Watershed Management

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Module No. # 06

Lecture No. # 23

Remote Sensing and Applications in Watershed Management

[FL] and welcome back to the video course on watershed management in module number 6, lecture number 23.

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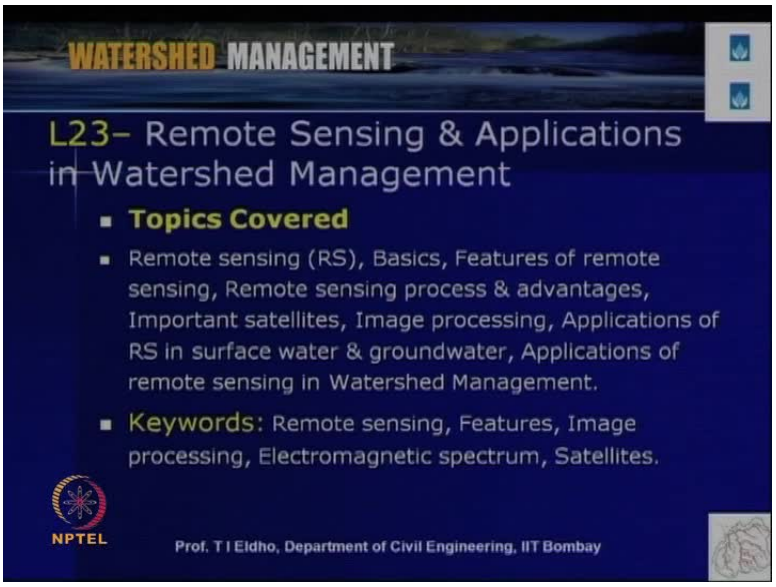

Today, we will see remote sensing and applications in watershed management. Some of the important topics what will be covered in today's lecture include remote sensing, basics, features of remote sensing, remote sensing process and advantages, important satellites, image processing, applications of remote sensing in surface water and ground water, applications of remote sensing in watershed management. Some of the key words for today's lecture include remote sensing, features, image processing, electromagnetic spectrum and satellites.

As I already mentioned earlier, when we deal with watershed management or watershed management plans, we will be dealing with large area just like watershed river basin or a catchment. It is a very huge area, so we have to get so much of data like the topographic data, land use data, land cover data, soil data. So, like that so much of data are needed to develop appropriate management plans or to develop models to study the various behaviour of the system, related to water resource management or land management or the development of various rainwater harvesting structures, since we need huge amount of data. If we go to field and collect data, there are limitations, since we cannot get entire data in an appropriate way, which requires for a modeling or which requires to develop appropriate management plans.

As we discussed earlier, the remote sensing helps in a big way for hydrologic related modeling or watershed related planning and management and so in this context, in today's lecture, we will discuss some of the basic aspects of remote sensing. Remote sensing is a big area, where so much detail has to be discussed, but in today's lecture, we will be discussing only the important perspectives, which are related to watershed management and some of the basics and applications related to watershed management.

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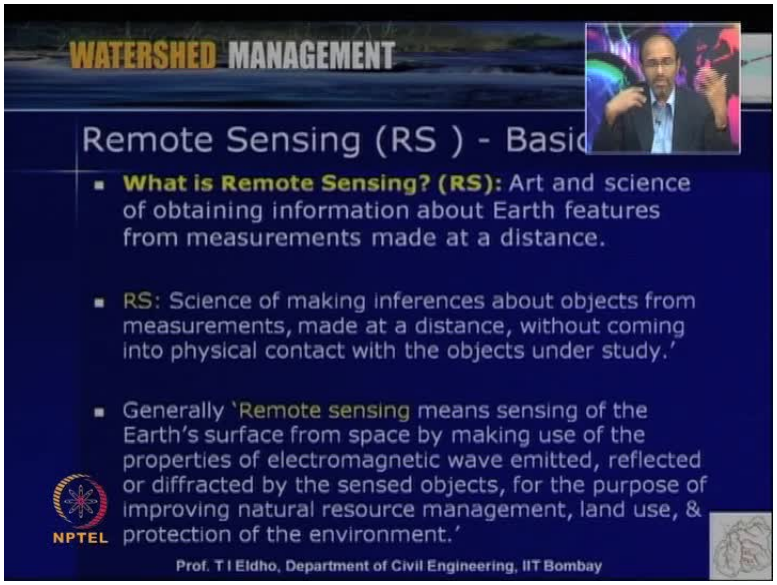

Let us now look into the some basic aspects of remote sensing. As already discussed earlier, remote sensing is an art and science of obtaining information about earth features from measurements made at a distance. As the definition shows, we are not directly

going and getting the data or we are not coming in contact with various data, which we are directly collecting. We are getting the data remotely from a distance; either it can be an aircraft flying over the area for a satellite passing over the area.

At a remote distance and through various means, we are getting the data required. Art and science is called a remote sensing, so that way, remote sensing is a science of making inferences about objects from measurements made at a distance without coming into physical contact with the objects under study. When a satellite is passing over an area like watershed or a river basis, then it is sending certain signals or it is collecting certain data based upon its movement and various other parameters. We are processing and utilizing that data.

There is no direct contact with the objects, but we are getting the correct data remotely. Generally, remote sensing means sensing of the earth's surface from space by making use of the properties of electromagnetic wave emitted, reflected or diffracted by the sensed objects for the purpose of improving natural resource management, land use and protection of the environment. So, this is a general definition in modern times with respect to remote sensing. Earlier, there used to be number of ways and we used to get this data remotely; either using some balloons or we use aircrafts. Nowadays, we are using mainly satellites; remote sensor satellites.

In this, we are getting the data in such a way that the electromagnetic waves emitted, reflected or diffracted by the sensed objects. We get back this data, we process this data and we use it in an appropriate form, so that is the modern day remote sensing. In earlier times, we used to get data through flying over the… or by using the aircraft or by using balloons or other kinds of mechanism. Remote sensing plays a major role in most of the watershed development management plans.

Since we can get so much of data, one scene gives entire spectrum of the watershed, which we consider. Once we process those data, we can get the details on our computer like land use, land cover, soil map or the slope map. After processing, all these are in remote sensing package or GIS package. We can make it at appropriate format, so that way the modern remote sensing uses satellites.

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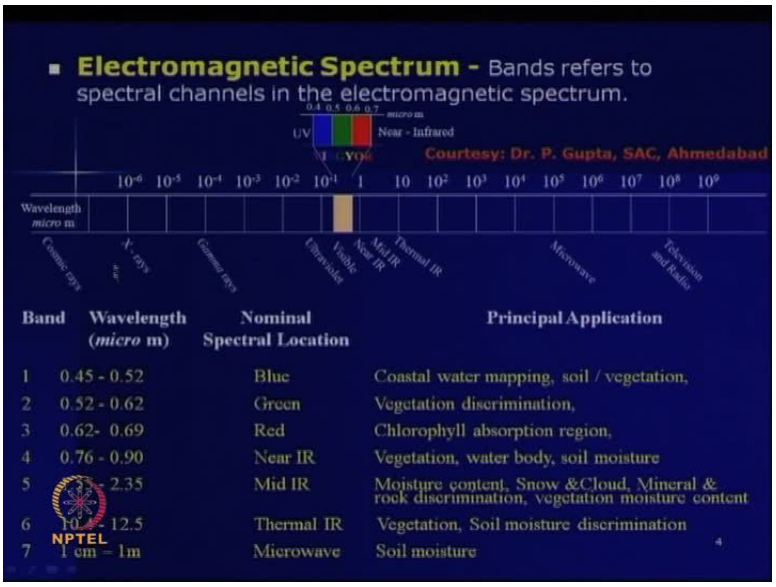

We are using the electromagnetic spectrum. It means that you can see that the various spectrums of electromagnetic spectrum and I have listed here. Here, we use the bands that refer to spectral channels in the electromagnetic spectrum. Here, we can see that as per the wavelength in micrometer, there are various electromagnetic spectrum bands like cosmic rays, X-rays, gamma rays, ultra violet, visible, near IR, mid IR, thermal IR, microwave, so the wavelength used for television and radio.

Actually, for remote sensing purpose, we use these ranges starting from ultra violet to sometimes to microwave. Here, I have listed various bands, so the band here refers to spectral channels in the electromagnetic spectrum. So, bands one to seven; their wavelength is given in micro meter, starting from 0.5 to 1 meter, so that nominal spectrum location, for example, within the wavelength of 0.45 to 0.52 is blue and then 0.52 to 0.62 is green. Correspondingly, the principle applications are also listed, for example, in this range 0. 45 to point 0.52, we can use for coastal water mapping soil or vegetation. 0.5 to 0.62, which is the nominal spectral location in the green range. So, we can use for vegetation discrimination. 0.6 to 0.69 is the range of red bands, so we can use for chlorophyll absorption region. 0.76 to 0.9 near infrared to identify or to get the application in the field of vegetation, water body, soil moisture etc.

So, for various applications, what kinds of bands, which we are using are listed here. Principally, the bands start somewhat remote sensing and generally, it is starting from

this ultra violet or this this range and going up to microwaves. That is the main region or the band of the electromagnetic spectrum, where we generally use for remote sensing. For example, 1 meter or seventh band, which is the microwave, we can use it for soil moisture. So, some of the advanced remote sensing satellites use this band and that can be used for even for soil moisture study.

We use particular bands for particular applications. So, depending upon where we are using the remote sensing satellites, whether for land use, land cover or soil moisture or ocean application or coast region applications. Accordingly, we can choose specific bands of the electromagnetic spectrum or specific satellites are put for those particular bands like the microwave region. We can choose particular satellite; remote sensing satellite in particular bands for the specified applications, which we are trying to do for that particular application.

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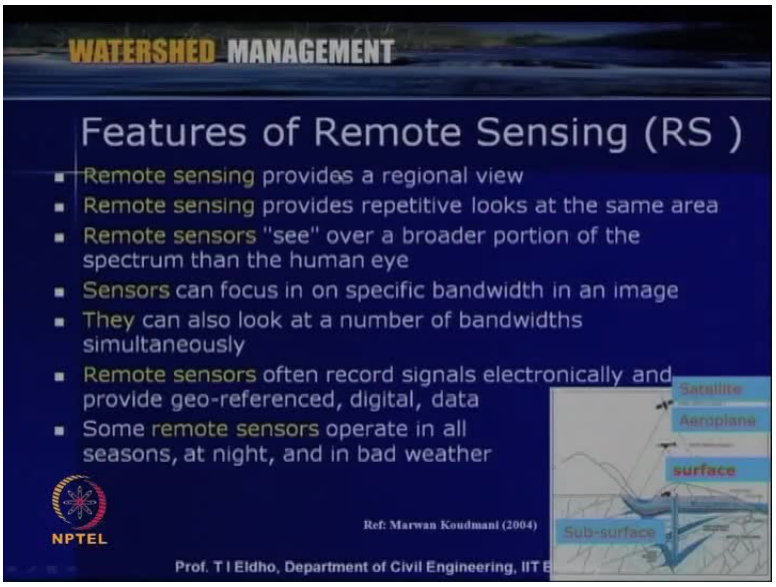

Now, within this background, let us look into what are the important features as far as remote sensing is concerned. In this slide, various features are listed here. So, we can see that here in this figure, which is taken from Marwan and Koudmani, 2004. This is the satellite or the aircraft, which is flying over or this is a satellite moving over the surface. You can see that this is the way the scanning or the reception of the particular electromagnetic spectrum band is the receiver obtained. This remote sensing provides a

regional view, if this is the watershed, so that entire region within one passage of the satellite that we are obtaining.

Another important aspect is- it provides repetitive looks at the same area. Once the satellite is passing over this after few days or one week or two weeks and like that in the same area, we get the data again in a repetitive manner. The remote sensors see over a broader portion of the spectrum than the human eye, so that is the advantage. When we are in an aircraft, we can see larger area. If you are in the satellite, which is further above the aircraft and this range, so it will be getting much broader portion of the area, which is it is taking.

It may be watershed or a river basin scale. We can easily get the data required for the various hydrological modeling or development of watershed management plans. It is possible that the sensors can focus on a specific bandwidth in an image. As I already mentioned in the previous slide, they can also look at a number of bandwidth simultaneously. Some of the satellites can look into the area at a number of bandwidth simultaneously, so that is the advantage. Nowadays, the modern satellites; remote sensors often record signals electronically and provide geo-referenced digital data.

The data, which is either through diffraction or reflection or whatever way it is getting back to a satellite, so data is obtained geo-referenced. We can easily identify what is the location and this data will be digital. We can process and can develop appropriate maps or appropriate data required for hydrologic modeling or the development plans. Some of the other advantages like remote sensors. Nowadays, with modern techniques, we can have remote sensing or remote sensors operating in all seasons at night and even in bad weather.

Like microwave or the advanced types of remote sensing satellites can give their data all time at night or any bad weather like a heavy rainfall or cyclonic or whatever the weather conditions and in all these, data can be obtained. This remote sensing technology has developed in the last few years. We can see that very sophisticated data; high-resolution data up to 1 meter resolution. Some of the satellites from USA or Russia can even go higher resolution, further to 1 meter like 0.5 meter level are available nowadays.

Depending upon whether the usage or depending upon climate or the army or navy or whichever the agencies, various remote sensing satellites are available. Various agencies like NASA or Indian Space Research Organization. We are not going to be covering all the aspects of remote sensing and it is not possible also. I am planning to give only one lecture to this remote sensing application as far as watershed management is concerned. We will be only going to some of the important aspects, which is relevant to the applications related to watershed management. Now, we have seen the basics and let us see how the remote sensing is done and what are the important processes taking place.

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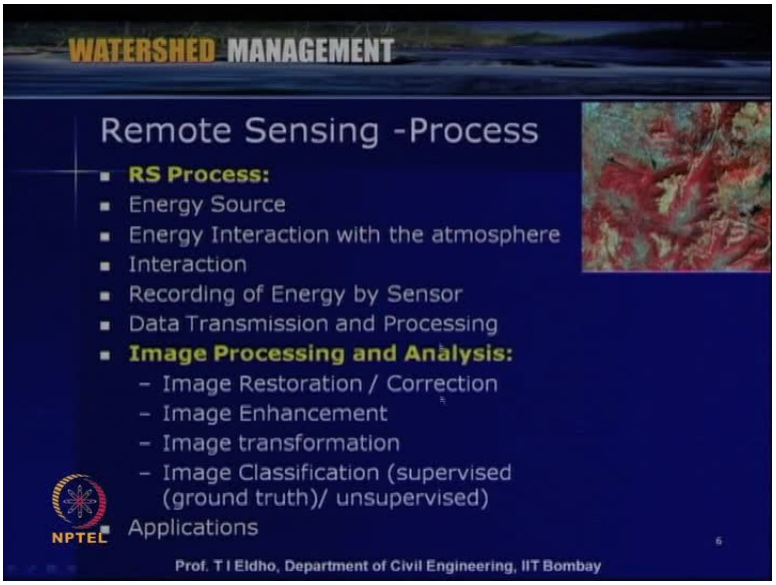

These details are given in the slide. To get the remote sensing data, there should be an energy source, which is either reflected or diffracted like that. As I mentioned in the previous slide, this energy interaction with the atmosphere takes place. After the interaction, the satellite is getting back. So, recording of energy by sensor and then data is to be transmitted to the stations on the earth. That data will be processed, so that way remote sensing process is a quite complicated process. First, the satellite should be there; remote sensing satellite should be there. Satellite is collecting, sending certain signals, for example, with respect to the heat from the solar heat, which is reflected on that way and also some satellites are there or infrared region or whatever it is.

First of all, the remote sensing satellite is passing over particular area, the energy resource and then energy interaction with the atmosphere. Once that satellite has done, it

has to get back this data. Data has to be transmitted to the station and then that data has to be processed for further utilization. Remote sensing process is a complicated process. Number of steps are there and there are specified centers like remote sensing centers, for example, in India, it is national remote sensing space center, NRSC located at Hyderabad.

As far as watershed management plans are concerned, we are looking directly at the data from the agency concerned for the specified date or for specified location by providing the latitude and longitude for that particular location. We request the data to the NRSC or specified agencies and we collect the data and we have to process in specified softwares like Erdas or other kinds of specified softwares and that process is called the image processing.

Image processing and analysis - specific softwares are nowadays available, what we are doing is the image restoration and correction and we enhance the image, so that is called image enhancement, image transformation and then we do image classification. This image classification can be either supervised or classified. We can compare with the ground truth at few locations and that is called a supervised classification or we can do unsupervised classification. So, these are the fundamental steps involved in image processing, starting from image restoration or correction.

Once we get the image, we do image enhancement, image transformation and then image classification. We can utilize this particular image for various applications, for example, this is for a particular watershed and the data is obtained. We get a FCC or false colour composition and it is based upon that. We can get the surface features of that particular watershed like the drainage pattern or the river location or the land use or land cover. Nowadays, various software are available and that softwares like Erdas can be used for this image processing and analysis. Since our aim in this lecture is not to go into the more details about the remote sensing, but we are mainly looking within the perspective of applications to watershed management.

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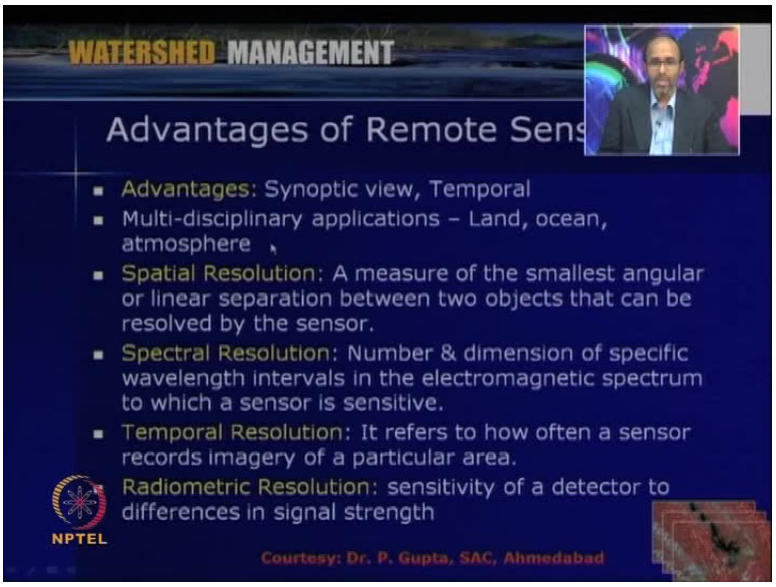

Let us look into what are the important advantages of remote sensing. Some of the few advantages, I have listed here. First one is we can have a synoptic view, when a satellite is passing that specified area or wherever the scanning is taking place that particular watershed is there. So, we get a total view of that particular area.

We get a synoptic view and then a temporal, so that means when the satellite is again coming back after few days, especially various plans for agriculture or the flooding problems. This kind of temporal variations can be easily obtained using the particular satellite data. This is another advantage and of course, this remote sensing is multidisciplinary applications. So, various applications are there in hydrology like land related applications, ocean related applications, climate or weather predictions or atmosphere related application. So, number of applications are there, which you will be discussing in the coming slide.

Now, within the perspective of remote sensing data like spatial resolution, spectral resolution, temporal resolution and radiometric resolutions. So, these terms are important and let us look into the definitions of these terms. So, spatial resolution means a measure of smallest angular or linear separation between two objects that can be resolved by the sensor. We can consider the spatial resolution, which we consider using the specific satellite used for remote sensing. Spectral resolution means the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a sensor is

sensitive. So, it is called as a spectral resolution and temporal resolution means that it refers to how often a sensor records imagery of a particular area.

The area which we are covering that particular area, after few hours or few days or few weeks, how we are getting the data? That is called a temporal resolution and the last one is radiometric resolution, which shows the sensitivity of a detector. Two differences in signal strength - what is the signal strength, which is getting back and accordingly, the data resolution will be varying. When we deal with the remote sensing data, we have to see the spatial resolution, spectral resolution, temporal resolution and the radiometric resolution, since we are now discussing only some preliminary aspects of remote sensing.

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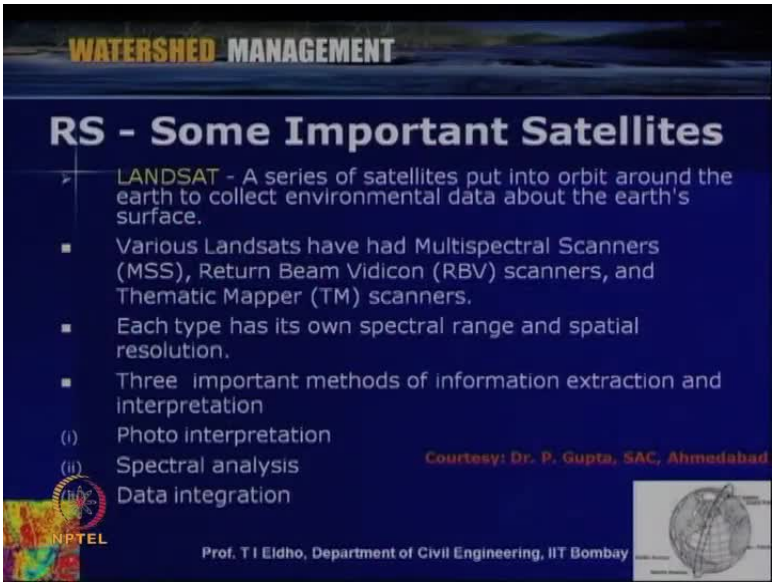

Let us look at what are the available satellites and some of the important satellites that are internationally available and also some of the remote sensing satellites available in it. Let us have a brief look into this. These data are given and one of the major sets of satellites, which we use for remote sensing from a Landsat satellite. A series of satellites are put into orbit around the earth to collect environmental data about the earth's surface are called as Landsat satellites. So, this is specifically for remote sensing and it can be for land related, ocean related or weather related satellites. Various LANDSAT have MultiSpectral Scanners – MSS, then Return Beam Vidicon - RBV scanners and thematic mapper scanners.

Actually, various countries like USA and other countries came together and that is the system of series of satellites available for remote sensing, so that series are called Landsat satellites. Each type has its own spectral range and spatial resolution as far as Landsat is concerned. So, three important methods of information extraction and interpretation using Landsat data like photo interpretation, spectral analysis, data integration. So, Landsat is a series of satellites that are very commonly used for remote sensing.

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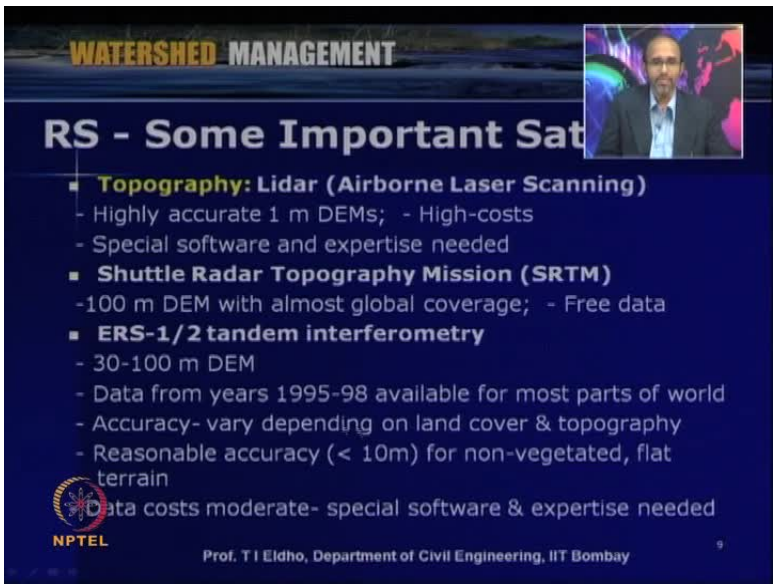

Depending upon the purpose, whether we are looking to topography or related to climate, parameter or vegetation and accordingly, specific satellites are available. If you are looking for topography, then the satellites called Lidar, which is an airborne laser scanning based satellites. For higher resolution data, we can use Lidar data. So, it is highly accurate even up to the level of 1 meter. So, we can get 1 meter digital elevation models using this data. The cost will be high because special softwares and expertise needed to process such data, so we can actually use. For example, to get the entire data for specified area, how the topographic features changes even into up to 1 meter resolution? May be defense purpose data can be used.

Another series, called as shuttle radar topography mission, It has SRTM related satellites and data. Here, 100-meter digital elevation model with almost global coverage are done. Under SRTM, which is the data provided by NASA in collaboration with other countries

is called SRTM data. It is available in the internet, which is supplied by NASA. Here, the interval is that it is very coarse data of 100-meter resolution, so this is actually free data. For hydrologic purpose or watershed management purpose, we can utilize this data, but the resolution is very coarse. In many of the applications, this SRTM data can be used.

Another series of satellites called ERS 1 by 2 tandem interferometry. Here, it is somewhat higher resolution, 30 to 100 meter digital elevation model can be obtained from this. so, data from years 1995 to 1998 is available for most parts of the world. Accuracy varies depending on land cover, topography, and reasonable accuracy; less than 10 meter can be obtained for non-vegetated or flat terrain. Data costs are moderate, so here the cost is less, special software and expertise are needed to process this data from the ERS satellite data. This is another one related to vegetation, if you are dealing with the land use, land cover and related data.

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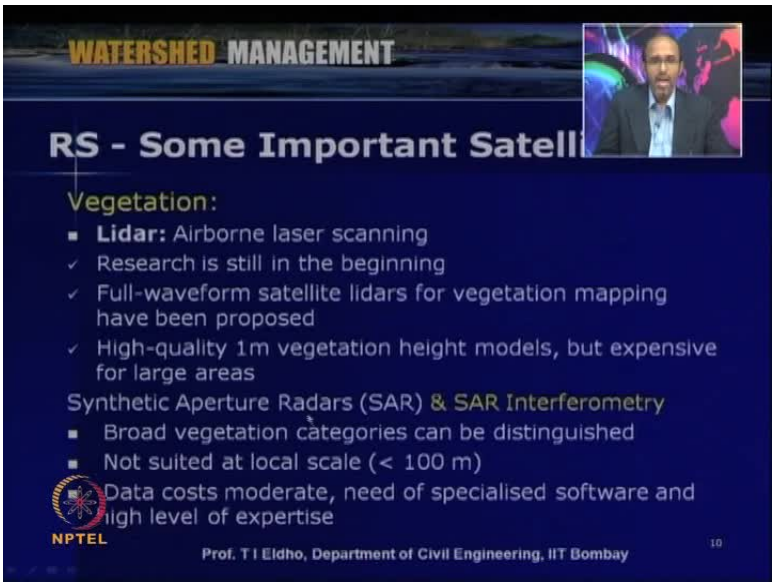

We can further use the Lidar - airborne laser scanning. Actually, this is a new series of satellite data, which is a having higher resolution up to 1 meter resolution. We can have the data and some of the satellites already started to give data. Further, agencies like NASA, European space agency and Japanese space agencies including Indian space agencies are also now in the process of having further satellites in this Lidar related satellites.

They are putting and then getting the data, here full waveform satellites like Lidars for vegetation mapping have been proposed. They are high quality data, we can obtain even 1 meter resolution, but these data will be expensive for large areas. It is difficult to get for a larger watershed or larger river basins, but for small areas, we can get the data and process. Another satellite or series of satellite is SAR data. So, Synthetic Aperture Radars or SAR system or SAR interferometry.

Here, broad vegetation categories can be distinguished and this is not suited for local scale. I mean it is less than 100 meter, data costs are moderate and need of specialized software and high level of expertise is required to process this data. Various systems are available for specified problems or specified cases. We can get specified satellite data, process it and utilize for that particular application.

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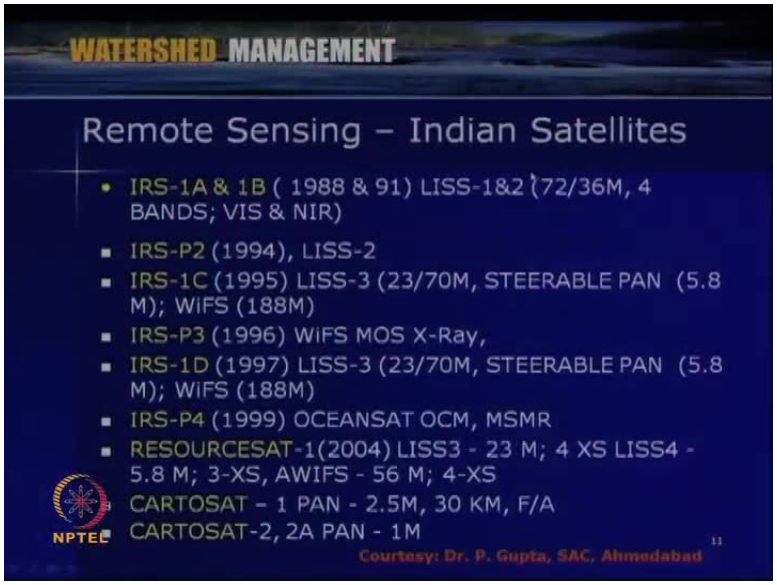

Now, let us look into the Indian remote sensing satellite. I have listed some of the important series of satellites put by Indian space research organization – ISRO. Beginning is in 1988 with Indian remote sensing satellite 1A and then 1B has been put in space. There are resolutions that was up to 72 or 36 meter with four bands and in 1994, IRS-P2 has been put. IRS-1C in 1995, IRS-P3 in 1996, IRS-1D in 1997 has a higher resolution like 5.8 meter. IRS-P4 is RESOURCESAT, which is giving 23 meter resolution in 2004 and the latest development is called CARTOSAT.

Some satellites may give resolution of 1 meter and for larger applications related to either hydrology or watershed management or ocean studies or atmospheric studies. These series of satellites can be used. This shows some of the important satellites available from India provided by Indian space research organization. So, this is about the available satellites internationally or from India.

Let us look into what are the important applications as far as remote sensing is concerned. As I mentioned earlier in this lecture, we are mainly concentrating in water related applications like surface water ground water and watershed related applications, so mainly we are looking to the application sides.

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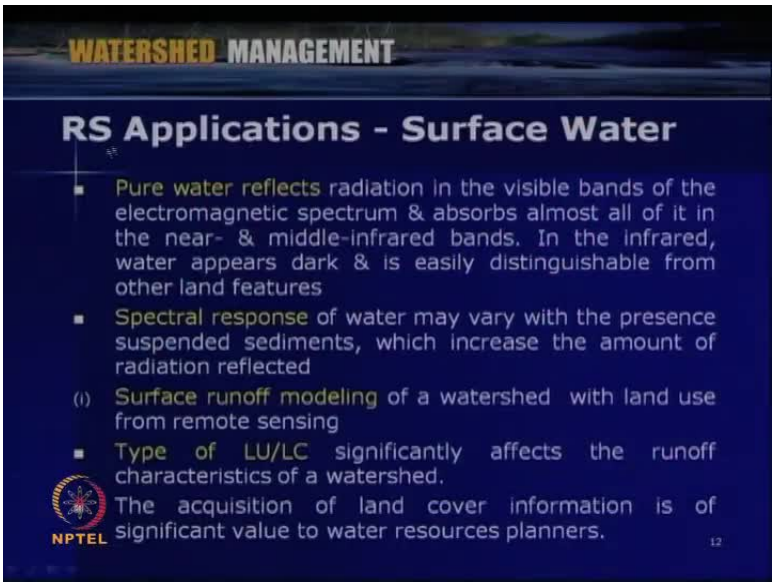

Here in this slide, remote sensing applications for surface water are given. The various applications have been listed here as far as the remote sensing is concerned. Pure water reflects radiation in the visible bands of the electromagnetic spectrum and absorbs almost all of it in the near and middle-infrared bands. In the infrared, water appears dark and it is easily distinguishable from other land features. Remote sensing data easily identifies the pure water bodies like lakes or rivers or the ponds to that level. Spectral response of water may vary with the presence of suspended sediments, which increase the amount of radiation reflected.

If any sedimentation is there or sediment problem is there in a different way, it will be reflecting. We have Surface runoff modeling of a watershed with land use from remote sensing. We can use in hydrologic modeling, which we will be discussing in later lectures. We can obtain the land use or land cover for the particular area and then from that we can obtain the roughness co-efficient like manning's roughness co-efficient. It can be directly used in the watershed-based modeling.

Type of land use, land cover affects the runoff characteristics of watershed, so that way, this data land use, land cover for a watershed or a river basin can be directly utilized. The acquisition of land cover information is of significant value to water resources planners. We can utilize the remote sensing in an effective way for watershed based or water resource based planning and management.

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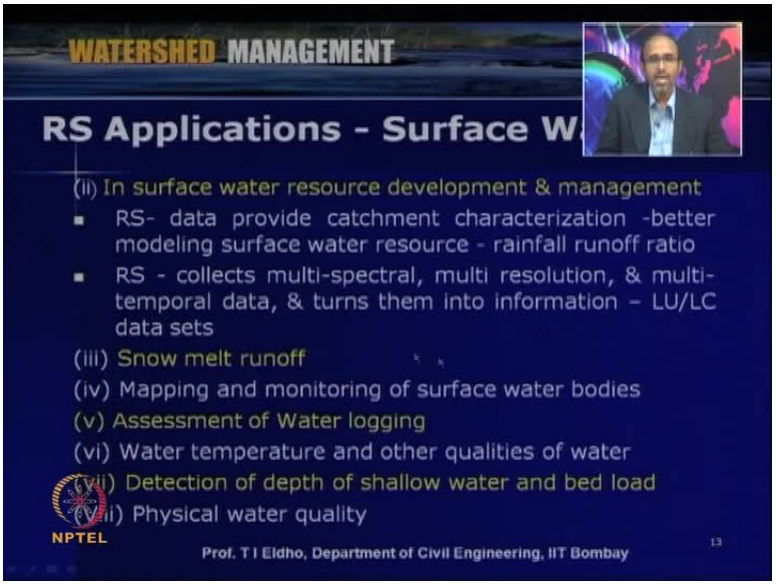

In surface water resource development and management, remote sensing data provides catchment characterization, better modeling surface water resource like rainfall to runoff. So, we need to identify, for the given rainfall, how much will be the runoff? We can either have distributed models or lumped models. We can utilize this remote sensing data in various ways for the hydraulic modeling to identify how much will be the runoff for the given rainfall condition. Remote sensing data collects multi spectral multi resolution and multi-temporal data and turns them into information like land use, land cover data sets, which we can directly utilize.

As far as surface water applications are concerned, we can identify the snowmelt runoff. If a particular area is snowfall, how much is the snowfall? How is the snow melting? so in the repeated way, temporal variation can be obtained and that gives lot of information as far as snowmelt, snowfall, snowmelt runoff is concerned. For surface water, we can identify mapping and monitoring of surface water bodies. If a reservoir is there, how much area is flooded or if any flooding problem is there, how the flooding is increasing or decreasing? Also on river basin scale or for large areas, we can assess how the water logging is taking place in that area, water temperature and other qualities of water. We can identify water pollution or sedimentation, related to ocean like oil spillage in ocean.

We can identify all those things using the remote sensing techniques and detection of depth of shallow water and bed load. Nowadays, with modern remote sensing techniques, we can obtain how much is the bed load taking place in a particular river and the depth of shallow water. In another area, particular river or lake or pond is polluted by using multi resolution or multi-temporal data or multi-spectral data that we can easily identify. For surface water, remote sensing has number of application that I have already shown in the previous slide.

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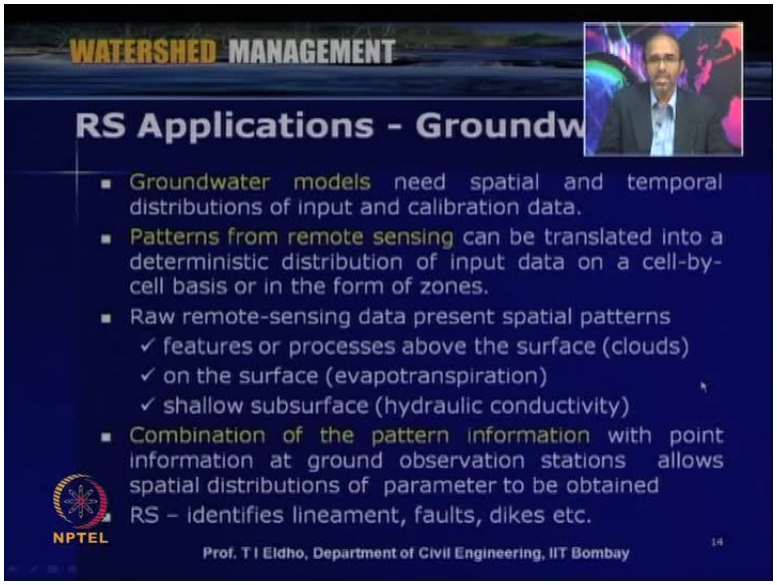

Let us look at what are the important applications related to ground water. Ground water is one of the very complex problem as far as hydrology is concerned. Since most of the ground water details can be obtained mainly through modeling, since data collection

through borewells or bore holes are very difficult process. So, with limited field data, we have to go for computer modeling. We get various aspects of ground water, variation of ground water flow and transport by running the models. This model generally require huge data, so that data can be given by remote sensing.

Ground water model needs spatial and temporal distributions of input and calibration data and we can obtain from the remote sensing. So, patterns from remote sensing can be translated into a deterministic distribution of input data on a cell-by-cell basis or in the form of zones. It can be for a small area like a grid of 50 meter by 50 meter, 100 meter by 100 meter or various zones like zone 1, zone 2 like particular homogeneous zones can identify the data.

Some of the raw remote sensing data present spatial patterns like features or processes above the surface. On the surface, how the evapotranspiration takes place? How the cloud variation, shallow sub-surface like hydraulic conductivity or soil moisture variation is taking place? All those things can be identified using the remote sensing and in combination with pattern information. With the point information at ground observation, stations allows spatial distribution of parameters to be obtained especially in ground water modeling. It identifies the linear means, faults, dikes etc. We can easily put it in our models; a ground water models and that will be very helpfully in the overall ground water model development. Remote sensing has number of applications as far as ground water is also considered.

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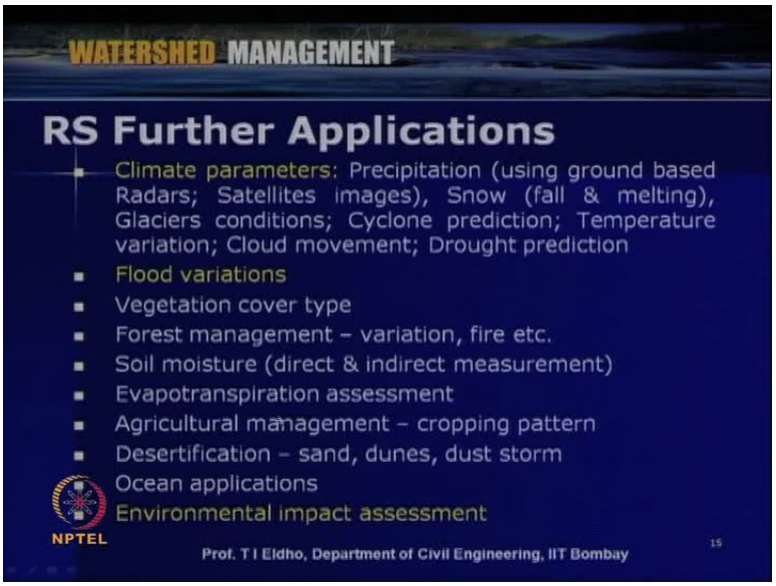

Now, let us look into further applications of remote sensing. I have listed here various applications like we can identify number of climate parameters using remote sensing like precipitation using ground based radars or satellites images. Nowadays, instead of getting the rainfall or precipitation using the automatic or non-automatic gauges, we can use radar-based system. It can give various rainfall variation in a larger area in a very accurate way, so that way radar data can be used or satellite images can be used.

Snowfall and melting - As I already mentioned, it can be obtained through either radars or satellite data and then glacier conditions. The movement of the glaciers or the melting of the glaciers can be easily identified by using the satellites. Cyclone prediction - we can identify the cloud movement and any cyclone formation is taking place. It can be easily identified by the satellites that is remote sensing satellites and we can easily use for a cyclone predictions. So, how the movement is taking place, with hourly movement or a daily wise movement? That that particular area will be affected by cyclone, so that way we can easily predict.

We can obtain temperature variation through modern remote sensing satellites. As I mentioned cloud movement or drought prediction as far as weather predictions or climate parameters are concerned, we can use remote sensing satellites in a very huge way at various cases. We can utilize some other applications like flood variations in

particular area due to rainfall or bridging of dam; whether flooding situation takes place, how the flood is progressing.

All those variations can be easily obtained from the remote sensing data and then vegetation cover type, huge applications are there in forest management. At particular time, how the forest is spreaded? With respect to time, how the variation is taking place? For example, in winter, summer or from year to year, how the forest variation is taking place? We can easily obtain it from remote sensing. We can identify forest fire; we can identify soil moisture using remote sensing either directly or through indirect measurement, Evapotranspiration assessment can be done. Another important area is agriculture management like we can identify through climate predictions or the rainfall predictions. We can also asses the agriculture conditions and then crop health or the cropping pattern.

For all those things, we can use the remote sensing, then drought management like desertification- sand, dunes or dust storm. So, all those things can be identified using the remote sensing and another area, where huge applications are there in various ocean or coastal regions. If there is an oil spillage, how much area is affected and where the plume is moving. W can easily identify that and using lot of application related to fishing or related to various behavior that can take place in the ocean. So, we can obtain all these through remote sensing.

Another area is environmental impact assessment. If a particular system is built, how the river basin or the watershed is behaving? We can identify that also in the environmental impact assessment using the remote sensing. Now, whatever we discussed is the remote sensing application for surface water ground water or ocean applications or further applications.

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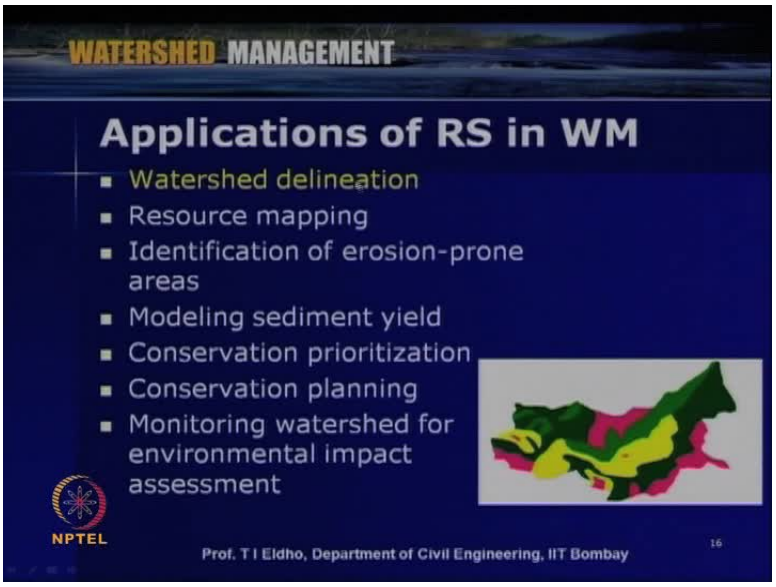

Now, let us come back to the watershed management. How remote sensing can be effectively utilized either in the development of watershed management plans or the implementations or the evaluations. In this slide, I have listed various applications. First one is watershed delineation. We have already discussed about the watershed delineation in one of the previous lecture, so we can obtain the remote sensing data.

We can process with the help of topo sheet and other maps. We can delineate the watershed either in software like RPO or other GIS software. Some of the other important areas are resource mapping, identification of erosion prone areas, modeling sediment yield, conservation prioritization, conservation planning, monitoring watershed for environmental impact assessment. So, all these points we would discuss in detail in the next slides.

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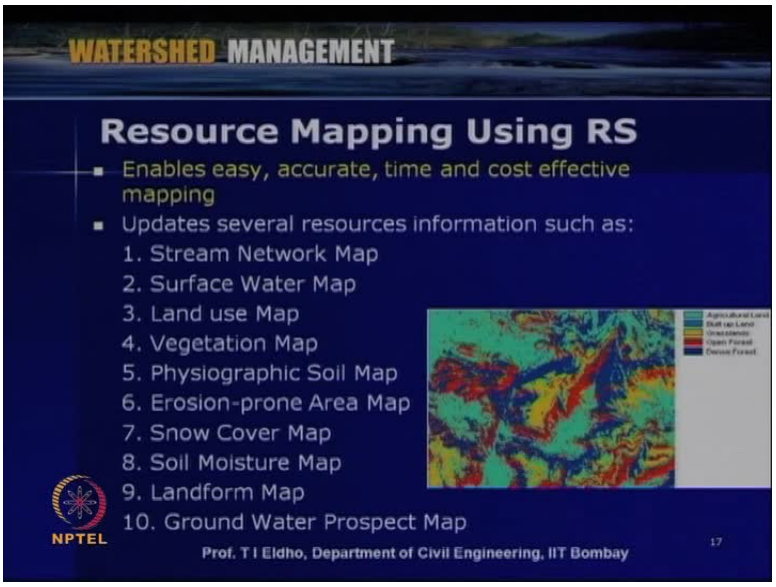

First one is resource mapping. Using the remote sensing, as I already mentioned in the earlier lectures, we are dealing with larger area as far as a watershed or river basin is concerned. So, to get a synoptic view for that particular area in a total view, if you can get like land use land cover or soil related issues or the vegetation, then that will be very useful for a watershed development management plans.

Remote sensing enables easy, accurate, time and cost effective mapping as far as the watershed is concerned. Remote sensing updates several resources information such as like stream network map within the watershed, surface water map, land use map, vegetation map, physiographic soil map, erosion prone area map, snow cover map, soil moisture map, landform map, ground water prospect map, so like that based upon the remote sensing data. Once we put this after processing in software like Erdas and then putting to appropriate GIS packages and manipulating with respect to the various input data, we can generate a series of maps like land use map, land cover map, vegetation map, erosion prone map, snow cover map, soil moisture map. So, various maps or resource maps can be generated using the remote sensing, so that way, remote sensing is very important in watershed management development plans.

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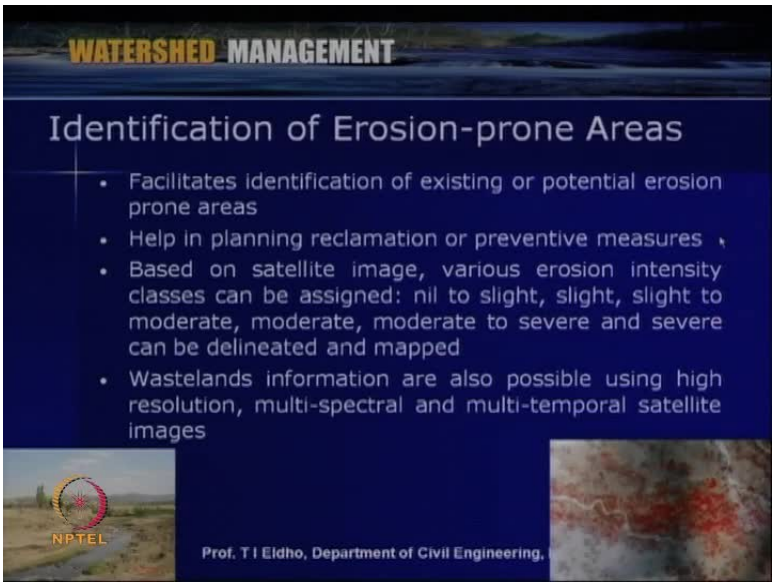

Second application is identification of erosion prone area. As we discussed earlier, soil erosion is a major problem and related sedimentation issues. Remote sensing uses a synoptic view on a temporal basis, I mean in a repetitive basis. If we analyze appropriately these remote sensing images, we can get lot of data to identify what the erosion prone areas.

Some of the important aspects are listed here in the slide. So, remote sensing facilitates identification of existing or potential erosion prone areas remote sensing. Help in planning reclamation or preventive measures. So, based on satellite image, various erosion intensity classes can be assigned like nil to slight or slight to moderate or moderate to severe or severe can be delineated and mapped. We can even go for prediction using the remote sensing images, then waste land information are also possible using high resolution, multi-spectral and multi temporal satellite images, so that way we can use the remote sensing data.

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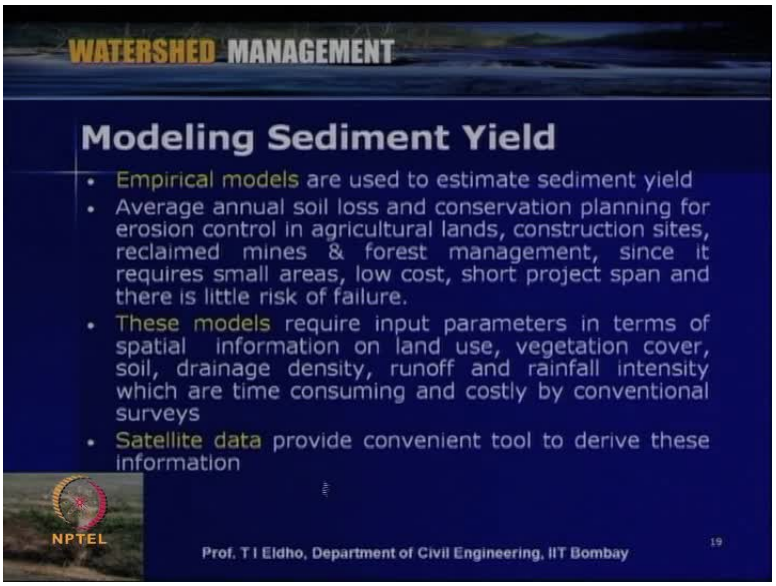

Another application related to watershed is modeling sediment yield. Due to the soil erosion, sedimentation takes place in reservoirs that is a major problem in watershed development plans or river basin development plans. Generally, we use empirical models or a numerical model to identify how much is the sediment yield for particular area for particular reservoir. For that purpose, we need lot of data and this data can be given by the remote sensing. The empirical models are used to estimate empirical or numerical models are used to estimate the sediment yield.

Average annual soil loss and conservation planning for soil or erosion control in agricultural lands, construction sites, reclaimed mines or forest management, since it requires small areas, low cost, short project span and there is little risk of failure. These models require input parameters in terms of spatial information on land use, vegetation cover, soil, drainage density, runoff and rain rainfall intensity, which are time consuming and costly by conventional surveys. So, we can get this data from the remote sensing satellites and this data provide convenient tool to derive these information. We can utilize the remote sensing data to model sediment yield.

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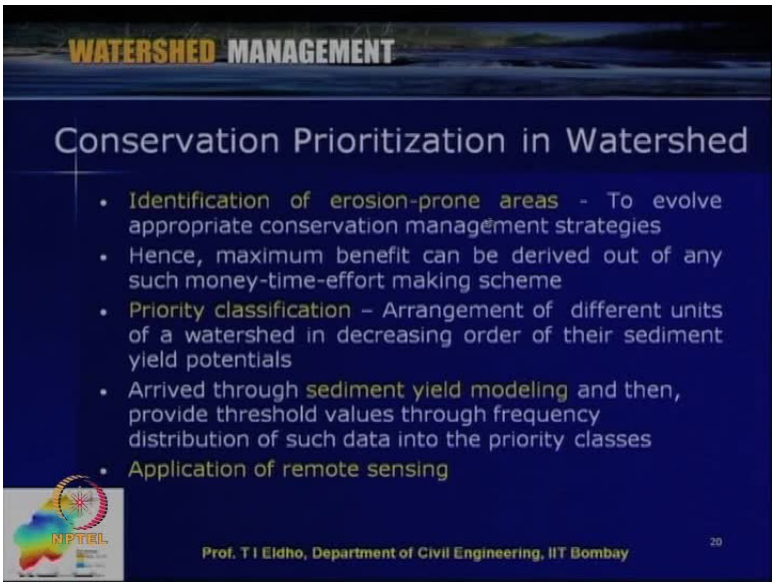

Another area is conservation prioritization watershed, identification of erosion-prone areas - to evolve appropriate conservation management strategies. Hence, maximum benefit can be derived out of any such money-time-effort making scheme. So, we can prioritize which one is the first priority and second one like that. So, we can make a priority and then we can classify.

Priority classification can be obtained using the remote sensing. Priority classification means arrangements of different units of watershed in decreasing order of their sediment yield, for example, if we consider sediment yield potentials. Arrived through sediment yield modeling and then provide threshold values through frequency distribution of such data into the priority classes. This can be either for sediment yield or water resources assessment or water resource planning for the particular watershed. We can have the applications of remote sensing for conservation, prioritization in watershed.

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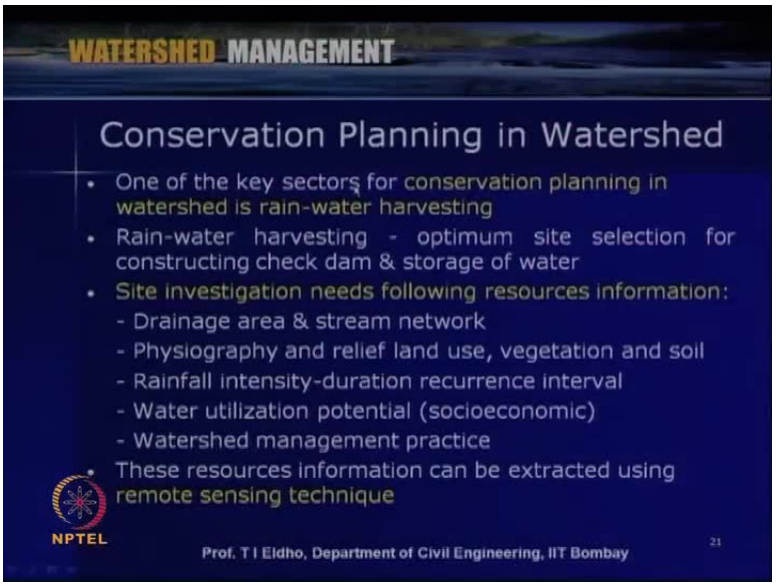

Another application is conservation planning in watershed. Here, one of the key sectors for conservation planning in watershed is rainwater harvesting. Rainwater harvesting can be used to improve the water availability in the area or also can be used to reduce the soil erosion problems. Rainwater harvesting - we need optimal site selection for constructing check dams and storage of water.

Site investigation need following resource information. This information can be obtained through remote sensing like drainage area and stream network, physiography and relief land use, vegetation and soil, rainfall intensity-duration recurrence interval, water utilization potential that is socio-economical aspects, watershed management practices that are already in the area. So, these resources and information can be extracted using the remote sensing data and can be directly utilized. Remote sensing data can be used for conservation planning as far as watershed is concerned.

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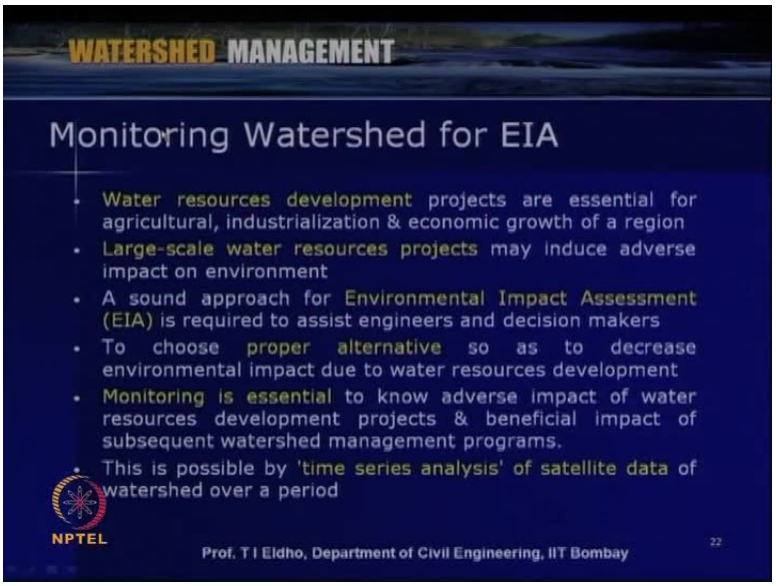

Another important application is monitoring watershed for environmental impact assessment. As I mentioned, if we implement any scheme in a particular watershed, what will be the effects? All those things can be studied using the remote sensing. So ,water resource development projects are essential for agricultural, industrialization and economic growth of a region. Large-scale water resource projects may induce adverse impact on environment. A sound approach for environmental impact assessment is required to assist engineers and decision makers.

To choose proper alternative source to decrease environmental impact, due to water resource development. We can use the remote sensing and we need to monitor what will happen if a particular scheme is implemented, if a reservoir is there. So, with respect to the effect of reservoir, what will happen? So, these data can be repetitively collected for that area. We can process it and use, so that way, remote sensing will be very useful in the EIA. So, monitoring is essential to know adverse impact of water resource development projects and beneficial impact of subsequent watershed management programs.

This is possible by time series analysis of satellite data of the watershed over a period. What would have been happening in monsoon and in summer time and year by year, with respect to that particular project dam project to see how the system is behaving. So,

we can study and then we can analyze, so that way remote sensing is very useful for environment impact assessment.

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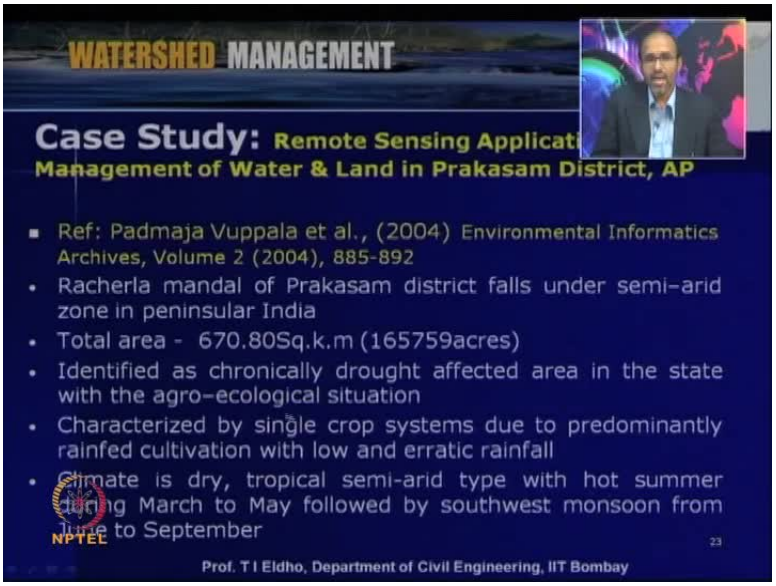

Before closing today's lecture, let us look into one case study, where remote sensing is extensively used. This case study is taken from Padmaja Vuppala and others from Environmental Informatics Archive, volume 2 of 2004, page number 885 to 892. This is remote sensing applications from management of water and land in Prakasam district of Andhra Pradesh, India. Some of the features of this area are listed here, the Racherla Mandal of Prakasam district falls under semi-arid zone in peninsular India.

The total area is about 670.8 square kilometer, identified as chronically drought affected area in the state with the agro-ecological situation. It is characterized by single crop system due to predominantly rain fed cultivation with low and erratic rainfall climate. It is dry tropical semi-arid type with hot summer during March to May followed by southwest monsoon from June to September.

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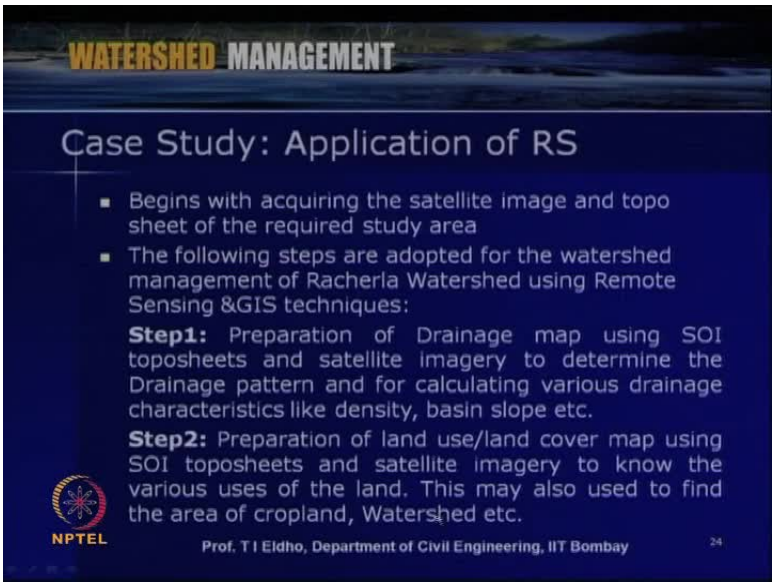

Here, the detailed steps for remote sensing analysis and applications are listed here. It begins or the process begins with accuracy. The accurate data that we obtained from the satellite begins with acquiring the satellite image and the topo sheet of the required study area. This is as reported by the authors in the reference. So, the following steps are adopted for the watershed management of this particular area using remote sensing and GIS techniques.

Step 1: preparation of drainage map using survey of India topo sheets and satellite imagery to determine the drainage pattern and for calculating various drainage characteristics like drainage, density, basin, slope etc. Step number 2: preparation of land use or land cover map using survey of India topo sheets and satellite imagery to know the various uses of the land in that particular area. Through this, we can obtain the cropped area or the watershed area etc for that particular region as used by the authors.

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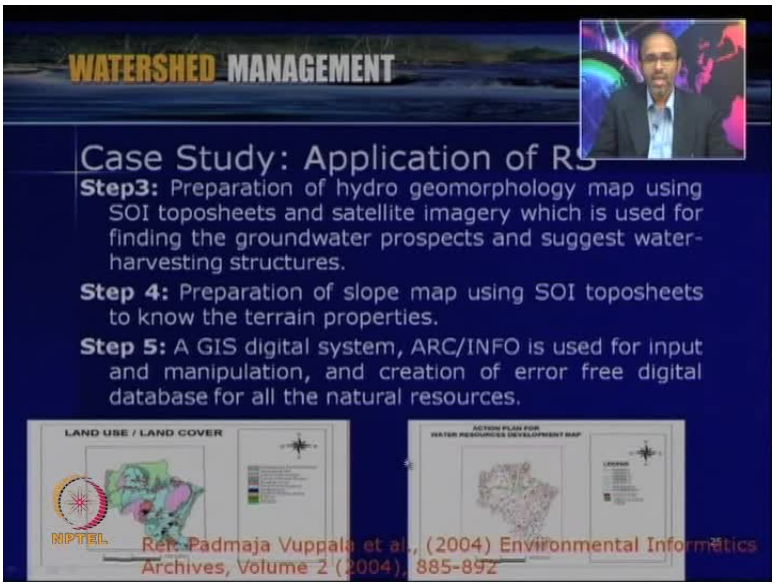

Sep number 3: Preparation of hydro geomorphology map using survey of India topo sheets and satellite imagery, which is used for finding the ground water prospects and suggest water-harvesting structures. This is the particular area as given by the… or this paper shows the land use or land cover details. Here, my aim of presenting this case study has various steps involved in such studies and how effectively remote sensing is used. That is the question, which I am trying to answer here. So, in step number 3, the hydro geomorphological maps are generated and land use or land cover maps are generated.

Step number 4: preparation of slope map using survey of India toposheets and the remote sensing data. Step number 5: A GIS digital system, ARC/INFO is used for input and manipulation and creation of error free digital database for all natural resources within the area, so that is the step number 5 reported by the authors.

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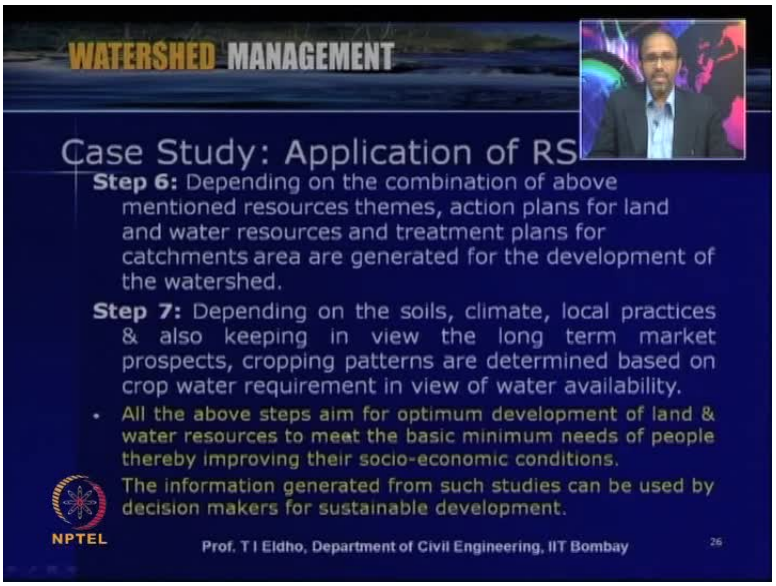

Step number 6: depending on the combination of above mentioned resources themes, action plans for land and water resource and treatment plans for catchment area are generated for the development of the watershed. Here, It is based upon these various steps mentioned here. The main purpose is to a come up with plans for rainwater harvesting and then other water related resource developments.

In step number 7: depending upon the soil, climate, local practices and keeping in view the long time market prospects, cropping patterns are determined based on crop water requirement in view of the water availability. The plans are using the G remote sensing and GIS. The plans were made, where the particular check dam should be constructed and where should be various rainwater-harvesting measures should be adapted.

These locations were identified to generate watershed development plans and then it has been identified the existing cropping patterns and how the cropping pattern can be improved with respect to soil climate and then local practices. All the above steps are aimed for optimum development of land and water resource to meet the basic minimal needs of people, thereby improving their socio-economic conditions. For that the authors did this study as mentioned in these seven steps.

Information generated from such studies can be used by decision makers for sustainable development plan for particular watershed. Using these steps, using the remote sensing

data within the GIS framework, we can propose watershed development plans and then which area should be going for specified crops. So, overall socio-economical impacts will be there for the concerned area, so that way remote sensing data is very effectively used for this particular area by the authors.

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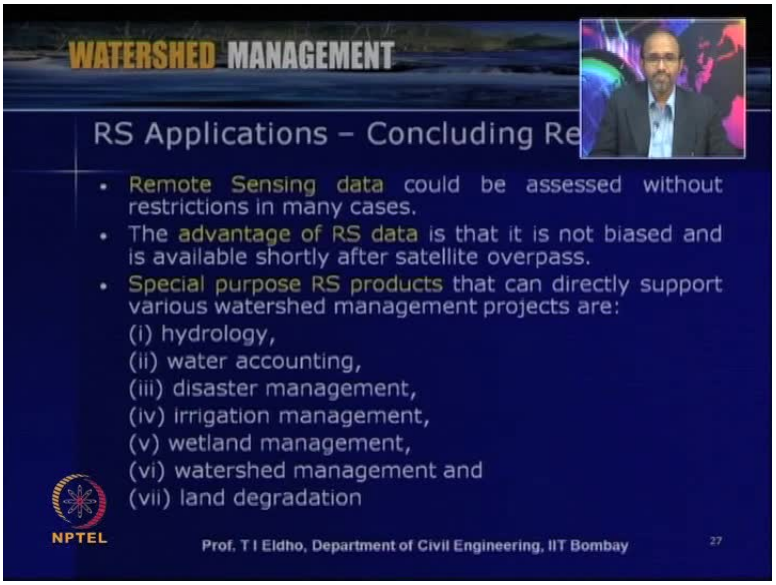

Before finishing this lecture on remote sensing applications, some concluding remarks. As I already mentioned in this lecture, remote sensing data could be assessed without restrictions in many cases, so we can use for various purposes. As I mentioned already, it gives a synoptic view and temporal variations with respect to repetition with respect to time.

The advantage of remote sensing can be effectively utilized for the development of various watershed development plans. Remote sensing data is not biased and it is available shortly after satellite overpass in that area. Those are some of the further advantages. So, special purpose remote sensing products can directly support various watershed management projects like hydrology, water accounting, disaster management irrigation management, wetland management, watershed management and land degradations are possible using the remote sensing. We can effectively utilize the remote sensing.

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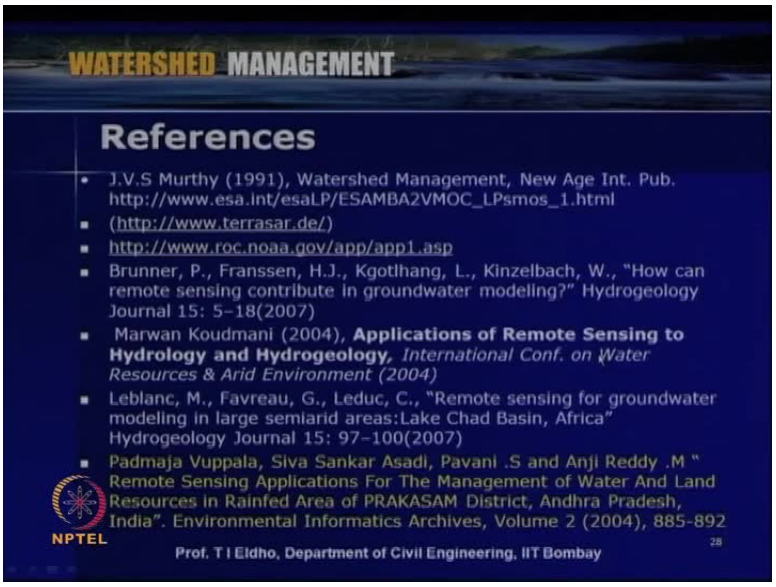

Some of the important references used for today's lecture are listed here. The case study is taken by from this paper by Padmaja Vuppala, Siva Sankar Asadi, Pavani and Anji Reddy, published in Environmental Informatics Archives.

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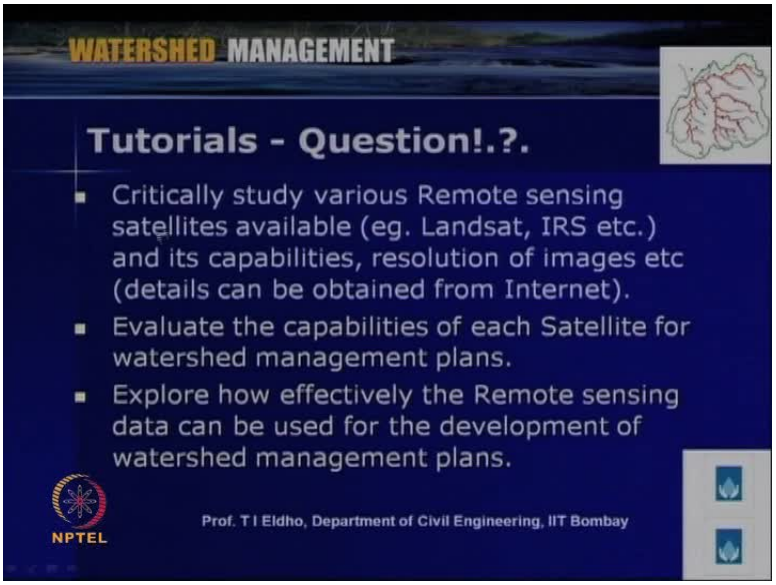

Before closing, few questions tutorial question. Critically study various remote sensing satellite available, example – Landsat, IRS etc and its capabilities, resolution of images etc. These details can be got from internet. Evaluate the capabilities of each satellite for

watershed management plans. Explore how effectively the remote sensing data can be used for the development of watershed management plans.

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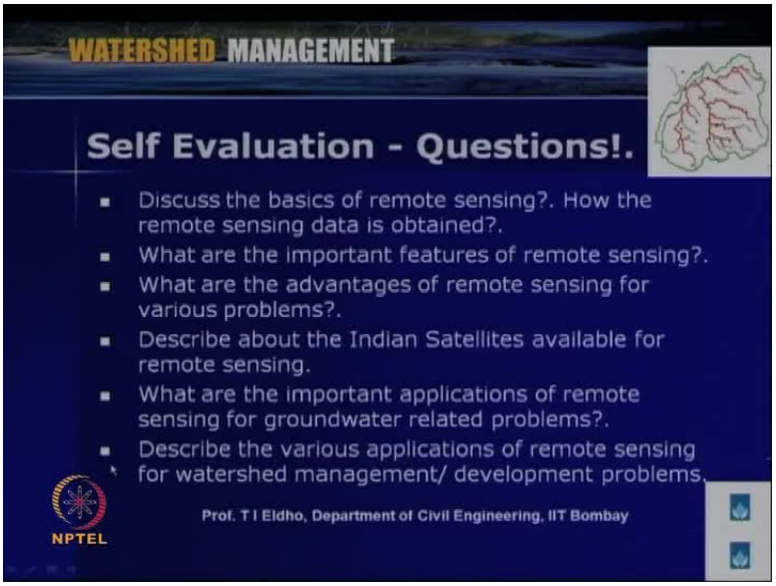

Some self-evaluation questions: discuss the basics of remote sensing. How the remote sensing data is obtained? What are the important features of remote sensing? What are the advantages of remote sensing for various problems? Describe about the Indian satellites program available for remote sensing. What are the important applications of remote sensing for groundwater related problems? Describe the various applications of remote sensing for watershed management or watershed development problems.

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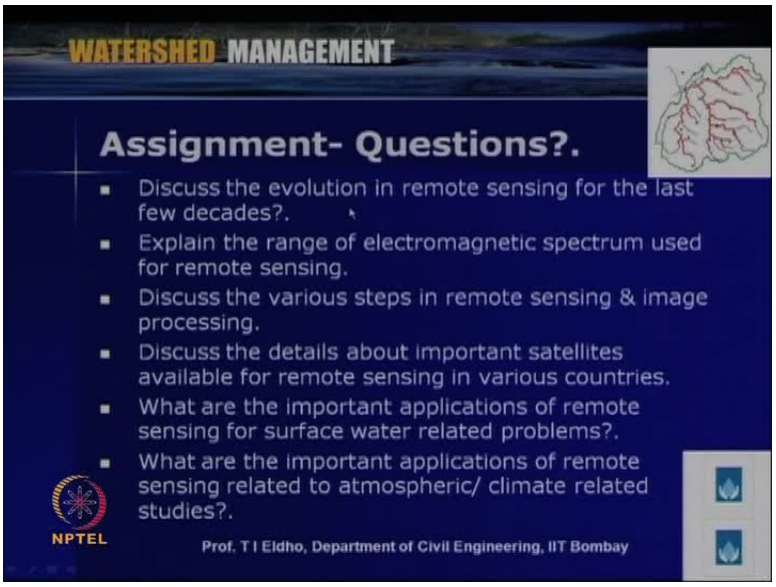

Few assignment questions: discuss the evolution in remote sensing for the last few decades. Explain the range of electromagnetic spectrum used for remote sensing. Discuss the various steps in remote sensing and image processing. Discuss the details about important satellites available for remote sensing in various countries. What are the important applications of remote sensing for surface water related problem? What are the important applications of remote sensing related to atmospheric or climate related studies?

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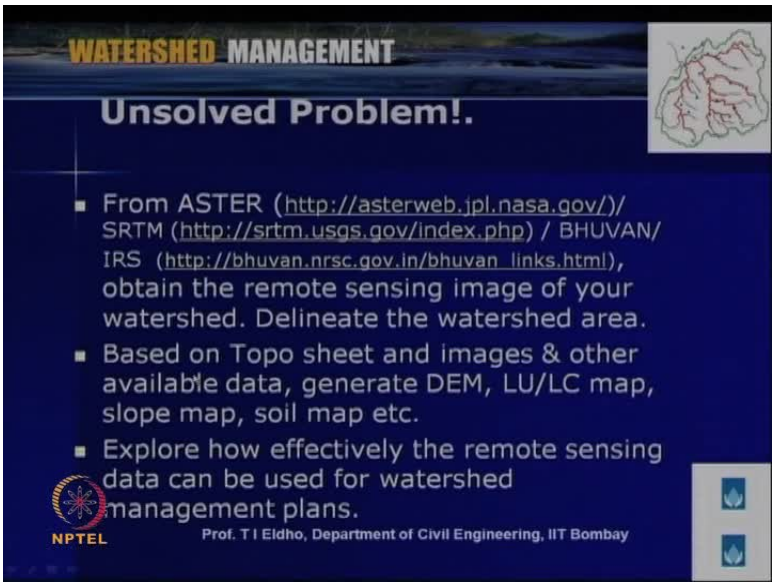

Finally, one unsolved problem from aster, as given in this website or SRTM, given in this website or BHUVAN or IRS data, as given in ISRO website, obtain the remote sensing image of your watershed area based upon the latitude longitude. Delineate the watershed area. Based on topo sheet and images and other available data, generate digital elevation model, land use or land cover map, slope map, soil map etc for your area. Explore how effectively this remote sensing data can be used for like hydrologic modeling or watershed development plans.

Today, what we discussed is how effectively remote sensing can be used for watershed management plans. We have already seen number of applications are there related to watershed. Anyway, due to lack of time and I cannot give my time, since only one lecture has been planned. So, further applications will be discussed in the coming lectures related to remote sensing applications, when we discuss the decision support system or the numerical modeling. Thank you.