

## Progress and Uses of Satellite Remote Sensing

V. Basil Hans<sup>1,\*</sup>

### Abstract

*Satellite remote sensing has become an important tool for watching, studying, and controlling both natural and man-made systems on Earth. Satellite sensors collect electromagnetic radiation that is reflected or transmitted from the Earth's surface. This data is needed for environmental monitoring, resource management, and hazard assessment. Recent improvements in sensor resolution, data processing techniques, and cloud-based platforms have made remote sensing applications much more accurate and easier to use. The quality, coverage, and dependability of satellite images have significantly increased over the last few decades due to quick advancements in sensor technology, data gathering techniques, and spatial and spectral resolution. The ability of contemporary satellites to record data in a variety of spectral bands allows for a thorough examination of atmospheric conditions, soil moisture, water quality, and vegetation health. Additionally, researchers, politicians, and business professionals can now more easily and effectively access remote sensing thanks to developments in data processing methods, cloud-based computing platforms, and artificial intelligence. This page talks about the basic ideas behind satellite remote sensing, such as the many types of sensors, their spectral properties, and how to analyze the data they collect. It also talks about important uses in farming, studying the weather, developing cities, and dealing with natural disasters. The report continues with a look at new trends that are changing the future of Earth observation and decision support systems. These trends include machine learning integration, hyperspectral imaging, and real-time data analytics.*

**Keywords:** Earth observation, environmental monitoring, geospatial analysis, sensor technology, and data processing

### INTRODUCTION

Remote sensing allows for the assessment and monitoring of terrestrial and environmental variables without physical contact [1], thereby facilitating sustainable development, biosphere preservation, and disaster prevention. Orbital satellites with Earth-observing equipment are the main tools that make it possible to quickly obtain important data from around the world [2]. These tools usually have sensors that pick up energy coming from the ground and reflect solar light in the optical range, as well as microwave radar devices that interact with the surface. A satellite that uses remote sensing gathers information from certain parts of the electromagnetic spectrum, such as the optical, microwave, near-infrared, short-wave infrared, ultraviolet, and thermal infrared. Evaluating land use types and changes at local, regional, and global scales is a significant worldwide issue that can be reliably assessed using remote sensing technologies.

#### \*Author for Correspondence

V. Basil Hans  
E-mail: [vhans2011@gmail.com](mailto:vhans2011@gmail.com)

<sup>1</sup>Research Professor, Department of Management and Commerce, Srinivas University, Mangaluru, Karnataka, India.

Received Date: November 6, 2025  
Accepted Date: November 10, 2025  
Published Date: December 31, 2025

**Citation:** V. Basil Hans. Progress and Uses of Satellite Remote Sensing. International Journal of Satellite Remote Sensing. 2025; 3(2): 8–19p.

In the 1960s, spaceborne remote sensing became more popular when the first satellites that could perform this type of observation were launched. These were the Japanese “JERS” and the US “Landsat” satellite systems. Since then, instrumentation has greatly improved, huge data archives have been built, new multi- and hyperspectral recording systems have started to be

used, and new technologies such as global positioning system (GPS), ground station systems (GSS), automated weather station (AWS), and others have helped remote sensing satellite systems grow all over the world. The ability to acquire and handle information has improved significantly, and the need for remote sensing applications has reached a new height. By the late 1980s, the idea of regional remote sensing emerged. It involves processing remote sensing images taken on two or three distinct dates from the same sensor to find changes in land use at the regional level. This is important and useful in most developing countries.

### **BASICS OF SATELLITE REMOTE SENSING**

Remote sensing is the process of viewing the Earth by measuring different types of radiation that are reflected or transmitted, such as visible light (0.4 to 0.7  $\mu\text{m}$ ), thermal infrared (8 to 14  $\mu\text{m}$ ), and microwave signals (0.01 to 1 m). This method does not require in situ measurements which are limited in space. Compared to traditional aerial surveying, satellite-based remote sensing also allows users to monitor huge areas quickly and cheaply [1].

Interpretation of these measurements is made more difficult by factors such as weather, surface features, and physical parameters. One of the biggest problems is determining the type of object or activity that gives off or reflects the measured radiation from recorded data. The need to quantify information in the data makes it even more confusing. This means determining the system from which the measured signal comes, such as how the sensor and platform behave, the object being measured, and the weather [2].

### **MISSIONS AND PLATFORMS FOR SENSORS**

Different types of platforms fly satellite remote sensing devices, such as Landsat, Satellite Pour l'Observation de la Terre (SPOT), Indian Remote Sensing (IRS) and Advanced Land Observing Satellite (ALOS).. These platforms can be divided into three groups: geostationary, polar, or sun-synchronous, and they can also be classified by how they take pictures [1].

The differences between geostationary and sun-synchronous orbits can have a substantial effect on planned missions. Geostationary satellites orbit at an altitude of 36,000 km, stay above the same location, and can keep an eye on things all the time. A geostationary platform can be a good choice for some uses, such as keeping an eye on the weather all the time. Sun-synchronous platforms pass over locations that are clearly lit by the sun, allowing them to take pictures at different times for use, such as classifying vegetation. Most sun-synchronous satellites reside in orbit between 700 and 900 km above Earth's surface. Locations in the middle latitudes return to the same spot every two to three weeks. The problem arises from having to choose between numerous types of sensors, such as optical, microwave, multispectral, and hyperspectral sensors. Each type has its own advantages and disadvantages, depending on what you want to use. Data fusion and other methods can help solve problems associated with some sensors.

### **Satellites that Orbit the Earth in a Geostationary or Sun-Synchronous Way**

The use of satellites to obtain remote sensing data has greatly improved our understanding of how Earth works. Earth observation stations either follow a sun-synchronous polar orbit or orbit the Earth in geosynchronous orbits. Geostationary satellites keep an eye on a set area all the time and send back reports on atmospheric changes every few minutes. This is particularly important for many weather-related uses, especially in severe weather watches. The difference between how much information an image can hold and how much it really does might make it more difficult to use. Geostationary satellites also have a revisit period of more than 24 h and can be used to determine how much vegetation cover decays.

Sun-synchronous satellites return to the same place every 1–3 days at the same angle, which makes time-series data possible. A lower altitude results in better spatial resolution. Models of climate change

and land surface hyperspectral data. However, calibrating hyperspectral data to absolute reflectance can be difficult because the sensors drift and are not always consistent. Currently, most users create relative spectra and employ empirical assessments. To maintain accuracy, it is important to examine the vegetation cover collected on a dense grid every day or less.

### **Optical, Radar, and Multisensor Constellations**

Satellite observation is still improving, with new satellites providing different kinds of data about Earth at different geographical, temporal, and spectral resolutions. For instance, the European Space Agency's Copernicus Program started its Sentinel missions as part of an effort to make high-quality data available for free to people worldwide. Sentinel-1 synthetic aperture radar (SAR) satellites use a C-band, multi-polarization, and all-weather setup to provide high-quality data for any weather. They have been working with high-resolution optical satellites in the Sentinel-2 constellation and the Italian Space Agency's COSMO-SkyMed constellation, which uses X-band SAR acquisition. These developments demonstrate how optical, radar, and multisensor constellations may work together to provide better temporal sampling and the chance to combine data [3].

For example, satellites can help locate fish by observing the temperature of the sea surface, ocean currents, sea ice, and wave conditions. They can also help to analyze biological production and improve oceanography [4]. Radar, infrared, and multisensor images monitor changes in temperature, storm surges, pollution patterns, sedimentation, and erosion of the shore. Regular, accurate observations of ocean height from satellites make it possible to study how tides and currents work. Using satellites with different sensors, as well as data from ships, planes, and buoys, helps us learn more about the ocean. Buoy programs give you the important ground truth you need to understand remote sensing data [5].

### **Licensing, Ethics, and Data Access**

In the last few decades, access to satellite remote sensing data has changed significantly because of improvements in satellite technology and the creation of open data rules since the Landsat-1 satellite was launched in 1972. Many national and international groups and agencies have started open data projects that allow people to obtain satellite data and products freely. For example, the European Space Agency (ESA) and the European Union's Copernicus initiative have made it easy for anyone in Europe to obtain Earth observation data and services. High-value datasets are still being added to the historical archives. Simultaneously, older datasets such as the Moderate Resolution Imaging Spectroradiometer (MODIS), the National Oceanic and Atmospheric Administration (NOAA), the Advanced Very High Resolution Radiometer (AVHRR), and the ESA Envisat still have large user bases.

Open-access programs have greatly expanded the amount of space covered and the frequency of revisits, which is usually described as the time it takes for a satellite to capture a picture of an area it has already seen. This has made spatiotemporal data available, which is necessary to provide useful information. It is also easy to obtain data from places other than space, such as weather stations, tide gauges, and in situ sensors, as well as data products from other organizations. To make it easier to obtain satellite data, the responsibilities and incentives for storing and sharing satellite datasets have been developed. This will ensure that satellite data will continue to help with scientific discoveries and benefit society.

Data sharing is still limited, especially for proprietary datasets. These datasets are usually trademarked and controlled by satellite companies and often have severe licensing agreements. There are concerns about using data collected for research that is not for profit in a business setting. Intergovernmental organizations and/or institutions may want to obtain satellite datasets, but they may not have the money or skills to run a satellite they want to watch because it could be too expensive and complicated [6].

### **MAIN APPLICATIONS**

Since its discovery, satellite remote sensing has made a lot of progress significantly. There are two main types of satellite remote sensing: Earth observation applications, which are used to monitor land,

---

oceans, and the atmosphere, and non-Earth observation applications, which are used in astronomy and planetary sciences. Montanari and Brivio regarded satellite remote sensing as a strong tool for risk analysis and management applications that are common in today's environmental settings. Satellite remote sensing helps us to understand the complicated roles played by oceans, land, and the atmosphere in the ecosystem, as well as how climatic signals affect local environmental dynamics. High-resolution data from satellite remote sensing have demonstrated their utility in late-twentieth-century Earth science objectives, including the documentation of land use changes and land cover, as well as in elucidating the factors influencing ecosystem structure and function. Advancements in satellite remote sensing significantly enhance diverse domains, including land surveillance, agricultural assessment, forestry and biodiversity, urban research, and climatological investigations [1].

### **Classification of Land Use and Land Cover**

Land use and land cover change (LUCC) is a key part of worldwide environmental studies, and we need land cover data to fully understand how the Earth's surface works. Satellite images are the main tool for mapping land cover on a global scale because they are cheap, easy to obtain, and provide a lot of information about space [7]. There are many different types of classification algorithms, such as visual interpretation, unsupervised clustering, supervised classification, expert systems, neural networks, and decision trees. Unsupervised approaches group data by spectrum; however, the results may be random. Supervised methods require large amounts of expert input and are less automatic. Neural networks and fuzzy logic are advanced solutions, but they are also more complicated. Decision trees are common but rely heavily on human expertise to determine thresholds. Change detection utilizing multi-temporal pictures has significantly enhanced land cover analysis; nonetheless, it continues to encounter obstacles owing to seasonal variations and the absence of validation data. A new semi-automatic method uses previous land cover data to identify changing pixels and classify the land cover. This makes the mapping more accurate and faster [8].

### **Monitoring of Crops and Agriculture**

To monitor agriculture and food security, it is very important to have access to timely information about crop conditions at both the national and field levels [9]. Satellite remote sensing provides this type of information by examining how biophysical features and farming methods affect surface reflectance and land use development [10]. The main goals are to map crop types, estimate yields, assess agricultural areas, find stress, and identify phenological markers. Since 2016, the ESA's Sentinel-2 network has made multispectral data available for free. This has sparked interest in novel methods for monitoring crops and simulating their environment. These data are useful for investigating phenology and stress in areas with limited latitude. Yield forecasting, which is greatly affected by changes in weather, is very important for planning and dealing with unknowns.

Estimation and validation operations use models as well as climate, agronomic, and soil data from around the world, including Africa. Many different methods, such as crop categorization systems, coupled models, and evapotranspiration assessments, have made use of decades of satellite images such as TM, SPOT, and AVHRR. Remote sensing methods allow for direct evaluation of crop conditions and stress, free from the effects of field sampling. Meteorological agency services can make the sector more adaptable by monitoring them at different scales. This is important because farms face cyclones, droughts, floods, and high temperatures.

### **Ecosystem Services, Biodiversity, and Forestry**

Forests and ecosystems on land are important for maintaining life on Earth. They are important for regulating the climate because they can store carbon, absorb water, and maintain biodiversity. However, climate change is still occurring, putting pressure on forest cover and soil stability. This makes it harder for ecosystems to provide services and causes habitat and species loss. Remote sensing provides a distinctive perspective for mapping and monitoring ecosystems, yielding a temporal data series essential for climate research and policy formulation. Sensor characteristics make them suitable for mapping ecosystems, determining the amount of carbon in forests, and other uses.

Remote sensing helps with spatial studies of terrestrial ecosystems by allowing researchers to examine broad areas that are frequently difficult to access for field campaigns. Forested ecosystems occupy over 30% of the land surface and are important for the global carbon cycle. On the other hand, shrubs are very important in arid and semi-arid regions because they provide habitats and maintain biodiversity. Remote sensing makes it easier to examine carbon stocks, habitat availability, and changes in biodiversity and ecosystem services. It also creates spatial indicators that help with management and decision-making. Data availability and processing techniques facilitate extensive evaluations across regions, especially amidst swift land cover changes, uncovering correlations between environmental factors and labor market evolution.

### **Monitoring Urbanization and Infrastructure**

Urban areas are the most active part of land use/cover change (LUCC), and they typically need to be closely monitored. Urbanization is typically non-linear and occurs at several geographical scales, complicating its tracking compared to other types of land cover change. Urban sprawl is often seen as a primary proxy for urbanization and its pace of acceleration. The growing need for more instruments to measure changes and monitor sprawl is pushing the remote sensing community to conduct more research on how to monitor urban dynamics. Urbanization impacts land surface changes. In cities, monitoring efforts are becoming increasingly vital and usually involve checking the land surface and infrastructure. Remote sensing images and computer-aided processing methods that go along with them offer quick, efficient, and ever-changing options to traditional methods. When imagery and elevation maps are used together in a single manner, land cover classification becomes much more accurate. To check how well plants recover after winter thawing, the normalized difference vegetation index (NDVI) signal works best in spring and summer [11].

### ***Risk Assessment and Disaster Response***

Natural hazards affect people, businesses, infrastructure, and ecosystems worldwide. In response, governments, universities, and humanitarian groups have set up mechanisms to keep an eye on things so that they can be found, assessed, and recovered quickly. SAR and very high-resolution (VHR) optical techniques that use satellites can quickly assess damage, map the area after an occurrence, and keep an eye on things over time. Digital elevation models help with hazard exposure analyses [12]. SAR data analyzes co- and/or post-event spaceborne imagery to facilitate the physical reconstruction of damage processes or the direct assessment of damage proxies at the building level [13]. These variables offer insights into infrastructure resilience and are pertinent for identifying the socio-geographic elements that influence urban vulnerability and post-disaster recovery trajectories.

### ***How to Respond to a Disaster***

It is very important for any agency to be able to act within 72 hours of a catastrophic natural disaster to save lives and protect people's safety and well-being. As big cities are more likely to have large events, they are often the focus of research. When this happens, the international community usually supports the government and the people of the affected country. Consequently, response, recovery, and mitigation mapping performed by groups such as the ESA is now widely seen as a top priority. ESA's method asks for damage proxy mapping only for the metropolitan area of interest so that people can quickly understand what is going on and share that information with the rest of the world. This makes recovery and response easier.

It is important to gather both pre- and post-event photographs of interest, which makes it even more important to obtain a wide variety of images of the urban area of interest. If these pre-event photographs are meant to be an optional part of the operation, they can be sent to a dedicated system during the same project phase or priority intervention. Once the area to be covered is chosen, quick response demand mapping may be performed to show where optical A and B images can be given and what acquisition plan can be suggested.

---

## Hydrology and Climate Science

Satellite remote sensing is of great help in climate science because it provides important information about how water moves on Earth. Therefore, land surface temperature data are used to create estimates of actual surface evapotranspiration, which are important for many hydrological models. Correct measurements of surface evapotranspiration form the basis of the water balance equation. This allows hydrologists to determine the amount of water available to rivers, lakes, and reservoirs worldwide [14]. Satellite remote sensing has improved early warning flood forecasting systems that are very important for managing flood risk in places like South Asia, Mesoamerica, and Africa, where there isn't much data [2].

## NEW TECHNOLOGIES AND ANALYTICAL METHODS

Modern Earth observation provides an extensive array of satellite remote sensing data for scientific purposes and decision-making support. The design of strategic sensors and survey missions affects revisit time, coverage, and other acquisition parameters that significantly influence the availability of temporal data. The availability of these data, together with the open-source nature of many processing implementations, has stimulated global studies and applications, fostering a nascent, multidisciplinary remote sensing community.

A variety of satellite remote sensing based variables across multiple disciplines address key Sustainable Development Goal (SDG) indicators and support national and subnational SDG monitoring [4]. Examples of data acquisition service commitments include electronic data access and availability records provided by several commercial and scientific organizations. These include the World Bank, the United Nations, the United Nations Environment Programme (UNEP), the Food and Agriculture Organization (FAO), the Global Climate Observing System (GCOS), the South African National Space Agency (SANSA), and satellite remote sensing information platforms such as GeoDrought and Meter Group.

## Image Processing, Change Detection, and Data Fusion

Image processing, change detection, and data fusion are important parts of multispectral, multisource, multi-temporal, and hyperspectral image analysis in remote sensing [15]. These methods make it easier to get information, better data, better visualization, less redundancy, and combine information from many sources. Change detection looks at the changes between numerous frames of the same scene taken at different times and shows which pixels have changed. Data fusion combines many photos from one or more sources to make a new image that has more information than the original images [16]. Change detection and data fusion are important ways to look at multi-temporal remote sensing images, and they have many real-world uses.

## Machine Learning and Artificial Intelligence in Remote Sensing

Recent studies on remote sensing have shown a growing interest in incorporating machine learning and artificial intelligence (AI), with model-driven predictions being progressively enhanced by data-driven methodologies. Data-driven models are typically considered as black-box methods that are difficult to understand and see [17]. To train the models, we need labeled data. This can be a significant problem for using them in many situations. Many models based only on data also tend to use pixel distribution more than contextual distribution, which makes them less suitable for remote sensing data [18].

Different semi-supervised and unsupervised methods can help solve the problem of labeled data. Transfer learning allows models developed for similar tasks or datasets to work for other tasks as well. Transfer learning is very useful when there is not much training data available for increasingly difficult tasks. Recent research has shown that transfer learning works well in several remote sensing applications. Additionally, techniques that improve model interpretability have been created for a range

of uses in remote sensing and unlabeled data, making it possible to use data-driven methods, even when model transparency is very important.

### **Improvements in Hyperspectral and Microsensor Technology**

Hyperspectral sensors look at the light reflected by objects in many bands, from the visible to the infrared range. These types of measurements make it possible to find materials, determine how they are doing, and follow their changes across time or space. The ongoing collection of hyperspectral data encourages the development of additional promising evaluation techniques that require further physical modelling for surface product inversion and in-material property characterization using spectral unmixing techniques, temporal unmixing methods, or collaborative co-learning operations. These data collection and analysis methods apply to Earth observation, and their advantages may also extend to in situ measurements conducted by space missions or governmental organizations with ground networks dedicated to environmental monitoring.

Recent developments in satellite missions and onboard sensors are creating new ways to obtain spectral data that are different from standard pushbroom hyperspectral sensors. Earth-observing satellites equipped with fish-eye cameras designed for multiview and multispectral bands from various channels enhance ground retrieval post-processing and facilitate time-dependent estimation of vegetation variables, including chlorophyll concentrations and other optical properties. To keep an eye on the environment on land and in the ocean, we need to manage data that can help us analyze how the environment is changing on land using existing software, such as 3D remote sensing ground information capture systems that use Hyperion and Earth-reflected data assimilation from observations all over the world. The comparable examination is confined to a selected number of prominent global facilities that are fully equipped with expertise in the processing of hyperspectral devices and programs.

The significant differences between spectral unmixing (SU) and target detection (TD) are relevant to the latest generation of Earth observation satellites. SU aims to disentangle several coexisting materials at the pixel level, whereas target identification aims to pinpoint a specific material type among various components already present inside the same pixel. New ways to accomplish SU and TD have recently become popular in Earth observation from both ground and space. These automatic methods have improved because there have been many spaceborne or airborne hyperspectral photos over the last few decades, and many underused datasets from the early years. In more complicated metropolitan settings made up of different man-made materials, such as roofs, sods, concrete, or bricks, good outcomes have been observed.

### **Privacy, Safety, and the Source of Data**

The United States Department of Defense's Bureau of Open Technology (BOT) and the United States General Services Administration (GSA) state that "Remote sensing data from commercial sources is becoming a significant part of the United States Department of Defense and the United States Intelligence Community operations," and that "United States Department of Defense and Intelligence Community personnel obtain these data on a routine basis." The Department of Defense systems are being adapted to obtain this data in near real-time from commercial sources." Therefore, it is desirable to create governance frameworks and mechanisms that would guide the use of satellite remote sensing technologies and adequate treatment of the data collected. These frameworks and methods could help the government stop privacy violations by predicting relevant disclosures and preserving national security by reducing the risks associated with sensitive information that rivals might learn about. The BOT's section on privacy and geospatial technologies suggests a number of privacy principles in these areas, including data integrity, security protection, accountability, and minimization [19].

Modern satellite remote sensing technologies and supplementary data can now provide insights into a wide array of activities of individuals and populations, prompting significant ethical inquiries over

the appropriate constraints on the expansion of this capability. The ability to see places and people in unprecedented depths and sizes, together with advanced processing skills, creates many privacy issues for everyone and for all human activities.

## CASE STUDIES

Even though there have been strong international efforts, tropical deforestation is still happening at an unprecedented rate. This has serious social, economic, and environmental effects, and puts the feasibility of climate accords and the United Nations Sustainable Development Goals [20] at risk. People often stop tropical deforestation because they are busy with other important issues, such as fraud, corruption, and geopolitics. New satellite remote sensing systems allow countries to monitor tropical deforestation and report it to stakeholders without depending on possibly compromised governmental authorities. Preliminary studies demonstrate that countries with credible national monitoring systems notice deforestation four to five years earlier than other nations, even for moderate deforestation rates [1].

Many tropical forest countries have a difficult time setting up any kind of dependable monitoring. The model is still being developed by simultaneously planting and stirring Forest Ecosystem Disturbance Index (FEDI) monitoring at the same time. Between peri-urban affluence immigrants, spenders, disinvestment, and abandonment arrive together with a new focus on forest regeneration for gathering, and targeting tropical forest increases are visible in free or semi-tropical rural landscapes such as farm settlements near dams or model-free possibilities are visible for increased savings in watersheds returning to watersheds of biodynamic gathering with scuppered banking arrangements.

### Tracking Deforestation in Tropical Areas

The decline in tropical forest cover has recently sped up because of farming, illegal logging, and other human activities [21]. There are now other ways to measure deforestation on Earth's surface, but remote sensing is still very important. To make good policies, strategies, and action plans, it is important to keep a close eye on the amount, rate, pattern, dynamics, and effects of deforestation and forest degradation [22]. Moreover, prompt reactions to major deforestation incidents can enable timely interventions.

### Predicting Crop Yields in Changing Climates

To predict agricultural yields in climates that change, we need models that can handle the uncertainty in ecological systems that are affected by climate. Forecasts of agricultural production are still an important aspect of food security plans and can be improved by combining crop modelling and remote sensing data. One such method uses the AquaCrop crop model to predict how crops will respond to water and help determine what changes need to be made in the future. Seasonal climate projections are used to create prospective outcome distributions, which makes it easier to trust the predicted crop performance and vulnerability evaluations. Combining spectral vegetation indices with near-surface temperature data makes it easier to determine how many water crops are missing and how it affects their yields. The creation of regional-scale models that include global climate and satellite data, as well as information about local soil types for direct site-to-model connections, is a promising way to improve and speed up yield predictions worldwide [23].

Remote sensing methodologies utilizing vegetation indices, such as the NDVI and the leaf area index (LAI), along with agricultural phenology indicators, are essential for modelling crop yields in fluctuating climates. Research has shown that multi-temporal satellite images can be used to make regional predictions of wheat, maize, and soybean yields, and that remote sensing data can be used in different models to improve crop growth forecasts. Long-term calibration of crop models using Landsat observations before the start of annual Operational Satellite for Applications and Research (OSAR) acquisitions is one way in which these methods are used. The other is through different types of data assimilation, such as particle filters, which improve regional yield predictions. These systems show the importance of keeping an eye on things over time with high resolution to make accurate yield predictions in a wide range of climates [24, 25].

### **Urban Growth and Resilience of Infrastructure**

Urbanization has manifested in irreversible, unplanned, and chaotic ways throughout numerous developing regions, attributable to the rapid global expansion of the urbanization process. Urban growth can lead to the development of some types of infrastructure and housing, but it is often poorly managed because even basic research on urban growth is not conducted or shared between government agencies, urban planners, or even other professionals. This is because using satellite sensors to measure urban growth in urban infrastructure is not an easy task. Urban growth modelling involves characterizing and subsequently integrating the empirical development of urban patterns using historical data gathered over time, typically through binary or continuous maps of urban extent, accompanied by a set of metrics generated from land use changes [11]. It is important to model urban expansion to protect the informal economy from moving away. While expansion is an essential aspect of urban growth, the informal sector's contribution to a country's Gross National Product (GNP) is substantial. Additionally, the informal economy facilitates the use of hazardous building materials in urban environments [26]. Urban resilience is the ability of urban areas to handle and adapt to change, which should help prevent urban infrastructure from breaking down. In general, resilience is measured by examining many different parts of the infrastructure of an urban area.

Urban growth modelling is an important way to monitor the growth of cities and manage their infrastructure. Most geographical analyses require interpolation and prediction to provide more information or to make predictions. Urban growth models are particularly important because they provide current information on the growth of urban structures, which encourages further work on quantifying urban growth.

### **PROBLEMS AND WHERE WE GO FROM HERE**

Measurement and go into further detail regarding the main problems and plans. Make calibration, validation, and uncertainty assessment better; provide standard reference datasets; and make cross-sensor Earth observations more consistent. Look into scalable processing infrastructure, use cloud platforms, and make open science methods possible. Encourage science and policy to work together, ensure that standards are the same in all areas, help developing countries build their skills, and foster cooperation across many countries.

Saint Petersburg, Russia's second-largest city with more than six million people, did not have any up-to-date information about the state of its urban infrastructure. PlanetScope and SkySat satellites captured pictures of cities that were added to GIS datasets. These pictures show that cities were growing, and their infrastructure was worsening. Satellite imaging enabled the spatial modelling of urbanization changes in the city for the first time, yielding substantial consequences for urban planning and regional policy formulation [1].

### **Calibration, Validation, and Uncertainty Quantification**

Calibration, validation, and uncertainty quantification of satellite products are essential research domains that guarantee extensive operational applicability [27]. The calibration determines how the sensor reacts to known inputs. On the other hand, validation checks the quality of the data created without considering how it was measured [28]. Calibration includes instrument characterization and cross-calibration among sensors that establish a unified scale for data intercomparison [29]. Validation involves comparing satellite data to reference data gathered independently using clearly defined and traceable methodologies, thereby confirming information pertaining to the autonomous quality of the satellite product, and must be differentiated from the evaluation of product algorithm uncertainties. A thorough examination of validation methodologies is provided to record current practices and promote enhanced collaboration among communities using satellite-derived Earth observational data. Fighting satellite product uncertainty produced by systematic errors is crucial for ensuring that Earth observations are consistent around the world.

---

### **The Amount of Data, the Processing Infrastructure, and Open Science**

Over the past twenty years, Earth observation (EO) satellite systems have become increasingly common, leading to a substantial rise in the volume of EO data collected for scientific, governmental, and commercial purposes. As the number of operational satellites and the volume of data they transmit and receive continue to grow, only a small portion of EO data is made publicly available, although it is often considered “open” according to certain definitions.

The volume of EO satellite data is increasing at an alarming rate, and EO satellite data archives now contain multiple petabytes of data that are difficult, if not impossible, to manage and analyze effectively. The Sierra Club’s Data That Counts dataset on average satellite acquisitions in 2019 shows that less than 1% of global satellite acquisitions are publicly available.

This rapid increase in EO satellite data acquisition is further highlighted by the fact that even smaller proportions of still images used for archival and documentation purposes, as well as GEOSS EO satellite data, remain unassessed. Large proportions of these datasets are still subject to usage restrictions, which limit a comprehensive understanding of EO satellite acquisition and its impact on contemporary society.

The Earth observation community is increasingly being encouraged to make EO satellite archives and associated datasets more open in order to improve the handling, processing, and analysis of large-scale datasets. Enhanced openness would support improved understanding of satellite observations and interventions occurring during this period of intensive satellite monitoring.

Although EO satellite missions worldwide are now better documented, challenges remain due to insufficient metadata and acquisition documentation. Large EO satellite datasets generated through global Earth observation initiatives have reached multiple petabytes in scale. However, many datasets remain unassessed, and until search capabilities and accessibility are improved through open, public archives worldwide, a significant portion of EO satellite data and related publications will remain underutilized.

Limitations in data transfer, accessibility, and interoperability further exacerbate these challenges. As a result, instead of enabling a comprehensive understanding of environmental processes, many EO satellite datasets remain of limited practical use for applications such as surface elemental analysis and seismic studies.

### **International Cooperation and Policy Consequences**

Internationally, strict and unambiguous rules for satellite remote sensing would undoubtedly speed up investments and growth in this industry. These rules would also expand the market for both consumers and suppliers of data, which would help meet many of the needs and wants of remote sensing in many areas. The user side, which often obtains and uses data from remote sensing satellites, sometimes has problems when using it because the standards used by different platforms or missions are not always the same. Even when they are run separately, platforms or missions still have to deal with an unexpected amount of empty space or large overlaps because of the limits on the design of orbits. Some places also limit the amount, frequency, and quality of data to protect users from adverse effects. Now that the user side has the correct data provided, they can focus more on the experiment and the variables. This allows them to examine useful factors and dramatically improve how they specify the model input. Setting the right price for data or making it public can help develop trust, gain competition, and improve the fairness and justice of the process. Other operational or maintenance policies that cover satellite position or situation perception can help make information more open, prevent unidentified interruptions or other problems from occurring during data collection, strengthen data assurance by providing general information about data that were lost or missed, and keep the design iteration process on track.

## CONCLUSION

Satellite photos provide a wide view of Earth's surface. They make it possible to quickly, cheaply, and safely examine their surroundings and observe how they evolve. Different sensors operate in different parts of the electromagnetic spectrum to provide information on the state of materials, their composition, and the physical circumstances. It is easy to process, change, and combine the digital data that comes out of this with geographic information systems. It is also possible to validate satellite observations by comparing them with ground truth data [20]. Consequently, satellite remote sensing has been extensively utilized for environmental monitoring, land cover mapping, and characterization of geophysical and biophysical features [1].

The field continues to grow owing to new scientific and technical breakthroughs. Current research includes sensor development, image analysis, retrieval of geophysical information, and diverse applications such as natural resource planning, disaster management, and early warning systems for floods and landslides. The combination of machine learning and AI has significantly improved the speed and accuracy of data analysis, leading to new uses in environmental monitoring and forecasting [30].

## REFERENCES

1. Shattri M. Overview of remote sensing attributes. In: Google the Earth: What Next? Serdang: Universiti Putra Malaysia Press; 2010. p. 6–130.
2. Thenkabail PS, editor. Remote Sensing Handbook. Biodiversity, Ecology, LULC, and Carbon. Vol. IV: Forests. Boca Raton (FL): CRC Press; 2024.
3. Bagheri H, Schmitt M, D'Angelo P, Zhu XX. A framework for SAR-optical stereogrammetry over urban areas. *ISPRS J Photogramm Remote Sens.* 2018;146:389–408. doi:10.1016/j.isprsjprs.2018.10.003.
4. National Aeronautics and Space Administration (NASA). Useful applications of earth-oriented satellites: summaries of panel reports; recommendations on future applications of satellite technology to earth-oriented fields. Contractor Report NASA-CR-101388. Washington (DC): NASA; 1969.
5. Grisham WH. Remote sensing of earth resources system capabilities vs. design constraints [master's thesis]. Orlando (FL): University of Central Florida, College of Engineering; 1973. Available from: <https://stars.library.ucf.edu/rtd/54>
6. Pope A, Rees WG, Fox AJ, Fleming A. Open access data in polar and cryospheric remote sensing. *Remote Sens.* 2014;6:6183–6220. doi:10.3390/rs6076183.
7. Jiang D, Huang Y, Zhuang D, Zhu Y, Xu X, Ren H. A simple semi-automatic approach for land cover classification from multispectral remote sensing imagery. *PLoS One.* 2012;7:e45889. doi:10.1371/journal.pone.0045889.
8. Nivedita Priyadarshini K, Kumar M, Rahaman SA, Nitheshnirmal S. A comparative study of advanced land use/land cover classification algorithms using Sentinel-2 data. *Int Arch Photogramm Remote Sens Spatial Inf Sci.* 2018;XLII-5:665–670. doi:10.5194/isprs-archives-XLII-5-665-2018.
9. Bazzi H, Baghdadi N, Amin G, Fayad I, Zribi M, Demarez V, et al. An operational framework for mapping irrigated areas at plot scale using Sentinel-1 and Sentinel-2 data. *Remote Sens.* 2021;13:2584. doi:10.3390/rs13132584.
10. Pinter PJ Jr, Hatfield JL, Schepers JS, Barnes EM, Moran MS, Daughtry CST, et al. Remote sensing for crop management. *Photogramm Eng Remote Sens.* 2003;69:647–664. doi:10.14358/PERS.69.6.647.
11. Blaschke T, Hay GJ, Weng Q, Resch B. Collective sensing: integrating geospatial technologies to understand urban systems—an overview. *Remote Sens.* 2011;3:1743–1776. doi:10.3390/rs3081743.
12. Schofield M. An artificial intelligence (AI) approach to controlling disaster scenarios. In: Ali M, editor. *Future Role of Sustainable Innovative Technologies in Crisis Management.* Hershey (PA): IGI Global Scientific Publishing; 2022. p. 28–46. doi:10.4018/978-1-7998-9815-3.ch003.

13. Solórzano J, Morante-Carballo F, Montalván-Burbano N, Briones-Bitar J, Carrión-Mero P. A systematic review of the relationship between geotechnics and disasters. *Sustainability*. 2022;14:12835. doi:10.3390/su141912835.
14. Khan S. Satellite remote sensing and hydrologic modeling for flood monitoring in data poor environments [dissertation]. Norman (OK): University of Oklahoma; 2011. p. 5–144. Available from: <https://hdl.handle.net/11244/318464>
15. Albanwan H, Qin R. Spatiotemporal fusion of remote sensing. In: Kwan C, editor. *Recent Advances in Image Restoration with Applications to Real World Problems*. Rijeka (Croatia): InTech; 2020.
16. Simone G, Farina A, Morabito FC, Serpico SB, Bruzzone L. Image fusion techniques for remote sensing applications. *Inf Fusion*. 2002;3:3–15. doi:10.1016/S1566-2535(01)00056-2.
17. Zhu XX, Tuia D, Mou L, Xia GS, Zhang L, Xu F, et al. Deep learning in remote sensing: A comprehensive review and list of resources. *IEEE Geosci Remote Sens Mag*. 2017;5:8–36. doi:10.1109/MGRS.2017.2762307.
18. Taskin G, Aptoula E, Ertürk A. Explainable AI for Earth observation: current methods, open challenges, and opportunities. In: Prasad S, Chanussot J, Li J, editors. *Advances in Machine Learning and Image Analysis for GeoAI*. Amsterdam: Elsevier; 2024. p. 115–152. doi:10.1016/B978-0-44-319077-3.00012-2.
19. Brien LF. Privacy and geospatial technologies [master's thesis]. New Orleans (LA): University of New Orleans; 2009. p. 1–69. Available from: <https://scholarworks.uno.edu/td/971>
20. Huang S. The potential of multi-sensor satellite data for applications in environmental monitoring with special emphasis on land cover mapping, desertification monitoring and fire detection [dissertation]. Munich: Ludwig-Maximilians-Universität München; 2005. doi:10.5282/edoc.3483.
21. Salas WA. Optical and radar remote sensing of land use and land cover change in the tropics: An assessment of deforestation and secondary vegetation [dissertation]. Durham (NH): University of New Hampshire; 2001.
22. Tang X. Near real-time monitoring of forest disturbance: A multi-sensor remote sensing approach and assessment framework [dissertation]. Boston (MA): Boston University; 2018.
23. Newlands NK, Zamar DS, Kouadio LA, Zhang Y, Chipanshi A, Potgieter A, et al. An integrated, probabilistic model for improved seasonal forecasting of agricultural crop yield under environmental uncertainty. *Front Environ Sci*. 2014;2:17. doi:10.3389/fenvs.2014.00017.
24. Lyle G, Lewis M, Ostendorf B. Testing the temporal ability of Landsat imagery and precision agriculture technology to provide high-resolution historical estimates of wheat yield at the farm scale. *Remote Sens*. 2013;5:1549–1567. doi:10.3390/rs5041549.
25. Kasampalis DA, Alexandridis TK, Deva C, Challinor A, Moshou D, Zalidis G. Contribution of remote sensing on crop models: A review. *J Imaging*. 2018;4:52. doi:10.3390/jimaging4040052.
26. Hall GB, Malcolm NW, Piwowar JM. Integration of remote sensing and GIS to detect pockets of urban poverty: The case of Rosario, Argentina. *Trans GIS*. 2001;5:235–253. doi:10.1111/1467-9671.00080.
27. Chander G, Hewison TJ, Fox N, Wu X, Xiong X, Blackwell WJ. Overview of intercalibration of satellite instruments. *IEEE Trans Geosci Remote Sens*. 2013;51:1056–1080. doi:10.1109/TGRS.2012.2228654.
28. Ong C, Thome K, Heiden U, Czaplá-Myers J, Mueller A. Reflectance-based imaging spectrometer error budget field practicum at the Railroad Valley Test Site, Nevada. *IEEE Geosci Remote Sens Mag*. 2018;6:111–115. doi:10.1109/MGRS.2018.2841934.
29. Loew A, Bell W, Brocca L, Bulgin CE, Burdanowitz J, Calbet X, et al. Validation practices for satellite-based earth observation data across communities. *Rev Geophys*. 2017;55:779–817. doi:10.1002/2017RG000562.
30. Kumar GK, Sankar P. Artificial intelligence powered satellite communications and Sentinel satellite constellations: An overview and future perspectives. *SN Comput Sci*. 2025;6:735. doi:10.1007/s42979-025-04268-8.