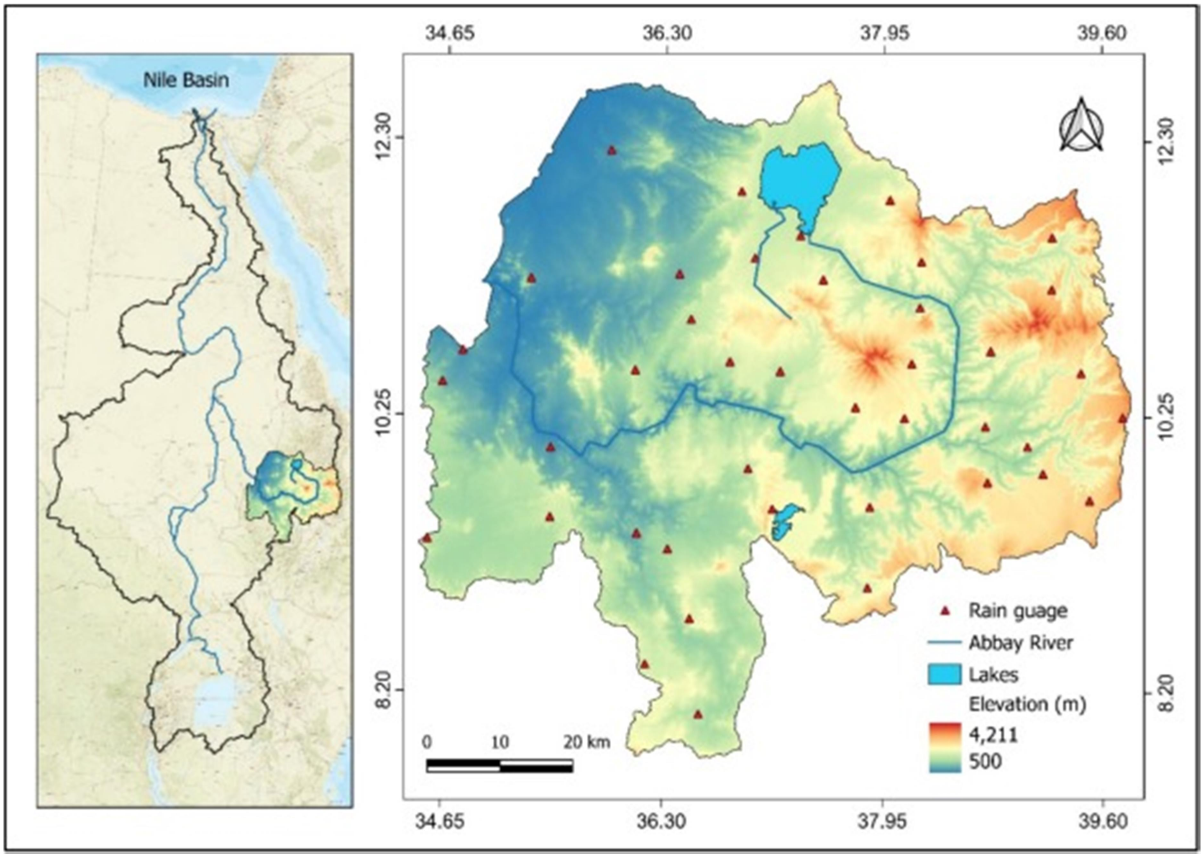
1. Analyzing satellite images in GIS
2. Delineating riverbanks over time
3. Measuring river width across multiple transects Discharge is estimated using topographic slope (generated in GIS) and Manning's equation**.** Ground-based cross-sectional data improve the hydrodynamic model calibration.

After correcting for topographic inaccuracies and geometric distortions, GIS-based flood mapping can achieve up to 80% accuracy when compared to actual flood profiles.

c. Erosion and Accretion in Riverbanks and Coastal Zones

Remote sensing effectively detects erosion and accretion trends**,** especially in inaccessible or rapidly changing regions. Using high-resolution imagery, the accuracy of shoreline erosion or accretion predictions can exceed 80% compared to field measurements.

By analyzing ground cover, elevation, slope, and soil type, GIS models can predict areas susceptible to soil erosion and sedimentation. This information supports better planning and environmental management in both riverine and coastal areas.



Source: Mekonnen, Y. G.,et.al. (2025)

Fig 4: Drainage pattern of Nile Rive

d. Groundwater Zone Identification

Groundwater potential zones are identified by integrating land use, land cover, soil, and geological maps—typically scaled between 1:30,000 and 1:100,000. Remote sensing and traditional methods are combined within GIS to correlate surface features with groundwater availability.

Maps of drainage density**,** slope, and soil type are derived from topographic data and overlaid to classify regions into categories ranging from high to low groundwater potential. Predictions are validated using field well yield data and show an accuracy range of 65% to 90%**,** depending on the region and data quality.

4. APPLICATION OF REMOTE SENSING AND GIS IN ATMOSPHERIC DISTURBANCE

a. Wind and Storm Speed Assessment:

Using spatial interpolation techniques like Inverse Distance Weighted (IDW) interpolation, GIS can transform scattered point data into continuous raster surfaces. This enables the creation of contour maps depicting wind or storm speed patterns over an area. The resulting raster or vector contour maps provide clear visualizations for analysis and decision-making.

b. Wind Speed Mapping with TIN and Linear Models:

The Triangular Irregular Network (TIN) method uses vector data structures to create surfaces from spatial points connected by triangles. TIN models can produce continuous raster surfaces representing wind speeds. Additionally, linear regression models based on spatial relationships between variables can be developed to predict wind speed distributions.

c. Lightning Strike Density Mapping:

GIS can map average annual lightning strike density using coarse resolution raster data, allowing for the visualization of lightning hotspots and risk assessment over large regions.

d. Disaster Monitoring and Response:

GIS supports the tracking of tornado outbreaks and tsunami arrivals by integrating spatial and temporal data for rapid situational awareness. Post-disaster, geospatial tools assist in accelerating power restoration and resource deployment.

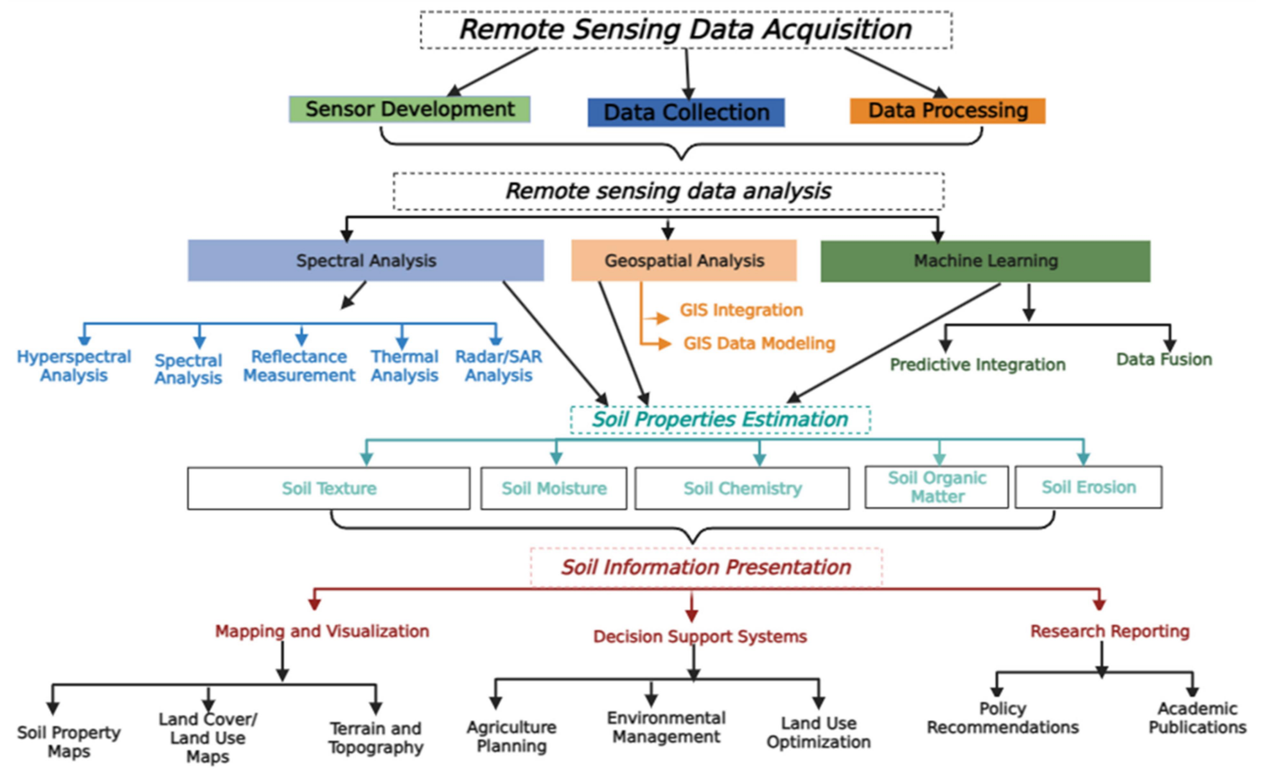
5. SOIL RESOURCE MANAGEMENT

Integrated remote sensing and GIS methodologies offer considerable potential for advancing soil and land mapping through three key components:

1. **Soil Type Classification and Mapping**: Remote sensing data, when combined with in situ (on-site) sampling, enables accurate classification and mapping of soil types.

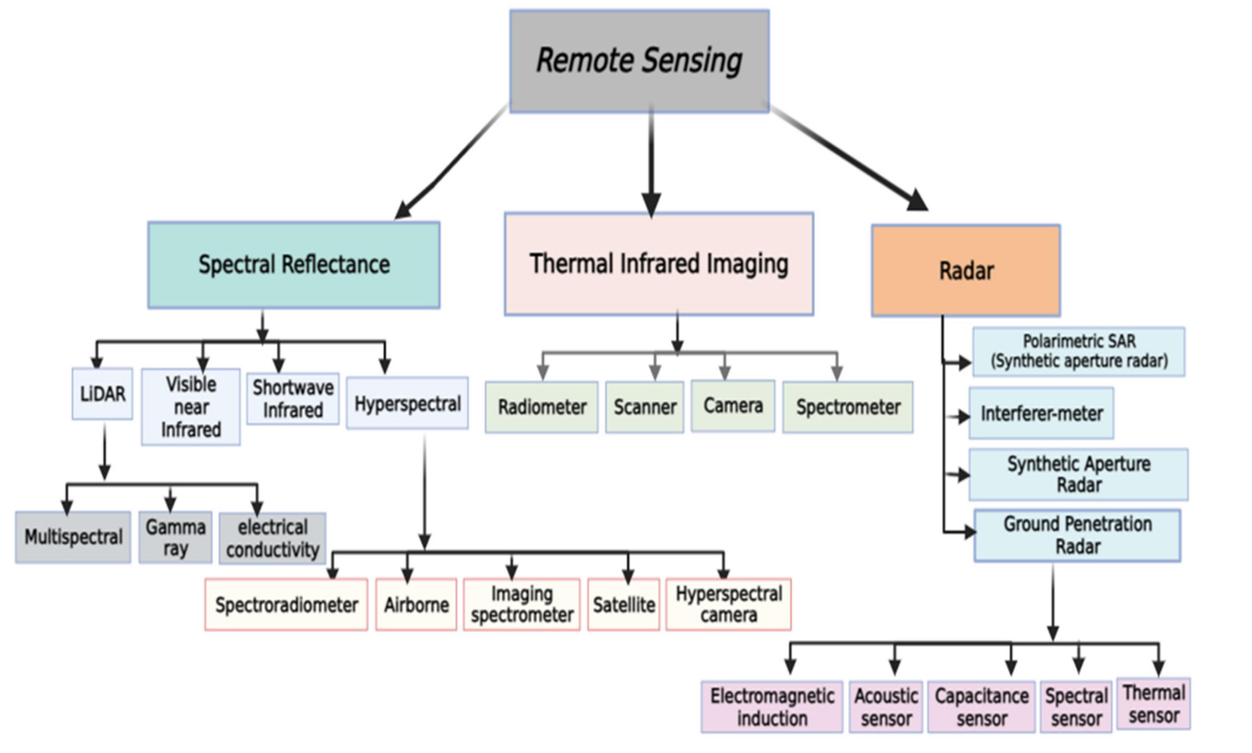
2. **Estimation of Soil Properties**: The spectral signatures captured in remote sensing imagery can be used to estimate both qualitative and quantitative soil properties through GIS-based empirical modeling techniques.
3. **Spatial Interpolation**: Even in cases of limited or sparsely sampled field data, remote sensing supports effective spatial interpolation of soil properties, enhancing the reliability of soil information across broader regions.

Remote sensing (RS) techniques have advanced soil measurement using satellite, airborne, and ground-based methods to assess erosion, soil moisture, and nutrient levels. RS also aids in detecting contamination and evaluating fertility.



Source: Abdulraheem, M. I., et.al (2023).

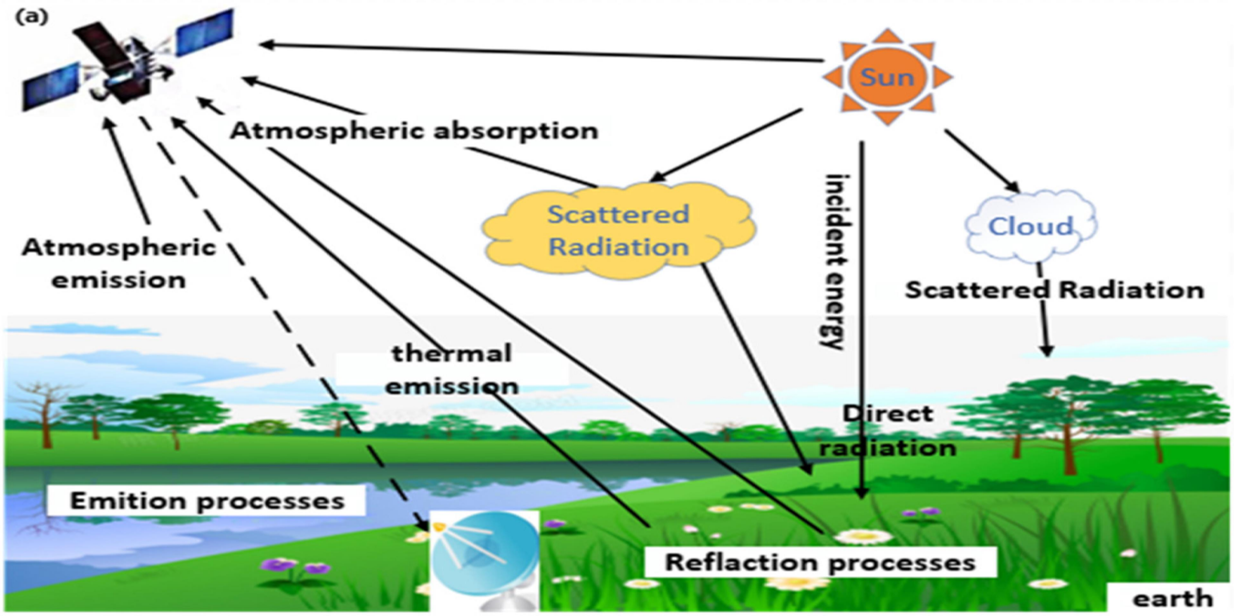
Fig 5: Remote Sensing Data Acquisition for Soil Resource Management



Source: Abdulraheem, M. I., et.al (2023).

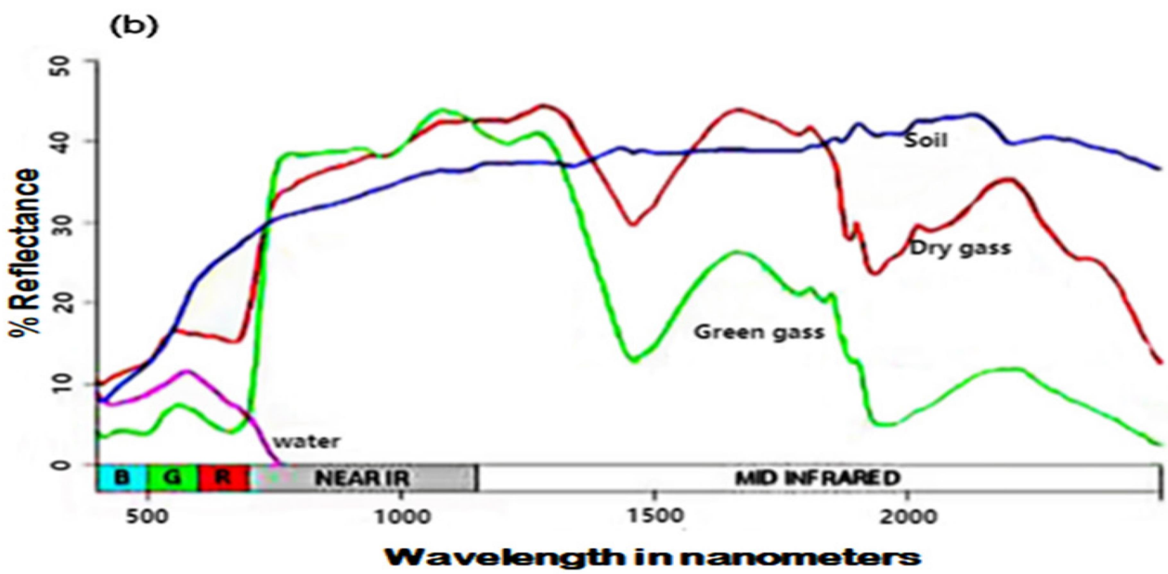
Fig 6: Remote Sensing for Source Resource Management

Remote sensing (RS) is especially valuable in regions with limited soil sampling or challenging terrain. It provides multi-scale data—from field to watershed levels—supporting detailed analysis of soil variability. High-resolution sensors can map key soil parameters such as organic carbon and moisture content. Hyperspectral RS is particularly effective for mapping soil properties and detecting erosion. RS also aids in identifying erosion-prone areas, supporting soil conservation and land management. In given Figure for UAV-based RS, a nadir view corresponds to a view zenith angle (VZA) of 0°. Positive VZA values indicate the sensor is oriented toward the sun (leading solar plane), while negative values point away from it.



Source: Abdulraheem, M. I., et.al (2023).

Fig 7 : Remote Sensing Process



Source : Abdulraheem, M. I., et.al (2023).

Fig 8 : Reflectance properties of different entities

In the upper Figure, color bars beneath the UAV represent four types of remotely sensed data, each guiding users to specific data products shown as circles on the right, grouped by estimated delivery time. Some outputs, derived from image indices, require minimal calibration. White circles on the left indicate in-field data collection sites. After spectral retrieval, further analysis can be performed. Algorithms in the lower right rely on GIS inputs for geolocation and image registration, assessing the feasibility of real-time geographic alignment. The schematic illustrates the data flow: the satellite network connects with the UAV, which gathers field data (soil and air), relays it to a base station for internet-based processing and analysis, and then returns actionable insights to the UAV for soil monitoring applications.

6. APPLICATION OF GIS AND RS IN FOREST AND ECOLOGY

Remote sensing (RS) plays a vital role in the monitoring and management of forest ecosystems and natural resources. One major application is in assessing biodiversity and species composition using environmental proxies such as vegetation types and canopy structure. For example, Turner et al. (2003) demonstrated how high-resolution imagery could be used to model species distributions, while Defries et al. (2000) employed AVHRR data to map global tree cover and infer traits like leaf type and longevity. RS also supports forest health monitoring, particularly in detecting stress caused by diseases and insect infestations. Everitt et al. (1999) used color-infrared imagery to identify oak wilt disease, while Wulder et al. (2006) analyzed the impact of the Mountain Pine Beetle outbreak, highlighting both challenges and opportunities of RS in forest health detection.

In forest resource monitoring, RS helps determine forest age, structure, and species richness. Cohen et al. (1995) successfully mapped old-growth forests with high accuracy, and Hernandez-Stefanoni et al. (2011) improved tree species richness maps by integrating regression kriging with RS data. RS is also widely used in forest-wildlife management, enabling habitat mapping and conservation planning. Stoms and Estes (1993) proposed a framework for biodiversity monitoring, and Franklin et al. (2001) used RS data to map grizzly bear habitats through land cover classification.

Forest fire monitoring is another critical area where RS proves invaluable. Giglio et al. (2003) developed a fire detection algorithm that minimized false alarms, and Lentile et al. (2006) reviewed RS methods for assessing fire behavior and ecological impacts. Urban forestry also benefits from RS, as shown by Jensen et al. (2003), who found that areas with higher Leaf Area Index (LAI) experienced lower household energy consumption. Zhang et al. (2007) mapped urban forest distribution in Jinan City to assess ecological importance.

In watershed management, the integration of RS and GIS is used for planning and impact assessment. A notable example is the Adarsha Watershed in Andhra Pradesh, India, where NDVI and IRS-1C/-1D LISS-III data were used to monitor vegetation improvements and identify soil erosion as a key degradation factor. Beyond these, RS supports broader applications such as monitoring phenology, ecosystem services, habitat conditions, climate prediction, coastal management, biogeochemical cycles, natural hazard mapping, and sustainable development. These capabilities make RS an indispensable tool in the effective and informed management of natural resources.

7. APPLICATION OF GIS AND RS IN URBAN AND REGIONAL PLANNING

a. Land Use / Land Cover Mapping

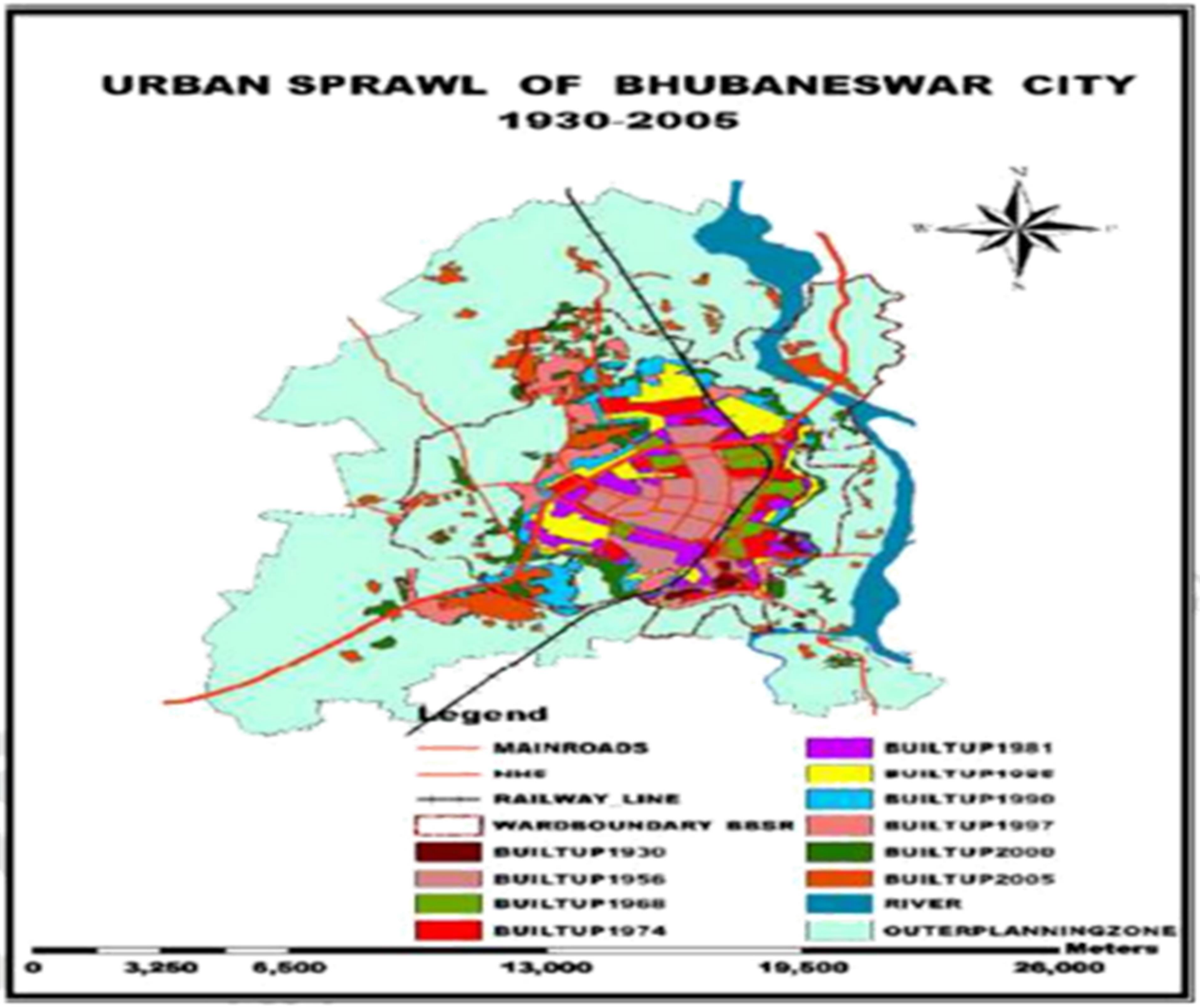
Land is one of the most valuable natural resources, and its proper use is essential for sustainable development. The term land use refers to the way humans utilize land, such as for residential, industrial, or agricultural purposes, whereas land cover denotes the physical and biological material present on the earth’s surface, including vegetation, water bodies, and man-made structures. Urban land use and land cover (LU/LC) studies are critical in a wide range of applications such as site selection, population estimation, zoning, taxation, and policy development. Rapid urban population growth and urban sprawl often lead to unplanned and sometimes improper land use, converting productive land into wasteland. As a result, mapping and monitoring LU/LC have become a major area of focus for urban planners, scientists, and geographers worldwide. Timely and accurate spatial data is essential for informed decision-making, effective planning, and policy formulation. Remote sensing and Geographic Information System (GIS) technologies play a pivotal role in this domain, offering cost-effective and scalable solutions for both macro- and micro-level planning. By integrating multiple datasets into GIS, planners can prepare homogeneous land development units, which help in identifying critical problem areas and recommending appropriate conservation measures. One of the commonly used formats for image-based LU/LC extraction is the False Color Composite (FCC) image, from which information is obtained through techniques such as image interpretation, spectral analysis, and data integration. According to Prasad and Sinha (2002), visual image interpretation based on image characteristics is crucial for accurate mapping. A notable example is the use of LISS III imagery, as seen in case studies like Jaipur district in Rajasthan and Ahmedabad city in Gujarat, where urban features are interpreted to classify different land use categories. LU/LC classification must follow certain guidelines: it should be applicable over large urban and peri-urban areas, compatible with temporal remote sensing data, and ensure a minimum accuracy of 85% depending on the classification level. It should also align with standard planning terminologies, be easy to understand and flexible for aggregation, and ensure mutually exclusive classes based on quantitative criteria.

b. Urban Land Use Suitability Analysis

Urban land use suitability analysis is a fundamental aspect of spatial planning, involving the assessment of land based on multiple criteria to determine its optimal use. One of the primary challenges in this process is assigning appropriate weights to each parameter, as not all land characteristics hold equal significance. Addressing this issue requires expert judgment supported by systematic methodologies. A widely accepted approach is Saaty's Analytic Hierarchy Process (AHP), introduced in 1980, which involves creating a pairwise comparison matrix to assess the relative importance of each parameter. The matrix, based on expert opinions—often from urban planning professionals—produces an "importance matrix" using a defined scale of intensities to quantify how strongly one element dominates another. Once established, the matrix can be analyzed using mathematical methods like the Eigen Vector method and the Least Square method. The Eigen Vector method calculates priority weights that reflect the relative importance of each parameter, while the Least Square method minimizes the overall error and reduces potential bias in the judgment process. These quantitative techniques ensure that the final land suitability assessment is scientifically robust and less influenced by subjective bias. Ultimately, this multi-criteria decision-making process helps urban planners in identifying suitable areas for various urban activities—such as housing, infrastructure development, and green space planning—ensuring sustainable land management and future urban resilience.

c. Urban Growth / Urban Sprawl Analysis

Rapid population growth and unplanned development have led to uncontrolled urbanization, often lacking essential infrastructure. Urban sprawl refers to the dispersed, low-density expansion of cities, typically spreading radially from urban cores or linearly along highways (Theobald, 2001). This form of growth directly impacts land use and land cover, placing pressure on environmental and natural resources. Mapping urban sprawl helps visualize growth patterns, identify at-risk areas, and predict future development trends. Remote sensing and GIS, when combined with collateral data, offer cost-effective tools for analyzing sprawl across different spatial and temporal scales, supporting informed infrastructure planning (Turkstra, 1996; Barnes et al., 2001). However, the responsibility for managing sprawl lies primarily with local authorities, whose capacity and willingness to address the issue vary. A case study by Monalisha Mishra (2011) on Bhubaneswar city from 1930 to 2005 illustrates significant phases of urban expansion. Initially (1930–1956), urban growth exceeded population growth due to infrastructure development, though land was not allocated for diverse urban functions. From 1956–1968, population growth surpassed spatial growth due to residential development for government employees. Between 1968–1981, both grew proportionally, but after 1981, spatial expansion continued even as population growth slowed. Notably, from 1985–1990, peripheral areas (7.5–10.5 km from the city center) witnessed major expansion, and between 1997–2005, significant transformation of agricultural and open spaces into built-up areas occurred, emphasizing the need for proactive urban planning.



Source: Mishra, M., et.al.(2011).

Fig 9: Urban Sprawl From 1930 to 2005 of Bhubaneswar

d. Urban Infrastructure and Utility Mapping

Urban infrastructure includes essential services such as water supply, education, transportation, power, recreation, and waste management. Effective planning and implementation require detailed spatial and demographic data. Remote sensing provides timely and reliable information, while high-resolution aerial photography (scales like 1:10,000 or larger) offers precise mapping of infrastructure. Panchromatic data from satellites such as SPOT and IRS 1C/1D enhances mapping of transport networks, effluent zones, and urban greenery. Case studies in Bhubaneswar and Kanpur have demonstrated the use of aerial photography for population assessment and site identification. Additionally, studies in Delhi using SPOT MS and PLA data showed the relationship between land use and transport systems, supporting infrastructure planning in fast-growing urban areas.

e. Urban Hydrology

Urban areas in India face major hydrological challenges including water scarcity, pollution, flood control, and inadequate stormwater drainage. Although rainfall-runoff cannot be directly measured using remote sensing, it provides critical input data such as impervious surface area and floodplain boundaries. Materials like asphalt and concrete increase surface runoff, which can be mapped using high-resolution imagery and spectral analysis (Ridd, 1995). Remote sensing aids in identifying impervious surfaces, monitoring water quality, drainage, slope, and land use. Studies in cities like Madras, Hyderabad, and Jhansi have shown the effectiveness of remote sensing in urban water resource management, including floodplain delineation using multispectral imagery combined with digital terrain models (DTM), LIDAR, or IFSAR.

f. Effective Traffic Management

Transportation is a vital component of urban infrastructure, enabling connectivity and economic activity. Remote sensing technologies are widely used for mapping transport networks, assessing road conditions, analyzing congestion at key locations, and conducting parking studies. High-resolution data, such as IKONOS imagery, can detect roads as narrow as 3 meters. The NCRST initiative, backed by NASA and the U.S. Department of Transportation, exemplified large-scale use of remote sensing for traffic management. In Jaipur, a study using IRS 1C LISS III and PAN data revealed that 94.3% of the population was affected by air pollution and 34.8% by noise, primarily due to traffic. Such analyses support strategies for pollution mitigation, road widening, mass transit planning, and emission control.

g. Solid Waste Management

Solid waste management poses a critical challenge due to growing populations and the limited capacity of local governments. Effective management requires separation of waste streams and strategic site selection for disposal. Remote sensing and GIS technologies enable identification of suitable landfill sites, monitoring of existing sites, and environmental impact assessments. Reclamation of abandoned landfills and isolation of waste from populated areas are essential for sustainable management. A GIS-based approach by Chalkias (2011) optimized municipal waste collection systems by reducing time, travel distance, labor, and environmental costs, demonstrating the value of geospatial technology in waste management planning.

h. Cadastral Mapping

Cadastral mapping involves the systematic recording of land ownership, boundaries, and property units, serving as a foundational register for land administration. While critical for economic development and environmental management, traditional cadastral surveys are often slow and costly, especially in developing countries. Aerial photography significantly enhances accuracy and cost-effectiveness compared to manual surveys, while remote sensing offers faster and more economical mapping solutions. High-resolution satellite imagery (sub-meter resolution) enables accurate cadastral mapping at scales of 1:4,000 or higher, supporting the geo-referencing of legacy maps and precise ground feature identification. The digitization of cadastral maps within GIS environments has modernized land administration by integrating spatial data for efficient land transfer and management. As such, remote sensing and GIS technologies are becoming essential tools in the modernization and maintenance of cadastral systems.

8. USE OF GIS AND RS IN CROP RESOURCE MANAGEMENT

a. Monitoring Vegetation Cover, Nutrient, and Water Status Using GIS and Remote Sensing

The combined use of Remote Sensing (RS) and Geographic Information Systems (GIS) provides a powerful approach for monitoring vegetation cover, as well as assessing nutrient and water status in agricultural fields and natural ecosystems. RS collects spatially extensive data through sensors mounted on satellites, aircraft, or drones, capturing images that reveal key information about land surface characteristics, including vegetation health and distribution.

RS-based indices, such as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI), quantify vegetation vigor and water content by analyzing the way plants reflect or absorb light in different spectral bands. NDVI serves as a proxy for chlorophyll content and nutrient status by comparing near-infrared and visible light reflectance, while NDWI detects water stress by exploiting the differences in radiation absorption between water and vegetation.

GIS complements RS by integrating these remote sensing datasets with other spatial information, such as climate data, soil properties, and topographic features. This integration allows for the creation of detailed maps and predictive models that visualize vegetation cover changes, identify areas of nutrient deficiency, and pinpoint zones experiencing water stress. GIS-based tools facilitate the analysis, visualization, and interpretation of these multi-layered datasets, making it possible to monitor environmental conditions over time and across landscapes.

Together, GIS and RS enable precision agriculture practices by guiding targeted fertilizer application and irrigation scheduling, optimizing resource use, and improving crop yields. However, the effectiveness of this integrated approach depends on the availability of accurate ground-truth data for validation and high-quality RS data free from atmospheric interference or sensor noise. Despite these challenges, advancements in RS and GIS technologies continue to enhance the accuracy, efficiency, and applicability of vegetation, nutrient, and water monitoring, supporting sustainable land and resource management.

b. Crop Evapotranspiration (ET)

Crop ET represents the total water needed by crops, including soil evaporation and plant transpiration. Accurate ET estimation is vital for irrigation and water resource management. RS and GIS enable effective ET estimation by capturing spatial and temporal data on temperature, vegetation cover, and soil moisture. Two common RS-GIS methods for ET estimation are:

- **Energy balance approach:** Estimates net radiation and heat fluxes to calculate ET; requires detailed soil and vegetation data and is complex.
- **Vegetation index approach:** Uses indices like NDVI to estimate transpiration based on vegetation health; simpler and quicker.

c. Crop Yield and Production Forecasting

RS and GIS, combined with crop growth models, facilitate forecasting by integrating satellite imagery, soil maps, and climate data. RS provides timely, large-scale data on land cover and crop conditions, while GIS organizes and analyzes this data spatially. This integration helps predict yields, identify high-potential areas, and guide management practices like irrigation and fertilization.

d. Precision Agriculture

Precision agriculture uses RS and GIS technologies to optimize farming inputs spatially and temporally. Key applications include:

- Monitoring crop health and detecting stress via high-resolution imagery.
- Creating planting maps based on soil and climate data.
- Managing irrigation efficiently through soil moisture and water stress mapping.
- Estimating yields by analyzing biomass and chlorophyll.
- Mapping soils for precise fertilizer application.
- Early detection and mapping of pests and diseases.

9. USE OF GIS AND RS IN COASTAL ZONE MANAGEMENT

Coastal landmasses are environmentally sensitive zones that face increasing threats due to climate change, particularly from rising sea levels and extreme weather events. Effective management of these regions is essential. Utilizing GIS data and GPS-based tools, government agencies, NGOs, and environmental managers can monitor the physio-chemical characteristics of coastal areas and classify zones based on risk and activity levels to implement targeted management strategies.

For example, coastal regions along India's east coast, such as Odisha and West Bengal, have been severely impacted by cyclonic storms like Cyclone Amphan (2020) and Cyclone Yaas (2021), which caused extensive damage to homes, wildlife habitats, and coastal ecosystems. While cyclones themselves cannot yet be controlled, GIS technology plays a crucial role in disaster response, land rehabilitation, and long-term coastal planning—ultimately helping to protect lives and restore environmental balance.

Freshwater and marine ecosystems near coastal zones—such as deltas, lagoons, and estuaries—are vital habitats for diverse species. However, they face growing threats due to industrial discharge, agricultural runoff, plastic pollution, and climate change-related events like cyclones and rising sea levels.
GIS (Geographic Information Systems) and RS (Remote Sensing) have become essential tools in Coastal Zone Management (CZM) and Integrated CZM (ICZM). These technologies help classify physio-chemical properties, monitor human activities, assess environmental impacts, and support strategic conservation efforts.

Key applications include:

- **Mangrove Management**: Using GIS and RS (e.g., LISS III, PAN), degraded mangrove areas are identified, mapped, and restored. This is crucial after storm damage or deforestation events.
- **Urbanization Monitoring**: GIS helps assess human expansion near coasts, guiding legal action under CRZ (Coastal Regulation Zone) laws.
- **Plastic Pollution Mapping**: 2D and 3D GIS modeling enables the identification of plastic-affected areas for cleanup and regulation.
- **International Boundary Management**: GIS cartography aids in resolving coastal disputes, as seen in the Sundarbans (India-Bangladesh).

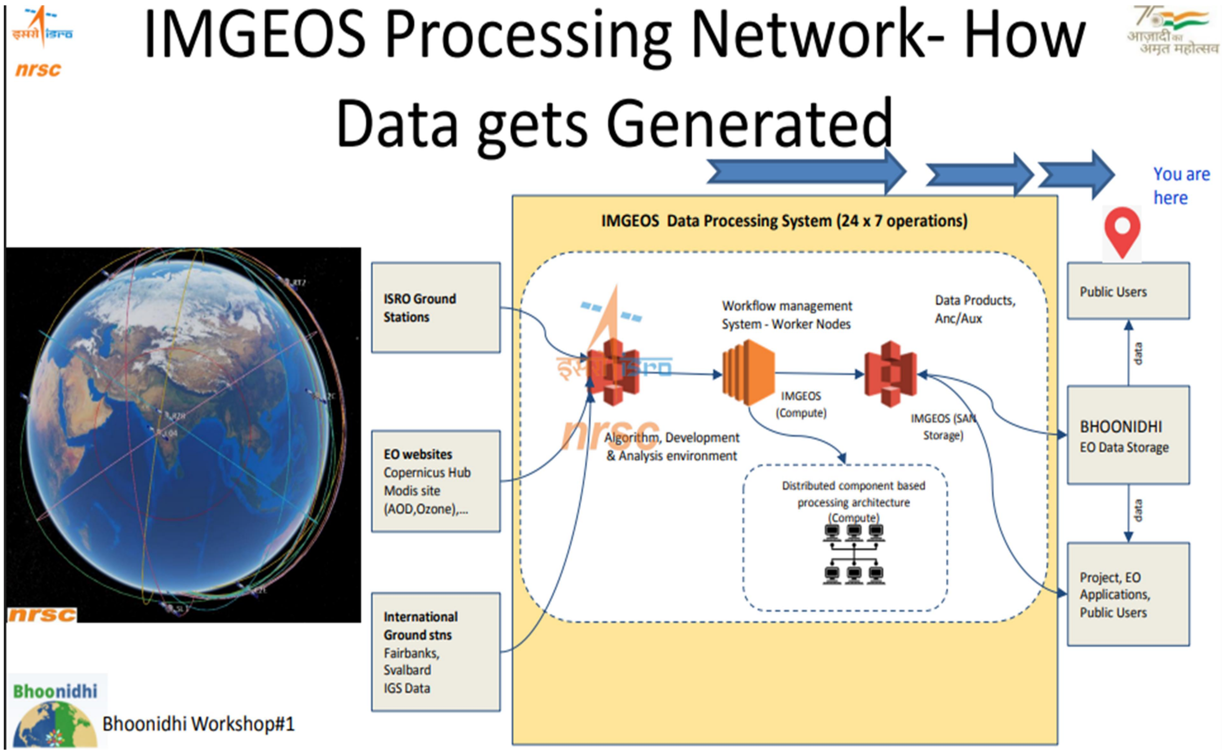
- **Marine Water Quality Monitoring**: Satellites like IRS-P4 OCM detect suspended sediments, oil spills, and algal blooms, which degrade marine ecosystems.
- **CRZ Enforcement**: RS technologies track violations within regulated zones (CRZ-I to CRZ-IV), based on Environment Protection Act (1986).
- **Shoreline Protection**: RS helps predict and assess storm impacts (e.g., cyclones) using data from LANDSAT MSS/TM, IRS LISS II.
- **Ecosystem Surveillance**: Satellite imagery identifies high-trespass areas threatening species like the Bengal Fishing Cat and Gharial in protected zones.

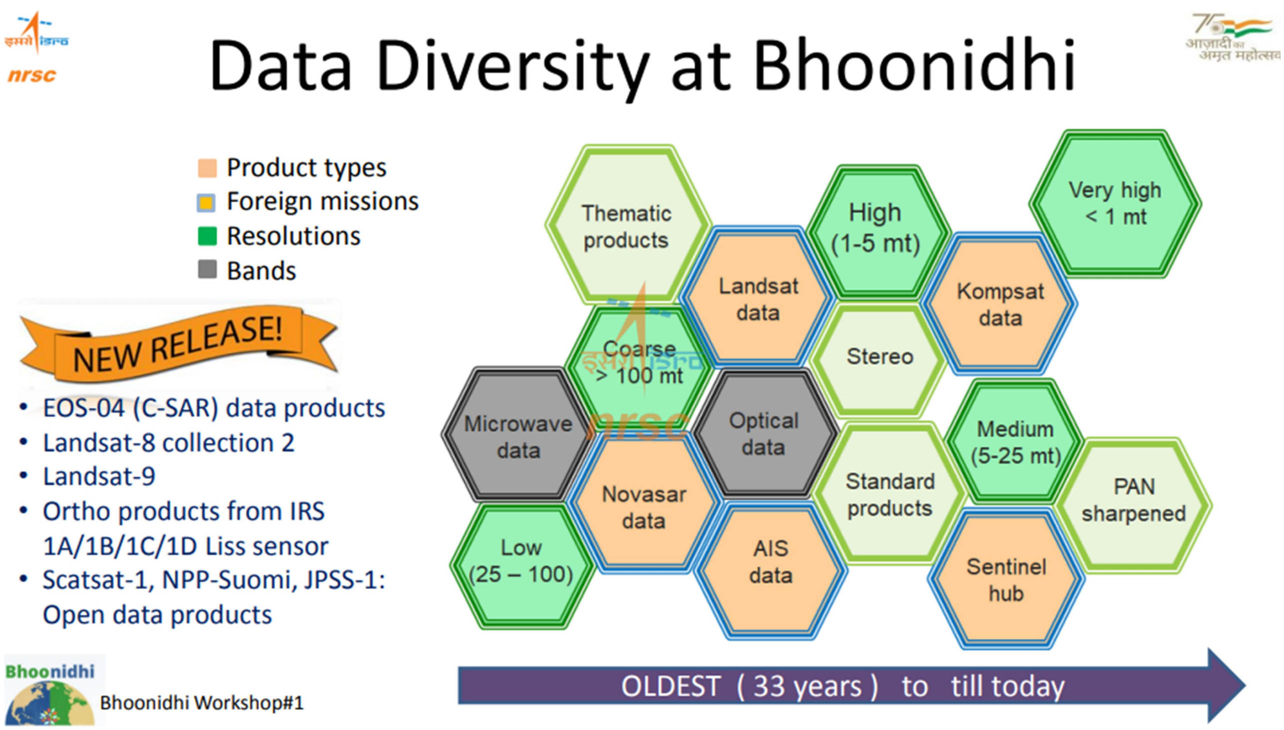
By integrating GIS and RS, policymakers, researchers, and environmental bodies can make data-driven decisions to restore, conserve, and sustainably manage coastal habitats—protecting biodiversity and livelihoods in the face of ongoing climate challenges.

10. USE OF ISRO'S EO DATA HUB (BHOONIDHI)

Bhoonidhi is a centralized platform that provides access to a vast archive of remote sensing data acquired over the past 33 years from 46 satellites, including both Indian and international sensors. It also facilitates the regional distribution of Sentinel and Landsat 8/9 data within India, supporting a wide range of geospatial applications across environmental monitoring, urban planning, agriculture, and disaster management.

Bhoonidhi offers a user-friendly interface with advanced search options to simplify target area identification. Users can filter data by multiple satellites, sensors, resolutions, and date ranges, as well as input event-specific parameters or use natural language text-based searches. Area of Interest (AOI) can be defined using freehand drawing, shapefiles, polygons, coordinates, or pre-defined locations. Additional filters include cloud cover, polarization, sub-scene, path, and row. For paid data products, ePayment is seamlessly integrated through the Non-Tax Receipt Portal (NTRP) via Bharatkosh, making the data acquisition process efficient and accessible.





Source: IIRS & ISRO (http://bhoonidhi.nrsc.gov.in/)

Fig 10: Image processing network and data availability on ‘Bhoonidhi’ Platform

CONCLUSION

With the increasing pressure on natural resources due to the growing human population, remote sensing and Geographic Information Systems (GIS) offer powerful tools for managing these limited resources effectively and efficiently. Geospatial information plays a vital role in identifying and analyzing the various factors that influence the utilization of natural resources. A detailed understanding of these factors enables informed decision-making that promotes the sustainable use of resources, ensuring that the needs of both current and future generations are met.

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