

## **GIS vs Remote Sensing in India: Demystifying the Mix-up in Simple Terms**

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**The article summarizes the uniqueness of the two fields stating definitions, differences, applications, and integration, and stresses a concerted effort to identify them as exclusive of each other**



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### **Abstract**

Remote Sensing and Geographical Information Systems are two technologies that, although thought to be similar, have very different origins, and possibly the output of one technology could be input to the other. With the Government of India taking unprecedented interest and measures in using these technologies for development and governance, these are now rapidly growing fields, indicating that geospatial science and technology will be central for information management and dissemination. And yet, these fields are struggling to have a strong presence in the country. There are several misnomers regarding GIS and remote sensing. One misnomer is that both technologies are synonyms, while another common mistake is that the two fields are just software such as QGIS. This article attempts to describe the two different technologies in straightforward terms while explaining the differences between the two. The two technologies have independent existence and thus, associated applications. We describe the basic concepts and current advancements in both technologies with specific examples. We also indicate possibilities on how the two technologies can be integrated and used together for decision-making. This article draws attention to the fact that though these disciplines are closely related, and much effort has gone into keeping them easily accessible, it is vital that other disciplines that are utilizing them respect the differences, understand the specific technical expertise required for each, and thus value the unique capabilities each of them brings.

‘That’s a great list of GIS product sources you have put together!’ said my colleague to me the other day. He was commenting on a database I had compiled on possible resources of spatial datasets as inputs to understanding a landscape’s potential for ecological restoration. I winced. In my clear understanding, it wasn’t a list of ‘GIS’ product sources, since it was obtained from a whole bunch of sources such as satellite imaging, weather stations, floral distribution databases, in addition to the GIS-derived analytics such as ecoregions and anthropological footprint maps. He was committing an oft repeated but overlooked error of terming anything spatial as ‘GIS’ data.

“Yes, I have done QGIS in my undergraduate degree course!” That’s the answer we get many times from applicants applying for Masters’ and sometimes even for PhD programs when asked if they know anything about GIS. That’s again, an error of substituting the tool for the method!

Many times, we have incidents that make us wonder about the misconceptions people have about many topics and on that line a prominent one is GIS vs remote sensing.

We decided it’s time to clear this mix-up of terms, and call a map, a map, and an image, well, an image!

### **Introduction -How does it matter?**

In India, industries that provide services in the field of geospatial technology are advancing rapidly.

The Government of India has taken unprecedented interest and implemented several measures in using geospatial technology as a major component in development and governance, showcased by most of the flagship programs such as Smart Cities, Digital India, Make in India, the Clean Ganga Project, energy, smart agriculture among several others. It thus forebodes that geospatial science and technology will form the core of information management and dissemination, planning, and implementation of these programs. A look at some estimates of the Global Geospatial Market shows that it was estimated at USD 452 billion in 2022, and is forecasted to grow at 14.61 percent annually to become approximately USD 681 billion in 2025 (Geobiz-22, 2022). Beyond 2025, it is expected to grow at a much faster rate of 16.1 percent annually, reaching a whopping USD 1.44 trillion by 2030 (Geobiz-22, 2022)!! With this expected growth in the geospatial industry, the need for geospatial experts is going to increase substantially. However, there are yet a lot of misnomers and misconceptions around the field of Geographical Information Systems (GIS) and Remote Sensing (RS). One such misconception is that they are the same field, and the two terms are used as synonyms for fields that are quite distinct. Another big misconception is that they are names for software utilized for performing the same operations. For example, when we talk about GIS/Remote Sensing, people will say I know QGIS or ArcGIS or Erdas. However, one would never hear anyone talking about statistics saying that they knew Excel, SPSS or

Stata!! But, when it comes to GIS and RS in our country, we have a long way to go to recognize RS and GIS as a field of information, as a science, instead of making these technologies look like mere software. This misconception is so wide, it exists across age groups and career levels (students to professionals), across sectors (natural resource management to economics) and even in the education system. In this article, we attempt to clarify some of these misconceptions to create a basic understanding of these two complementary, but distinctly separate fields that are being used for myriad applications, be it natural resource management, climate change, smart cities, infrastructure planning, disaster management, or species distribution predictions.

## **Definitions**

Let's look at some definitions of Remote Sensing as it evolved from its inception. The simplest definition of Remote Sensing as indicated by Jensen (2009) is 'acquiring information about any object without being in direct contact'. As per Lillesand and Kiefer (2015), 'remote sensing is defined as the science and techniques of obtaining information about an object, land area, phenomenon, or ecosystem process acquired by a device that is not in contact with the object, area, or phenomenon under investigation.' A bit more complex definition is that by James Campbell (2011) stating – 'Remote sensing of the Earth can be defined as a method which helps us evaluate information about our planet through satellite or aerial images and measurements of electromagnetic radiation in one or more regions of the electromagnetic spectrum reflected, absorbed or emitted by the Earth's surface'. Thus, most of the definitions of remote sensing clearly indicate that it is the science (and art) of gathering information about some pattern or process, without being in direct contact with it. In today's context, even Unmanned Aerial Vehicles (UAV's) or drones mounted with cameras are agents of remote sensing.

Now, let's consider the definitions and explanations of GIS as they evolved. The first GIS was developed in Canada in the 1960s to document the country's natural resources, specifically spatial data. Thus, GIS initially came into being as a 'System' of collective tools for putting large amounts of spatial data together, to make it easy to analyze and retrieve information from it. Hence the definition by Longley et al. (2001) "a tool for performing operations on geographic data that are too tedious or expensive or inaccurate if performed by hand" seems appropriate as the first definition of GIS. As computer technology, software and hardware evolved and became more and more affordable, the system became increasingly specialized and powerful, and hence several organizations began to use it regularly to maintain databases, for retrieval at will, as well as for analyses. It was recognized that GIS consisted of not only the databases, but in addition, also the hardware, the software, the processes or analytics, and the personnel trained to perform the analytics at all stages – input, processing as well as output. As the field grew, and the myriad possibilities of spatial data input, storage,

retrievability, analytics and display became evident, the S in the GIS began to be looked at as Science rather than System. In the words of Prof Michael Goodchild, the 'father of GIS' – "There is a pressing need to recognize and develop the role of science in GIS. This is meant in two senses. The first has to do with the extent to which GIS as a field contains a legitimate set of scientific questions, the extent to which these can be expressed, and the extent to which they are generic, rather than specific to fields of application. The second sense has to do with the role of GIS as a toolbox in science generally -with GIS for science rather than the science of GIS." Goodchild (1990).

Thus, it becomes clear that RS and GIS are not only geospatial tools but also encompass the science behind these tools, developed because of understanding and analysing various data about the earth. Let's now look further into the individual purpose which they serve.

### **What are the specific purposes of these fields?**

One of the main requirements in understanding earth's complexities is acquisition of data about land, atmosphere and ocean. Most times it is difficult, expensive, and time consuming to organize data collection exercises in the field, by visiting the sites. In such situations, collecting data through remote observations is most ideal, cost-effective, and timesaving. The data are acquired through different types of platforms. These platforms can be ground-based, through airplanes, drones or space-based satellites. The field of remote sensing is based on the interaction of light with different features such as lakes, ponds, buildings, pavements, crops, forests, soil, oceans etc. For this, the foremost requirement is to understand light and its interaction with different kinds of surfaces to analyze remotely sensed datasets. Therefore, this field requires knowledge of basic physics and physical geography. In addition, to answer different questions related to ecology, air pollution, water pollution, plant infestation, crops, bathymetry etc one needs to have specific domain knowledge in these fields as well. In recent times, when Artificial Intelligence has penetrated everywhere, it has contributed hugely to the field of remote sensing as well, providing an approach for accurate information extraction from remotely sensed data sets beyond statistics. Thus, state-of-the-art remote sensing is truly transdisciplinary in nature with interaction among many different fields. Fig 1 shows maps depicting multiple types of information derived from remotely sensed images.

The simplest purpose of a GIS is to represent information spatially. This is the beginning of spatial thinking related to the earth's physical forms and structures, flora and fauna, as well as human beings, as part of the systems that constitute the earth. While the basic use of GIS is to create a pictorial representation of the earth, its people, vegetation and fauna living there, it is also about recognizing the pattern (spatial arrangement) that could represent certain information when shown spatially, whether it is social information, such as economic strata, gender, religion, or natural phenomena

such as precipitation, temperature, or geomorphological features. To this end, it involves digitalization of the data available with us. In addition, GIS also includes database management, spatial statistics (quantification of spatial patterns to ensure it is not by chance) and spatial modelling. Spatial modelling could be for understanding the potential reasons responsible for specific spatial arrangements. For example, if we are interested in finding hotspots of a vector-borne disease and its relationship with socioeconomic status of people, and say, distance to certain water bodies, then we can use GIS to answer these questions. GIS is also used for different types of utility mapping like electricity networks, water supply, transportation networks, etc. Overall GIS is widely used as a decision-making tool as it provides information on hidden spatial patterns, relationships among different types of data, or even identifying regions with potential risks. Hence, applications of GIS are limitless as the founder of ESRI, a prominent GIS software company, has said “The applications of GIS are limited only by the imagination of those who use it”.

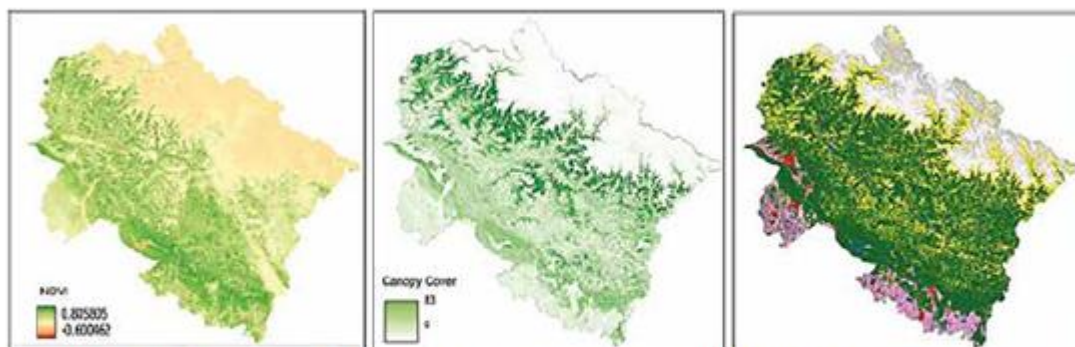


Fig 1. Left: Normalised Difference Vegetation Index derived from annual data for the year 2021 for the state of Uttarakhand. Lighter greens and yellows indicate lower vegetation vigour, darker greens are denser and healthier vegetation. Middle: Percentage of tree canopy cover for the state of Uttarakhand for 2015 – derived from Landsat data. Darker greens show a higher percentage of tree cover, lighter greens show a lower percentage of trees. Right: Landuse – Landcover map for Uttarakhand derived from Sentinel 1 and 2 data for 2021, as part of the ESA Worldcover database. The map contains 11 land cover classes

The basic concept of visualization in GIS itself is much more appealing compared to any other way of representation of data. Here is an example of two different cartographic representations of spatial information (Fig 2). Here are two maps depicting graduated colours which represent the total number of villages with ATMs in each district. The first map shows all districts of Karnataka with the true shape and size while the second map – called a cartogram – is a representation of the same data, but the geographic size of the district is distorted to show the proportional variation of number of villages with ATMs in each district.

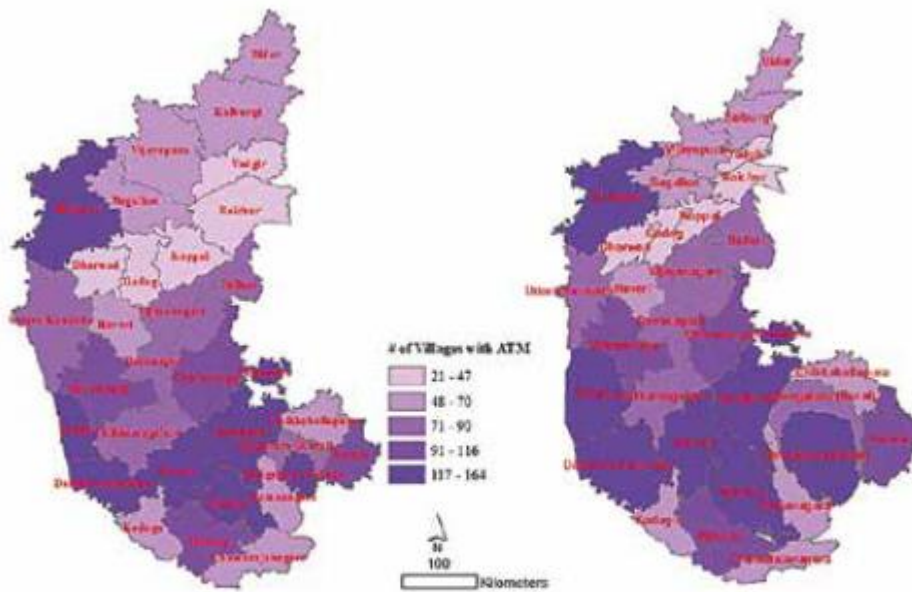


Fig 2. Cartographic representation of the number of villages with ATM. Left: True representations of district sizes and shapes. Right: Sizes distorted by the number of villages with ATMs in each district.

Here is another figure which shows an example of a different data model using GIS – a 3-D representation of the terrain surface indicating elevation changes over the landscape in the Alaknandariver basin, Uttarakhand (Fig.3)



Fig 3. 3-D representation of terrain variation in Alaknanda Basin

### **Why is it important to know the difference?**

While a lot of RS and GIS projects interface with one another, a clear distinction in the capabilities of each would enable the development of a specific understanding of the technical prowess of each. Knowing the difference between the two enables project managers to plan who should be recruited, for the specific applications that they have in mind. If you are working on a multi-disciplinary project, and need a geospatial scientist in your team, the first thing would be to figure out whether you need one who has expertise in GIS, or in the remote sensing domain, or one who has expertise in both (if you need seamless integration of the two technologies for better outputs). Similarly, if a new academic programme is developed where one would like to have a course related to geospatial technology, one needs to have a vision of what they would like the students to gain from it, and how they would like the students to be prepared when they step out of the course. Should they have hands-on knowledge of GIS, or remote sensing, or both? As described above, the two technologies and the science behind them are quite different and require different academic backgrounds to understand them and use them for effective implementation, and consequently, optimal use of both technologies.

### **Synergistic use of the two fields**

Ever since the technology for mapping using RS developed, and data handling capacities of software were adapted for managing graphic as well as non-graphic data, these two fields are being used in tandem for effective analytical studies on various themes. From addressing natural resource management problems such as habitat suitability mapping for wildlife, to assessing areas of urban land cover change over decades, the outputs of remotely sensed data analyses have been used as inputs to GIS tools to derive robust results for devising management plans. Fig. 4 is an example of the integration of GIS and remote sensing. Urban clusters are defined as built-up areas with at least 300 inhabitants per square kilometer and have at least 5000 inhabitants (Schiavina, et al. 2022). Here the built-up area was derived from satellite remote sensing, while the population data was brought into the GIS environment, and population density was computed for all the geographical locations.

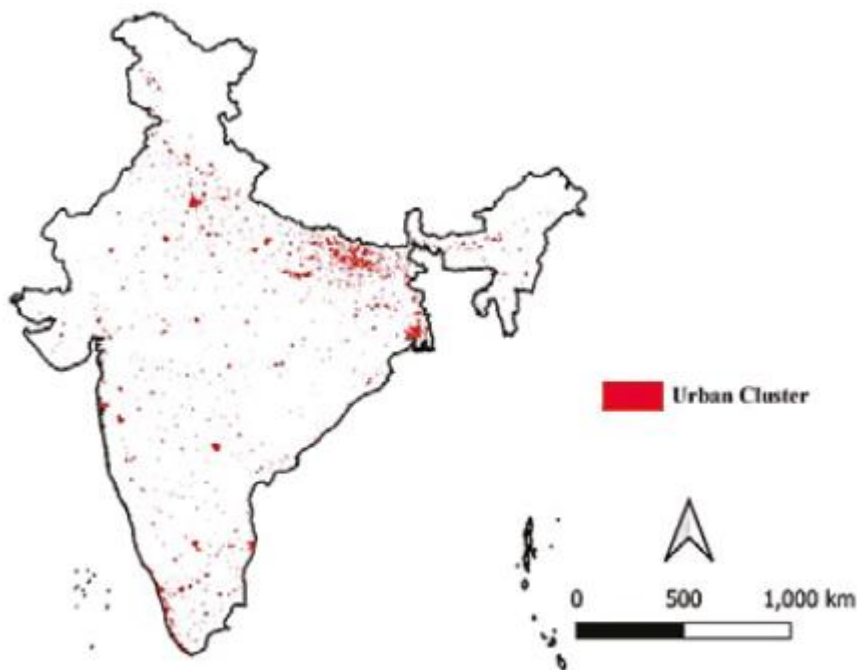


Fig.4 Urban clusters derived by integrating population density and satellite derived built-up areas

With the power of advanced computing and huge data holding capacity of hardware, as well as superfast internet capabilities, we now have the possibility of utilizing both these powerful tools for extremely meticulous and data-heavy analyses of patterns and processes on earth as well as underwater and in the atmosphere, on web-based interfaces. For example, investigating fine-scale landscape change, or forest fragmentation, or changes in species range due to climate change, investigating physical and anthropogenic drivers for disease spread, analysing water scarcity, surface water runoff, water and air pollution, understanding disparity in education access along with its relation to climate change, among many others. The combined use of RS and GIS enables not only data handling, and pattern description, but also realistic visualizations and advanced predictive modelling of future scenarios of phenomena occurring on earth, enabling forecasting for possible anthropogenic growth or natural calamities. In addition, there is a need for unceasing research and development of these tools not only as technological innovations but also as a branch of geospatial science, such that we can develop a repository of such approaches and further continue to use them to address critical questions related to the Earth, its people, and interactions among them.

The power of using these technologies, however, now lies not only in using the outputs of one as inputs for the other, but more so in their synergistic use to achieve greater precision and finer products that can aid in understanding our earth's phenomena in a much better way. For example, progressive computing technologies such as Artificial Intelligence (AI) are now being used along with advanced data-gathering tools such as

Unmanned Aerial Vehicles (UAV) to get data on the conditions of the landscape for interpreting their health conditions by running algorithms. The power of the internet also allows the use of these technologies to perform data analysis and mapping of disasters such as forest fires mapping ‘on the fly’, in real-time while the aircraft is in motion, and collecting photographs. Similarly, there are many advances in remote sensing for example the GEDI mission in space-borne remote sensing provides satellite data capturing 3-D structure of Earth surface (e.g. tree height). Similarly, GIS integrated with AI called geospatial artificial intelligence (GeoAI) are used for understanding the spatial pattern and process of the landscape. Here is an example of the use of different machine learning approaches in AI for mapping different land use/ land cover in parts of Delhi (Fig 5).

Thus, while technology is advancing rapidly as software and equipment develop, the ability of human intelligence and creativity to interpret and utilize these technologies is making progress in leaps and bounds. It is difficult to draw boundaries – where the imaging stops, the mapping starts, and the interpretation collates the results.

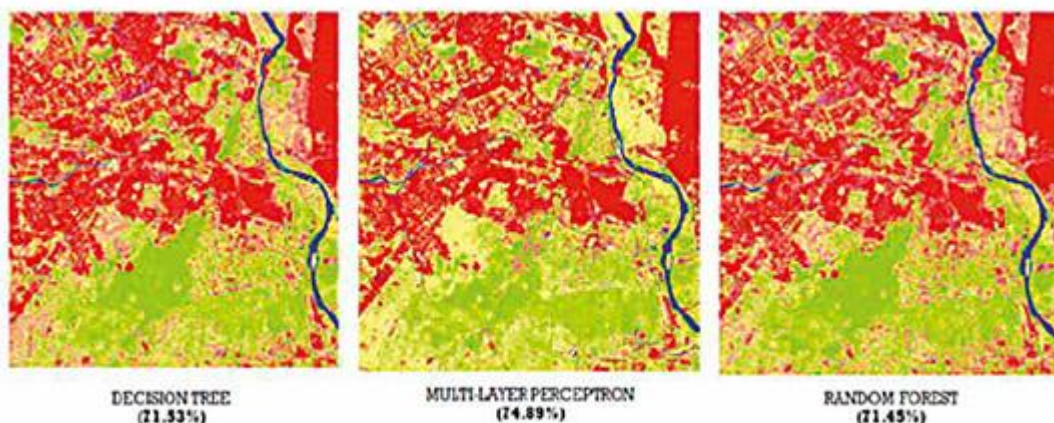


Fig 5. Examples of machine learning approaches (Decision tree, Multilayer Perceptron, and Random Forest) for land use/land cover classification with overall accuracy. Different shades of red represent dense/sparse built-up area, green is vegetation, yellow is cropland and tan is barren.

### ‘Geospatial science’ instead of calling everything ‘GIS’

A GIS professional may know how to do a bunch of spatial analyses, such as finding the most appropriate location for a retail outlet for a shoe-shop, or measuring the slope at a dam construction site, but may have no idea about satellite-derived vegetation indices or atmospheric pollutants. That would require a remote sensing scientist, who works with satellite data, and not with ‘GIS’ data! And similarly, a remote sensing professional may not be able to help in identifying the best locations for siting a fire-station, or in preparing, for example, an analytical map of sections of society served by hospitals. This would require a person trained in GIS, different spatial and non-spatial data, and analytics.

A few simple changes in our terminology would ensure that these small but important differences are demarcated. For example, teaching institutions must label their courses

correctly as 'GIS course' or 'RS course' based on the content, and some form of 'geospatial technology' course, when both are included in the teaching. So when I finally got around to explaining to my colleague the difference between 'GIS' products and other products in the spatial domain, I realized that using the correct terms in our own daily language would really help. For e.g., an image of a landscape could be a remotely sensed photo, a real physical photograph captured in time, but when you annotate it, you may transform it into a map. A map can be a representation of patterns on ground with different symbols, or it could be a satellite image obtained from 30000 m above the earth, with labels of the rivers and mountains that it has captured, but it gives more information than just an image because of its attributes such as scale, annotations and legend. Next time, when you use any application like Google Maps, see it as an application of GIS and not the other way around.

We hope that this attempt to clarify the differences in the two parallel, but overlapping domains has helped to show that GIS is not a precursor, nor a prerequisite for RS, and vice versa. Also, neither is RS an advanced form of GIS, as is indicated in some educational programmes – they are two distinct, but closely related fields of study. While we are striving to keep our discipline non-technical and easily accessible, it is vital that other disciplines that utilize these technologies respect the difference between the two terms and value what unique capability each of them brings, and the diversity of applications they can be used for. This will enable professionals in these fields to indicate their specializations distinctly and avoid confusion in expectations from the employers while delivering the desired outcomes.

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