REMOTE SENSING FOR NATURAL HAZARD STUDIES

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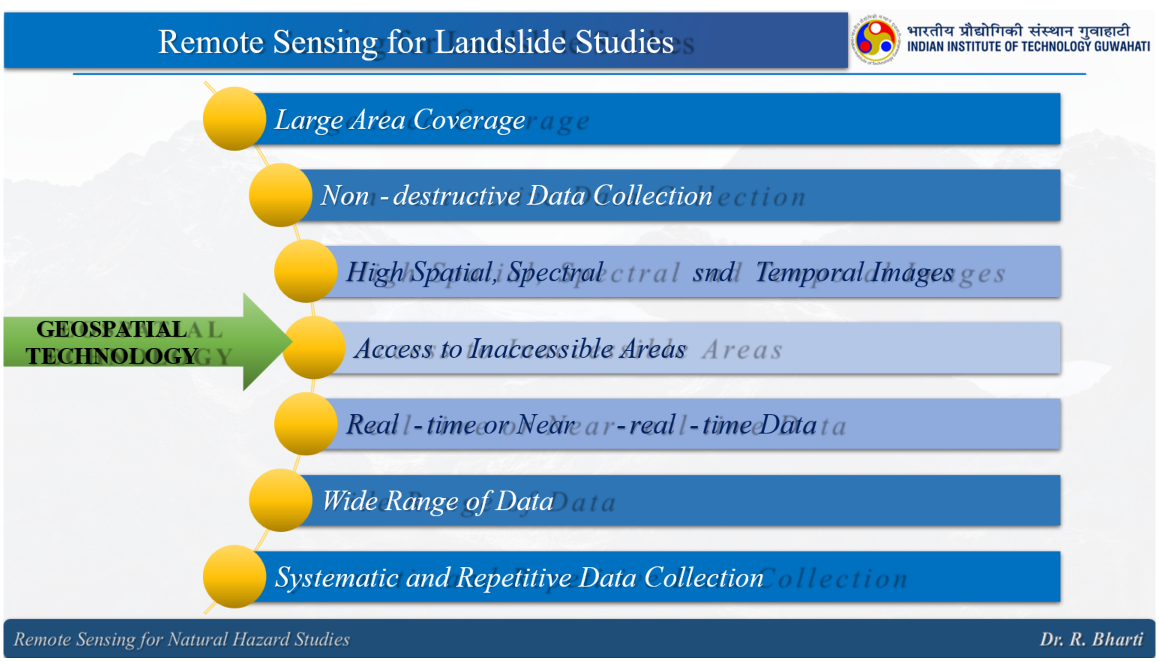
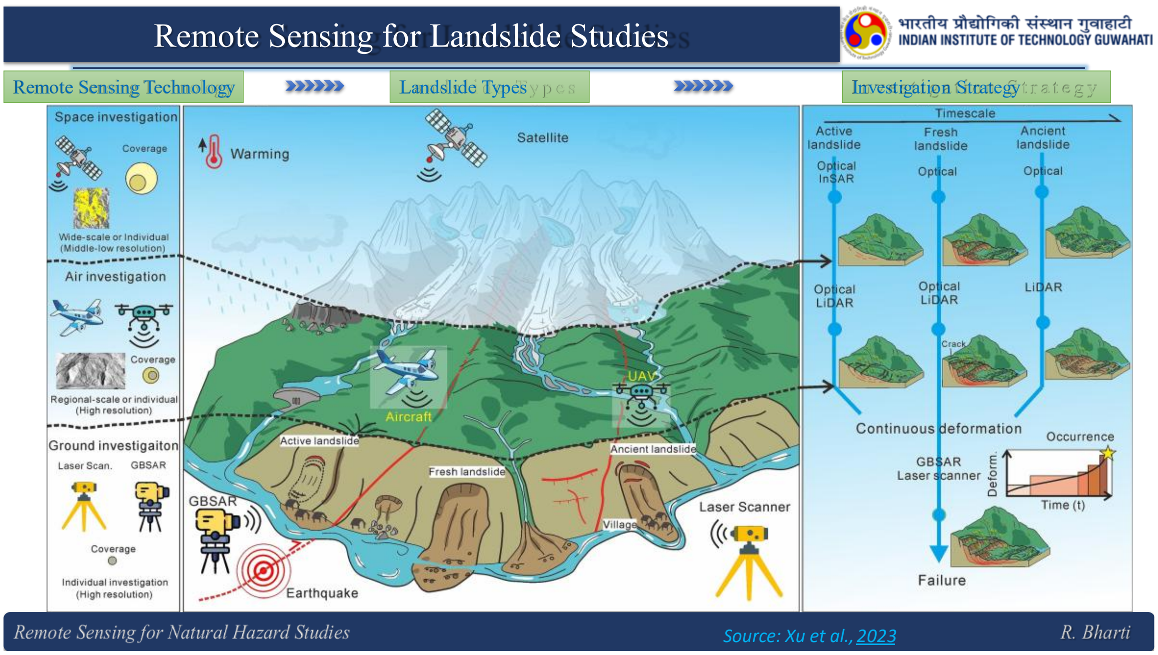
Lec 30a: Remote Sensing for Landslide Studies-II Part A

Hello everyone, welcome to Module 8, Lecture 30, and today we will discuss remote sensing for landslide studies. So, like other lectures, this lecture is also divided into two parts. So, this is the first part. So, before we continue and before we see the actual application of remote sensing in landslide studies, let us understand the potential of remote sensing. So, the first advantage of remote sensing, or let us say, geospatial technology, is. It is the large aerial coverage, which is not possible with the field investigation. So, when you go for the field investigation, what happens is we collect the point information or we collect the sample, so that will be dedicated to that particular location. So, whatever information you extract using the conventional method or different advanced techniques will be dedicated to that particular location.

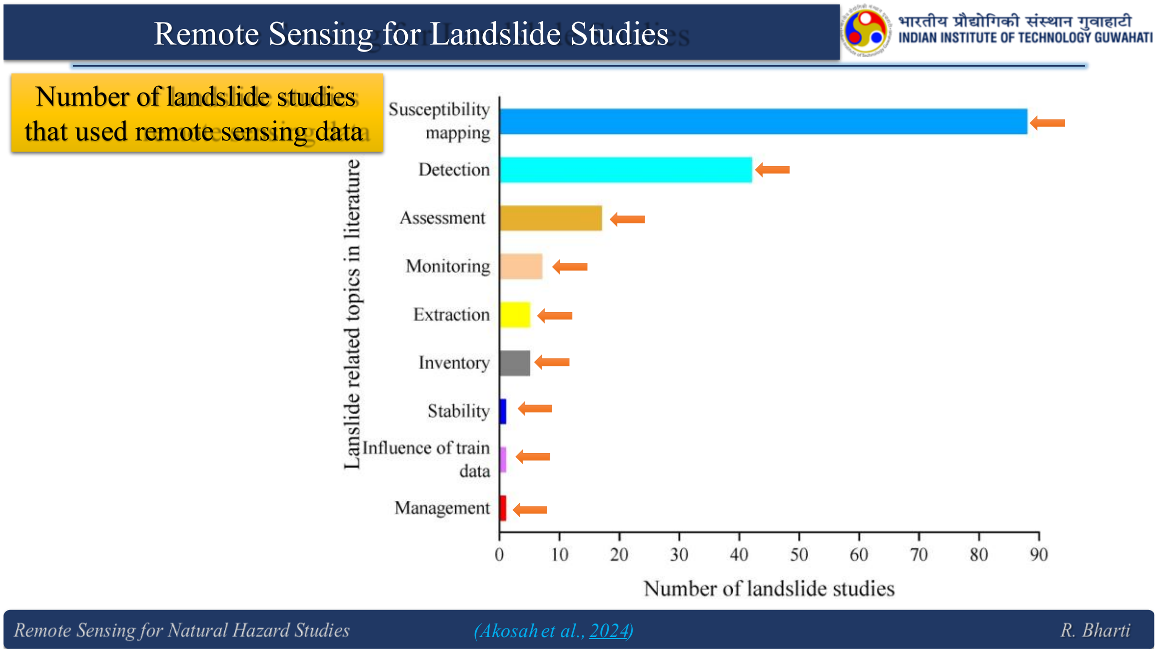


When we talk about remote sensing and analyze the different datasets captured in different wavelength regions, what happens? We are extracting the information using different wavelength ranges. So, that advantage we will have with respect to large aerial coverage. Next is non-destructive data collection. So, here when we say non-destructive, basically non-destructive means we are not disturbing the sample. We are not changing the form of the sample, but if you remember, if you go for XRD, XRF, ICP, or any other conventional or geochemical analysis, or geotechnical investigation.

We are disturbing the natural form of the sample. We collect the sample, and we try to make it fodder or maybe liquid, depending on the instrument. So, depending on the instrument, we will be preparing our sample, and that will be destructive in nature. But when we talk about remote sensing, it is non-destructive; that means we are simply acquiring information in different wavelength regions. Now, the next one is the high spatial, spectral, and temporal image.



So, spatially, what is the size of your pixel? One pixel represents 30 by 30 meter of the ground, or maybe 1 meter by 1 meter, or maybe a few centimeters by a few centimeters. The higher the spatial resolution, the more information you will have about the target. With the advancement in technology, we now have high spatial resolution. Not only in the panchromatic images, but also in the multispectral domain, do we have high spatial resolution. Now comes the spectral resolution. So, this spectral resolution provides you with the characteristic absorption feature information about the target, whether a particular target is x, y, or z, that is identified using the characteristic absorption feature given by that particular target in different wavelength regions. Then we have temporal images. So, we have subsequent acquisition of the images, or we have temporal images captured in different time frames, or the temporal images are basically the images captured for the same area by the same satellite, maybe after a 10-day or 15-day interval. And that will be utilized to observe the changes on the ground. So, when we talk about natural hazards, especially landslides, these temporal images will try to provide you with information about the pre-landslide condition and the post-landslide condition.

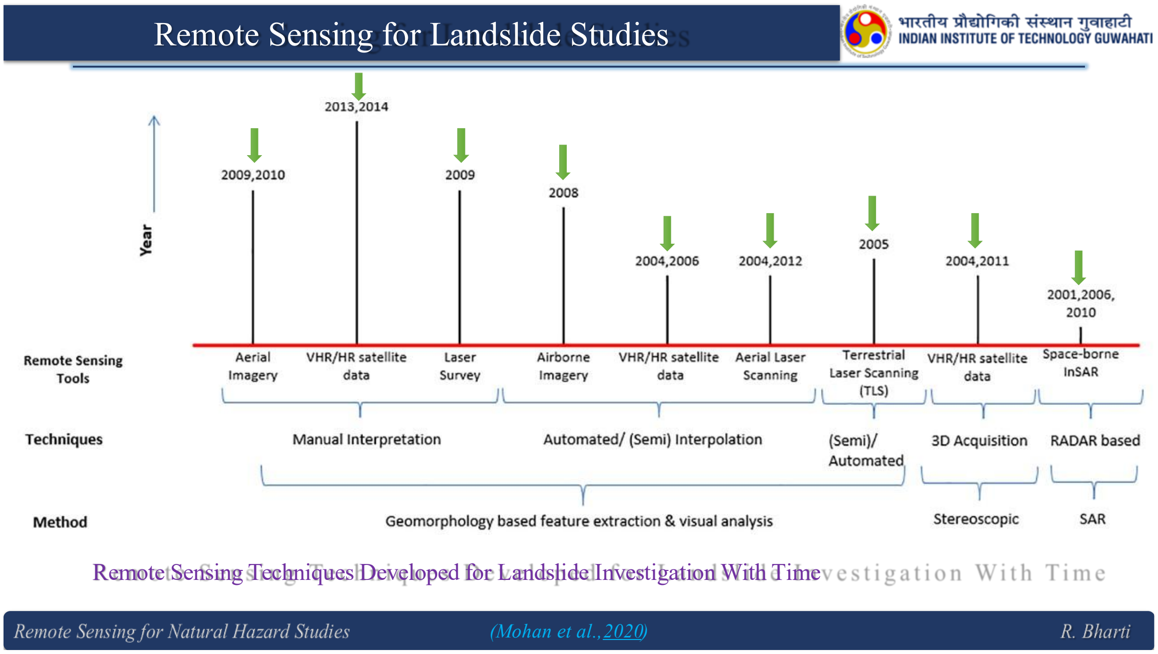


So, these spatial, spectral, and temporal resolutions are very useful in natural hazard studies. Now, access to inaccessible areas comes. Because some of the areas we all know are restricted, we try to visit them, but due to some limitations, we may not be able to visit that particular area, and we will not be able to conduct any analysis. But when we have remotely sensed images that provide you the opportunity to investigate the inaccessible area from space. So that is the advantage.

Real-time or near-real-time data. So, as we discussed, the images are very, very useful for natural hazard pre- and post-event analysis. So, in real time, there are measurements happening from different satellites that you can utilize for pre- and post-event information. A wide range of data means we are utilizing different wavelength regions, starting from visible to infrared to microwave. So, all this information can give you different insights about the target, and those different wavelengths can convey different properties of the same material.

So, depending on the application, we try to utilize the different domains of wavelength in our remote sensing. This is systematic and repetitive data collection. If you remember, I talked about the Landsat Data Series. So, we have different sensors or satellites launched since 1979, and up to the present date, we have had different measurements from various series of Landsat data. So, here you can utilize this systematic data acquisition to superimpose or use the algorithm to see the changes. So, the pre- and post-event information, or if you want to see how an area has evolved over time in a decade or two decades, can be done with a remote sensing dataset. So, this is a brief introduction to the advantages of remote sensing or geospatial technology. Now, we will move forward with remote sensing for landslide studies. So, here there are three different categories. The first one is landslide inventory mapping, which is your detection.

If you remember, when a landslide occurs, the pre- and post-information is very, very crucial. So, when we want to do any analysis, the first thing is to detect the landslide. Now, the next one is the landslide susceptibility mapping, and then comes the landslide deformation monitoring. So, we will discuss all of these in today's lecture. And we will see, one by one, the potential of remote sensing applications in landslide studies.



So, starting from detection to susceptibility to deformation, we will try to see different examples, and we will be referring to some of the standard publications. So, here you can see the key remote sensing data sources for landslides. So, the first one starts with optical imagery from Landsat, Sentinel, and Google Earth. The application is landslide inventory mapping and land cover analysis, which are very crucial. Then comes the SAR, or synthetic aperture radar. So, here you have Sentinel-1, ALOS, and Pulsar, which are being used for ground deformation detection and monitoring. Then comes the LIDAR; here are the airborne and UAV-based LIDARs that are available. So, here you can go for high-resolution terrain modeling, which is important when you are dealing with very small-scale landslides where you need very minute details about the topography. So, the digital elevation model available in the public domain of 30-meter or 20-meter resolution is not useful, then you have to go for the lidar. Here comes the rainfall data.

Here, TRMM and GPM rainfall-induced landslide assessments are very, very important because sometimes the in-situ information is not available. So, in such condition, the rainfall data from TRMM or GPM that will help you to analyze the area. This particular slide provides you with a comprehensive understanding of the remote sensing application. So, let us go one by one. So, here you can see this is the space investigation; here you have satellites, and here you can monitor how parameters are changing in a particular area.

Then comes the air investigation, which is the airborne survey, and here you have UAV space aircraft. Those will be used to generate a high spatial resolution dataset. Then we have the ground investigation. So, we have a laser scanner or the GBSAR. GBSAR is basically a ground-based synthetic aperture radar. So, this is very useful in identifying the minute changes or deformations in the study area. Then let us see here; when we have a satellite, it has a fixed orbit. So, it has a temporal measurement.

So, maybe today at 10 a.m., then again at 10 a.m. after 14 days, and then again at 10 am. after another 14 days. So, this information will help you understand how the area is changing, how the topography is changing, and when you are using the aircraft or UAVs. For a particular area, you can fly these instruments in different wavelengths, and then you can capture information about the landslide. So, here is the example of an active landslide; here is a fresh landslide, and this is the ancient one. So when you are having this, you can use the laser scanner here or maybe the GB-SAR, and then you can see the surface deformation, which will be of very high accuracy. Now, here on this side, we have the time scale; then we have active landslides, fresh landslides, and ancient landslides.

Here, they have used optical InSAR and optical data. Here you have LIDAR, LIDAR, LIDAR. So, you can see how remote sensing data from different wavelength regions is used in landslide studies. Now, this particular slide says the various optical, radar, and thematic data used in landslide studies, particularly in Europe. So, the first one is the optical data; the blue color represents detection and mapping, and the red color represents monitoring.

So, this is the highest one, then comes the monitoring. And here you can see the visual interpretation, then photogrammetry, then change detection, image processing, object-oriented analysis, classification, spectral indices, how they are used in different detections and mappings, and monitoring. So, here you see that in visual interpretation, detection and mapping are high, whereas this monitoring is low. So, similarly, you can see this particular graph, and you can understand how optical remote sensing or how optical techniques are used in landslide studies.

Then come the radar techniques. So, here again, blue represents the detection and mapping, and red represents the monitoring. So, here you can see the A-DInSAR, DInSAR, SAR, and GB-SAR, how they are used because these are all space-based, but here this is ground-based. So, this ground-based are the instruments are costly. So, that could be a reason why very few people are using it, but it also has the potential in landslide studies. Now comes the thematic map. So, here you can see the percentage is on the y-axis, and on the x-axis, you have DTM and derived maps, as well as the landslide inventory map. Geological maps, geomorphological maps, hazard maps, lithological maps, risk maps, hydrogeological maps, land use maps, damage survey data sets, and hydrologic maps. How remote sensing is used in different landslide studies, including the detection and monitoring represented by blue and red colors. So, this will provide you with concise information about the remote sensing datasets used in landslide studies, particularly in Europe. This particular graph will provide you with the information on the number of landslide studies that used remote sensing datasets.

So, the first one is the susceptibility mapping, which shows how our area is susceptible to failure. So, this is the highest, then the detection, then you have assessment, then monitoring, then extraction, then inventory, stability, and influence of training data. then management. So, here you can see the number of landslides. So, this susceptibility mapping is where people have used the remote sensing maximum.

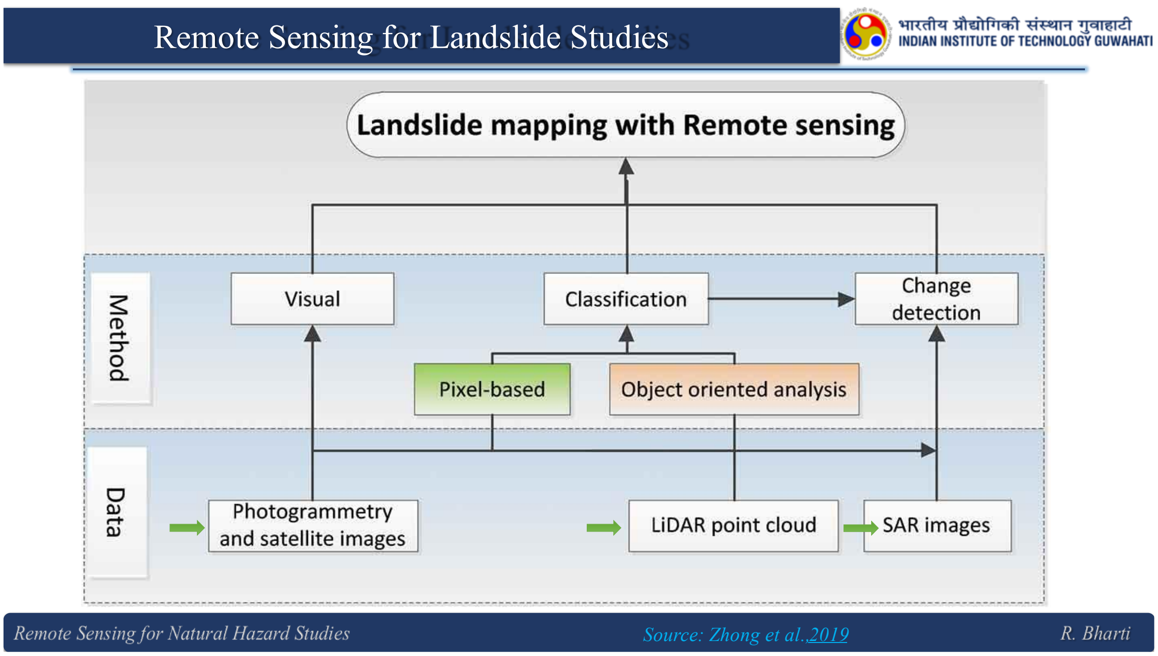
I will try to summarize the advantages of remote sensing once again so that you will have a better understanding and be able to perceive how remote sensing can be used in your studies. So, the large-scale coverage captures data over vast and remote areas, including inaccessible terrain. Then high-resolution data, where we have optical Lidar and SAR-based measurements, provides fine-scale spatial resolution, allowing precise mapping of landslide-prone areas. Then comes the multi-temporal data. So, as I discussed before, multi-temporal data sets are the data sets captured at a particular frequency.

So provides historical and real-time data for detecting changes over time. Then, high-resolution topographic data, the lidar, and the stereo satellite images generate high-resolution digital elevation models to identify terrain features that contribute to landslides. Stereo satellite images are basically the images captured by the same satellite from 2 different positions. So, this is the distance between these two, and they are capturing the same area. It is like our eyes; both of our eyes are placed at a particular distance, and because of that, we are able to generate stereo images, which allows us to perceive height and depth information.

Similarly, when you are having the stereo satellite images captured from 2 different positions. So, we will be able to generate a high-resolution digital elevation model, and the digital elevation models are basically yours. x, y, z values: x is your latitude, y is your longitude, and z is your elevation. So, that information will be used further for slope and aspect calculations. This is a non-invasive and cost-effective method; the integration with GIS and machine learning is the best part of remote sensing and GIS, as these images are generated through remote sensing satellites.

So, that can be part of our decision support system or our So, any machine learning methods can be used here to analyze our remote sensing images. Detection of ground deformation using interferometric SAR, which I hope you remember I discussed in the remote sensing component. Detects millimeter-level scale ground deformation that can be used for the early warning system. So, what happens in the interferometrics is that we are generating the interferograms, and then we are generating the phase information, and that phase information will be used for identifying the changes, and that will be on the millimeter scale. Rapid disaster response quickly assesses post-landslide damage using optical and SAR imagery.

So, it is very difficult to read the area if there is a major landslide. So, in such a condition, the satellite provides you with the additional eye that will be looking at the area and will provide you with the actual scenario after the disaster. Satellite-based rainfall data for landslide assessment is important because many regions do not have ground-based precipitation information. Satellite-based rainfall data for landslide assessment provides especially continuous rainfall estimates over large areas and remote areas. This is very, very useful when you do not have the ground measurements.



So, many of the areas do not have ground stations for precipitation measurement. So, in such conditions, the satellite-based rainfall data will provide you with the information that will help you do your analysis, and you can perform the landslide susceptibility or landslide studies. So, let us talk about landslide inventory mapping. So, that is basically your detection. Collection of data and information on the occurrence, spatial distribution, and intensity of landslides, along with the identification of elements impacted by the deformation process

So, this is very, very useful. So, the first one is the conventional method of how we do a geomorphological survey, then visual analysis of aerial images or orthophotos. Orthophotos are basically satellite images where geometric correction has been done. So, these are geometrically and topographically corrected datasets. Then comes the recent methods. So, now what we are doing is that we are still using visual analysis of optical remote sensing data, but we are also incorporating the multispectral, hyperspectral, and synthetic aperture radar-based datasets.

So, these will help you, and they will provide you with the information about the landslide. So, that is how we are generating the landslide inventory, which is very useful because when you use machine learning or any advanced techniques to monitor or forecast the landslide, you also need historical information, and that historical information can be identified or collected by remote sensing datasets. Here, this particular slide discusses remote sensing techniques developed for landslide investigation over time. Now, here you see that in 2009 and 2010, we had the aerial imagery, then high-resolution satellite data, then laser survey, then airborne imagery, and then high-resolution satellite data.

Here you see the years. Aerial laser scanner, terrestrial laser scanning. Then, high-resolution satellite data, then space-borne InSAR. So, here these are used for manual interpretation; this is for automated or semi-automated; this is again semi-automated; this is the 3D acquisition; then you have radar-based. And when you combine these, you have geomorphology-based feature extraction and visual analysis. And here you are going for the stereoscopic, and then we have the INSAR or radar-based, which is SAR, synthetic aperture radar.

So, this will provide you with concise information. I am just trying to give you the flavors of remote sensing and how different remote sensing techniques can be used in landslide studies. Let us start with photogrammetry and satellite-based. So, this can be used for visual analysis. When we have LiDAR point clouds, we can perform object-oriented analysis, and then when we have SAR, we can conduct change detection. And all of these can be integrated together in a GIS environment, and then we can go for pixel-based classification, and we can also go for object-based classification, and both will provide you the opportunity to identify the pre- and post-conditions of the area.

And then, when you are integrating all these datasets and all this information derived from remote sensing data, we can call it landslide mapping with remote sensing. When we talk about the visual interpretation of remote sensing data, the data sources will be the aerial photograph and the airborne survey that will provide you with the airborne datasets. And then you have high-resolution satellite images, because when you are conducting the visual analysis, you need high spatial resolution; only then will you be able to identify the objects on the ground or even the boundary of the landslide. So, that is why the high-resolution satellite datasets are used.

Then you have UAV-based images and digital elevation models. So, these are different datasets that are being used in the visual interpretation of the data. Then the characteristics identified in the image. So, shape, size, and photographic color. Tone, modeling, texture, pattern, site topography, and settings that can be studied using this visual interpretation.

When we go for the automated one. So, here are some of the traditional pixel-based algorithms, like threshold segmentation, change detection, and supervised and unsupervised classification; these methods are widely used, and here I have also mentioned the references. So, if you are interested in any of these methods, you can refer to their papers for more details; they have nicely represented their methodology. The difficulties in the automatic extraction of features arise due to landslides not having a distinct spectral or spatial signature. Why? Because when we talk about a landslide, we are talking about the failure of this slope, which can be made up of soil, rocks, and soil of different natures. So, all these different soils and rocks have different spectral signatures.

So, as such, landslides do not have any distinct spectral and spatial signatures. So, whenever you want to identify the landslide, you need to have high spatial resolution. Then, based on the geometry and the shape size, you will be able to identify whether this is a deformed surface or a failed slope. Due to the variety in types of landslide, a large number of possible scenarios exist. So, the landslide we have already seen, there are very different types of landslides, different types of mass movement, and different types of velocity; all of them will have different natures.

But when we are trying to automatically identify or interpret the remote sensing images for landslide studies, we have to be very cautious because landslides, as such, do not have any distinct spectral or spatial signature. So, in such a scenario, we have to be very, very careful, and we should look for the parameters that are influencing. Then comes the detection of landslides using microwave remote sensing data sets. So, the lidar, the light detection and ranging data, that is the first choice for very high resolution DEMs, can generate detailed spatial information on the surface of the earth. LiDAR can penetrate the tree canopy; thus, it is very useful in densely vegetated regions.

Because we are talking about a slope, this slope can have vegetation. So, normal optical remote sensing means the visible range, or VNIR or SWIR wavelength range; that information will be the reflected energy from this top surface. But when we talk about the microwave, it has the depth of penetration, and that can penetrate the tree canopy. So, microwave remote sensing can provide you with surface information in vegetated conditions. Now comes the DInSAR differential interferometric synthetic aperture radar. So, it is useful in the identification of creeping landslides because, if you remember, creeps are very, very slow; we need to have a method by which we can identify the millimeter level of creep, or the changes.

So, that comes with differential interferometric SAR. So, what will happen here? You will have continuous measurements at time intervals of the same area, and that will be used to generate the phase information. That phase information will be useful in identifying the velocity or the changes in area. and that will be at the millimeter level of scale. Permanent scatterer interferometry (PInSAR) can identify coherent targets. It allows millimeter-level accuracy in estimating the relative target velocity.

With this, I will end part 1 of lecture 30. We will continue this in Lecture 30, Part 2.