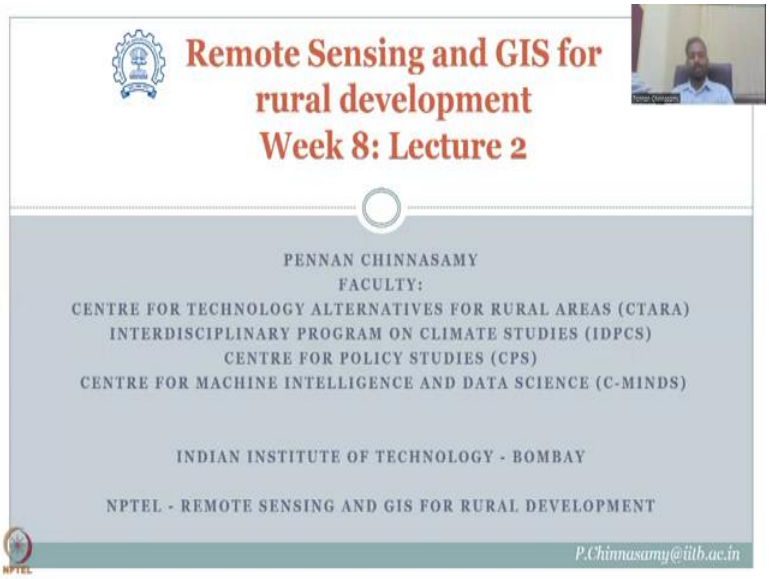
Remote Sensing and GIS for Rural Development
Professor Pennan Chinnasamy
Centre for Technology Alternatives for Rural Areas (CTARA),
Indian Institute of Technology, Bombay
Week 8
Lecture 37
Data for LULC and proxy data

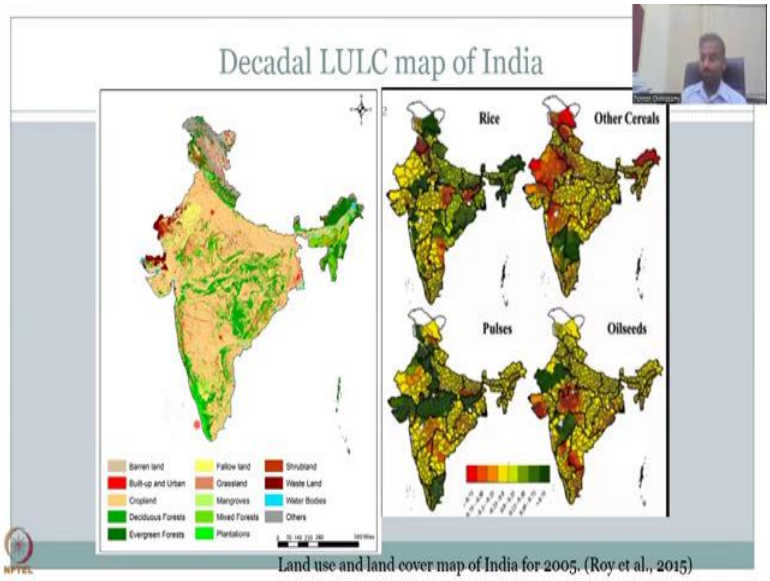
(Refer Slide Time: 0:21)



Hello everyone. Welcome to the NPTEL course on Remote Sensing and GIS for Rural Development, this is the week 8, lecture 2. In this week we have been looking at the land use land cover and all the attributes and classifications that one needs to remember while discussing rural development.

I have to say that the land use land cover data could only be satisfactorily given by remote sensing data, all the other data may be there people may argue that remote sensing is too coarse or it cannot be done etc but for land use land cover especially remote sensing data would be one of the best data that is available and it directly links to use in rural development. So, we will continue the part of discussing the land use land cover.

(Refer Slide Time: 1:23)



Land use and land cover map of India for 2005. (Roy et al., 2015)

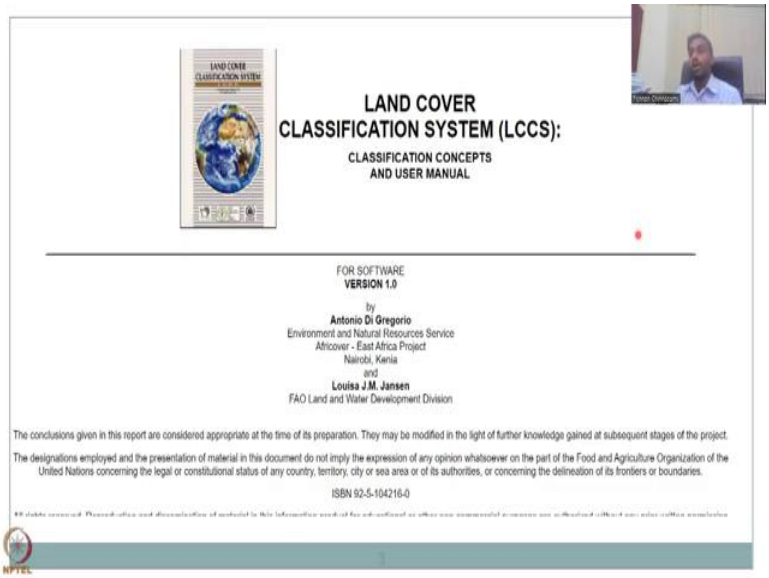
In the last class we stopped here on discussing about the land use and land cover differences. For example, on the left hand side you have the land cover which is basically the cover on top of the land and it also includes the artificial structures such as buildings and urban areas. Whereas your right hand side is how that land has been used, the white part is where there is no data.

However, if you look carefully within the mapping I just want to make sure you understand that in the left side it was pixel, each pixel has a color and that color is coordinated by the legend, you can see the classification given in the legend at the bottom, here this is part. On the right hand side the land use, what they have done is they have taken a district or a block level analysis and within the block what is the major crop they have taken.

If rice so as per the legend if the yield of rice is a particular value, let us say the yellow value they put yellow. So, what happens here is one should remember that how you represent data in remote sensing is very important, not throughout the district is going to be a yellow color for rice across Rajasthan, but it is the majority, the yield is the majority in that particular district that is what you should understand as per the visualization of land use land cover.

So, same thing here each pixel, inside the pixel what is the dominant land use land cover we have seen. This will become more evident when we are going to discuss the aspects of land use land cover and some real-time analysis using Bhuvan and NASA data.

(Refer Slide Time: 3:24)



For land cover classification systems it is recommended to use this given by FAO, so this is available on the FAO website, this book. And as I said that it is based on a particular year, so here the conclusions given in this report are considered appropriate at the time of its preparation. So, there is a time stamp on land use land cover, because it can suddenly change.

For example, Nepal was having lot of land and springs before 2015, but after the 2015 earthquake lot of springs vanished, lot of water bodies vanished. So, you cannot use what map was used in 2014 on 2018 because of the land use land cover change, it is not appropriate.

So, always every single land use cover and classification follows a particular time frame and this is given by the FAO, this book the software and the software they have some links to a book on the classification system, how it has been classified, it is a free open source software, you can just Google LCCS, FAO and then you will find the links to this beautiful software that you can install.

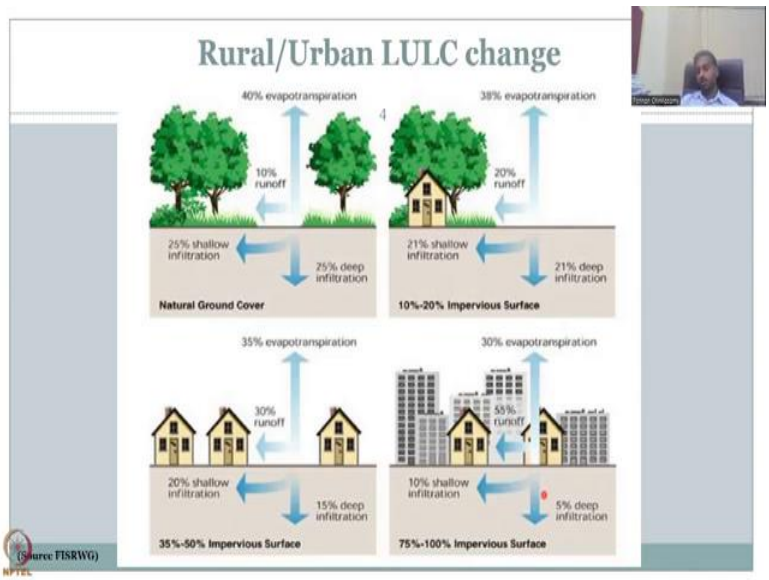
As I said it may be for a particular region and a particular time period so you cannot use it across unless you know the linkages. Let us say for example the people consuming kiwi, kiwi has been a big phenomena as a horticulture crop in the recent decades, before that kiwi was very expensive, you will only find it in high-end supermarkets but now you can find it on the road.

Same as strawberries, it was only at high-end supermarkets in 10 years ago, now you find it on the roads in Mumbai for example. So, the price has come down, the accessibility has come

down, now everyone can have this fruit which is very high in nutrients and magnesium, potassium.

So, the point here I want to cover is this land cover which was having kiwis and strawberries were not mapped 10 years ago but now these have dominant areas same as Nashik grapes. If you take 30 years, 40 years ago grapes was very less in Nashik but now there are a lot of acreages of grapes. So, to make sure that the land use land cover is still relevant you always need to compare it to the current time period or the time period of your research question.

(Refer Slide Time: 6:07)



So, now let us look at how the land use land cover can impact water and soil nutrients for rural development. Especially when a rural area is converted to urban or peri urban setting. This place where I am taking this lecture Powai was also kind of peri urban, outside Mumbai city.

But because of the IIT Bombay's establishment around the area the land converted to urbanization. For example if you go outside the gate of IIT Bombay it is called IIT market, so if you go inside IIT community they have nothing to do with what is happening inside because we have our own market but because of the landmark it is called IIT market, it is called IIT community, IIT park, IIT post office, IIT Bombay, IIT Bombay.

So, the point here is these areas were initially peri urban, lot of crop cover or lot of trees and forest cover but now it has been changed because of the infrastructures. The same thing happens in rural areas but at a drastic change. Here maybe some forest was clear and they say or some barren land was converted to IIT Bombay but in a forested area if you convert or a

rural area if you convert it has implications on the water and food security because the land that was producing rice paddy wheat and vegetables is now converted to buildings. So, you are not going to eat concrete but the produce is coming down the price is going up and the stress on the farmers is going up.

So, let us see how this impact happens, let us take the first image where you have a normal forested slash rural area where you have rainfall happening, there is land and on top of it, it is a crop cover, forest cover, grass cover and because of the cover there is lot of pore spaces inside the soil there is lot of space for water and air to move, so you have natural ground cover and within that 20, if 100 percent rainfall comes in 25 goes in as infiltration, 25 goes as deep infiltration so the shallow infiltration is something like soil moisture, the plant use, crop use, trees use, the deep infiltration is what goes into the aquifer.

Then after the 50 percent, 10 percent goes as runoff, so basically some water is on the top which is pondered and it goes into the rivers and lakes and ponds. So, 10 percent of your rainfall converts to runoff and the remaining 40 percent is evapotranspirated which means evaporation from land surface and water bodies, transpiration from plants and trees. So, the plants and trees consume water and it extracts water.

Now, the farmer has done a lot of farming has used the resources very well, he or she has become rich so now this case comes up. This is the case where some part of the land and land cover LULC change. LULC change converting from rural to urban. So, now you see that the farmer has become rich so maybe the community is building a house. Once you have built a house there are other associated things that come with it.

For example, you will put a road, you will clear some land for you to park your car, tractor and other things and also some land in front if you go villages you will see, there will be always a land in front of the house, it is just not like as soon as you step out of house you will see a field or a forest there will be a big land area in front of the house which has been clear, it is barren land.

So, now part of the land is converted to barren, part of the land is converted to house and the remaining is kept as in, as a forest slash crop ecosystem. Now, what happens is water comes in but not all 50 percent goes into the groundwater and soil moisture, there is a big cut. So, because now you have increased the impervious surface as 10 to 20 percent. What is impervious surface? It is a cover on top of the land which prevents water from penetrating, impervious to water.

So, as I said concrete jungles like Singapore you will not see water flowing into the cement, so there are some technologies where it allows the water to go but most of the roads, most of the buildings will not allow the water to go through. So, now you have limited the or cap the water that can go inside the surface by putting a impervious cover, it is like a plastic wrap on top of a fruit, if you put water it will not go in.

Same thing if you put a road on top of a soil the water will not go into the road and into the soil, very less will come. So, there is what is coming but very less, compared to the 25 percent, so if you add it, it is only 42 percent, there is a 10 to 20 percent increase of impervious area and because of the impervious area the surface runoff increases, water falls and then it goes along the land into the rivers and lakes.

So, this is also which contributes to floods because if you have too much water coming into the rivers and lakes then flooding happens. So, that now you can see that 10 percent has increased the 20 percent runoff and because there is less plant, trees and agricultural output there is less evapotranspiration only 38 percent, so compared to 40 percent, it is 38 percent.

The bulk of the rainfall goes now into your runoff as a change, it is 10 percent change here is only 2 percent reduction, 4 percent reduction in each 8 percent in total but you can see 10 percent change. Now, you come to the third, now again the farmer has become more and more rich the community, entire community is now converting their houses into inside the village and agroforestry locations.

You could see that instead of one house now it is 3 houses, the land has been cleared, more roads have been placed, more impervious cover has been added. So, now 35 to 50 percent impervious layer which limits the water that goes into the aquifers, ground water and soil water, so now the soil moisture is coming down.

Still some soil moisture is there compared to the initial version because you will leave some space where the water can go in, where the deep aquifer the groundwater will not get enough water. So, you see that if you increase the impervious from 35 to 50 percent you will have 25, 20 shallow infiltration, 15 deep infiltration and now the runoff has increased. So, again all this water is going back to the runoff, there is still high evapotranspiration.

Now, the question comes is Sir, if the plants are not there transpiration will come down. Why is it still high? Again you should remember that, it is evapotranspiration, evaporation is also there. So, if you have cement and waterfalls on it, then water suddenly evaporates, you can

see that in the tar road on the highways if you go you will see that when cars are passing and when it is raining along the place where the cars are passing and along the high temperature roads water will fall and at once evaporate.

So, there is a high evaporation from impervious layers, cemented tar roads, etc. So, that is why you see a high evapotranspiration and you could see that still there is runoff and some shallow infiltration and stuff.

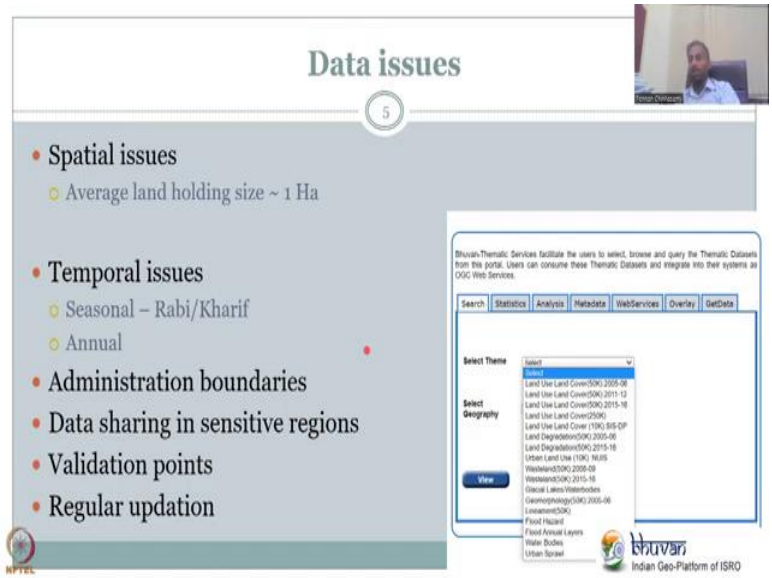
In the last one now this is like the case I said, the IIT Powai region from barren it has now become into a fully industrialized, fully urbanized location. Same like the Chennai region, the peri urban which was rural now is becoming more Chennai, suburban has become urban. So, in that case 100 percent is impervious, 75 to 100 percent, very very less water goes into the shallow infiltration and deep infiltration.

Again these are small cracks, small spots where they have rainwater harvesting and stuff. So, you have only 15 percent going into the ground, whereas the 30 percent evapotranspiration still holds because all the land is now converted to cement cover or impervious cover and the majority goes as run off.

Now, if you look at it you can look at how a piece of land has been converted across rural to urban and how the water and soil dynamics will change, most importantly the floods. The floods affect agricultural output a lot because the floods will damage the crops and then there is a lot of crop damage. So, all this has to be documented and it is documented by using land use land cover.

Again LULC maps play a vital role in scenario analysis we will showcase that in the following lectures. So, you could see here that because of the land use land cover change the water plus nutrients that are in the soil are going to come down which will affect the productivity of rural enterprises and also you will see that because every farmer wants to live in a good house which is not something that we should stop them, but is it done sustainably is the question and or converting a rural region into a fully urbanized region is a question.

(Refer Slide Time: 16:04)



So, moving on now we have understood the importance of LULC, now let us come to issues in mapping the land use land cover. We have spatial issues. For example, the land holding size of a farmer, average land holding size of a farmer in India is only 1 hectare, so approximately 1 hectare, 1.08 something.

But the problem here is your resolutions of the data that you have that has been mapped and put in satellites and other resources is at the order of 50000, 250000, 10000, etc which is approximately 60 to 90 meters, 30 to 90 meters per pixel. So, you could now understand that one hectare is going to be difficult for mapping of these areas and that is one very very big issue in the spatial terms.

In the temporal you could see that there is no seasonal maps. Why is seasonal important? Seasonal is important because you need to know how many crops are grown. Suppose we have an area and in that area you are putting rice, a farmer puts rice, after some time, after the rice harvest before the next rice they will put a vegetable, a cotton or legume, this is not map in the government records.

So, all the land use land cover you could see is still using a lot of government records for mapping. But government record cannot go at every single farmer, every single one hectare and then map. However, this cumulatively will have an impact on rural development because water, subsidies, fertilizer all these are given at rural entities level. So, if you are not mapping them correctly then the demand and the use of fertilizers and water in the soil conservation is not taken to account.

So, there is a lot of temporal issues in the data I am talking about observation data and data that is freely available. So, the goal of this lecture series is for you to understand the potential of remote sensing data and use remote sensing data for your analysis, rural development and other scenarios.

So, then you have annual so most of the data are at annual levels, but if you look at the examples given here you could see that this is a current, I can also open the Bhuvan portal and show you, you can see that the current available data is only 2015, 2016 which is approximately 7 years from today. Today is March 2023 and you are looking at a data which is 7 years old. How is that good for doing any policy recommendations or land water conservation in rural areas, it is very very important.

Also if you are going to look at road connectivity using a 2015 map and you find that farmers or manrega has already put down the roads how are you going to have the maps updated? So, these are big issues in temporal level data acquisition for land use land cover in India. Administration boundaries are always differing the data do not agree and administrative boundaries, maybe they are doing at block scale and then on the map it is at district levels, they do not know or they do not have the data at districts so they just do some average. So, all these map making metadata issues and concerns are not correctly given.

As I said there is a lot of data issues especially when it comes to sharing data in sensitive regions. Let us take for example the coastal regulation zones in particular Mumbai region. In Mumbai you have a lot of naval activity along the coast because of the naval activity there are allied industries and housing which are being set up along the coastal zones, this has an impact on the rural fishing communities.

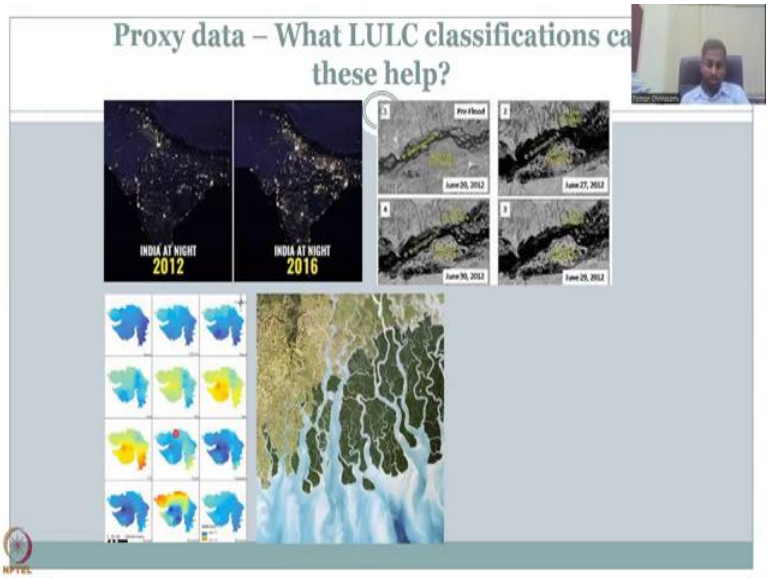
But if you want to map all this you need them to share data which is very very sensitive data they cannot share. Same as in ganges water basin, the floodplains, the trans boundary regions, all these are highly rural development related areas but getting the data and sharing them is very very difficult this is purely because of how the systems have been set up, not all areas but at least 10 to 20 percent of the data is considered sensitive and there is no or limited data sharing between the government agencies.

The forest cover will not give the data to the agriculture department, the irrigation department will not give cover or data to the urban department because they say no your jurisdiction is different mine is different, your area of interest is different my area of interest is different, so they will have different names, same analysis different names. So, this is a big big issue and

there are a lot of bias errors, correction errors, sensitivity errors in these government reports and data.

There is not much validation done as I said if you are mapping a grid you will not go through the entire grid you will go to one point and take a data, but how is it validated, how is calibrated these land use land cover maps is not clear. So, we need more information on the validation points and these maps should be regularly updated which are not getting regularly updated in the system.

(Refer Slide Time: 21:42)



So, with these issues what can we do? We do have some data that can save our land use land cover estimation and this has been already discussed but for the benefit of the class and the timing of this slide I am going to do it again. Proxy data, proxy data is a secondary data that is collected for a different purpose, however, can answer or support your hypothesis, it is not a primary data, it is a secondary data, it is a data that is not collected for this purpose but it can act as a proxy.

So, let us look at this first image, an India light image taken at 2012 and 2016 through NASA and you could see that the data shows that India at night 2012 and 2016 and if you just look at it, it could be a luminescence map, it could be a map that gives you color of different areas depending on the light but for rural development it gives beautiful hypothesis support such as connectivity, road connectivity, electrical power supply and then hot spots, urbanization, land use land cover all this can be taken from this data set.

For example, you could see that there you could see some roads which are being lit up so connected, the dots are connected, the dots are normally connected through a highway and highway has lights. So, now you know that 2 villages are now connected which were not connected in 2012.

Then you also see the hubs becoming bigger, so the main cities are becoming bigger and then as I showed in the previous map if Chennai grows big the regions on the periphery are now consumed or are taken up as City from rural it converts to City. Then you have more more lights in the rural regions, small small lights they are more in number which means rural regions are also getting electric supply.

Then you have a pre and post flood analysis using NASA data for the Brahmaputra river and this gives you the land use land cover change after the flood which means the water body which was on the upper part of the Brahmaputra region is now shifted to the down part. So, this part which was not in water now is having more water because of the floods and new regions have been charted above, charted away.

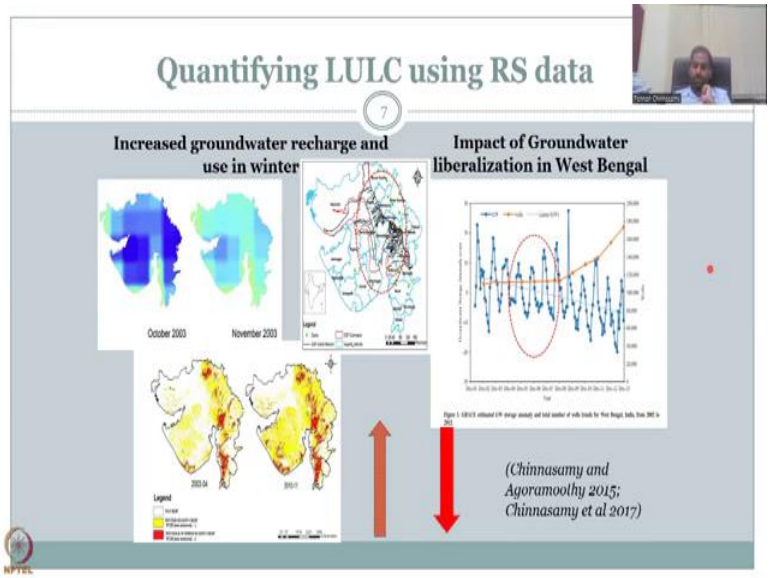
So, before June 2012, June 20, 2012 this area was considered to be flood plain and agriculture, after June 29 this area becomes water body. You see how a piece of land has changed from one land use land cover to the other in a time frame which has been captured by NASA.

The other data that I used in my own publication is the Grays data and this map shows very clear indications of the groundwater coverage across Gujarat, monthly groundwater coverage. And the important aspect here is groundwater changes mostly because of water used for irrigation.

So, you could see that from here these 3 months are using high ground water for irrigation and you will normally irrigate it for a cash crop or a crop that is going to bring you more money which can support the pumping activities. And in the last part where we had the change in land cover and land use of the wetlands in the Bangladesh region which also has been captured by the NASA satellites.

So, now you could see that proxy data or the data which has been used for one which has been collected for one purpose just as an image can be used for other purposes and remote sensing data can give you the best spatial and temporal coverage for land use land cover and rural development together. Let us see how it can be used.

(Refer Slide Time: 25:58)



Quantifying LULC change using remote sensing data, this is the water availability between 2 months October, November 2003. You could see that 2003 suddenly the water is depleting even though there is not much summer season and why is because the winters, November is winter, the winter crop is increasing so the red color is the winter crop kind of rabi but in the winter.

So, there are 2 types of rabi crops, one is in the summer and one is in the winter. The winter crop still uses irrigation, still consumes water and pumping. So, you could see that lot of this region where it turns from dark blue to light blue is the same region where you see lot of activity of water uptake for winter crops. The winter crop rotation 2, then there is a winter crop rotation 1 which does not consume much but it does consume a lot of winter crop rotation 2.

This is very very important to understand and document and now we are using 2 satellites, one is the water satellite, one is a land use land cover satellite. The land use land cover dynamics has been confirmed by water and the water dynamics has been confirmed by land use land cover. You see how 2 satellite data can talk to each other on a same hypothesis.

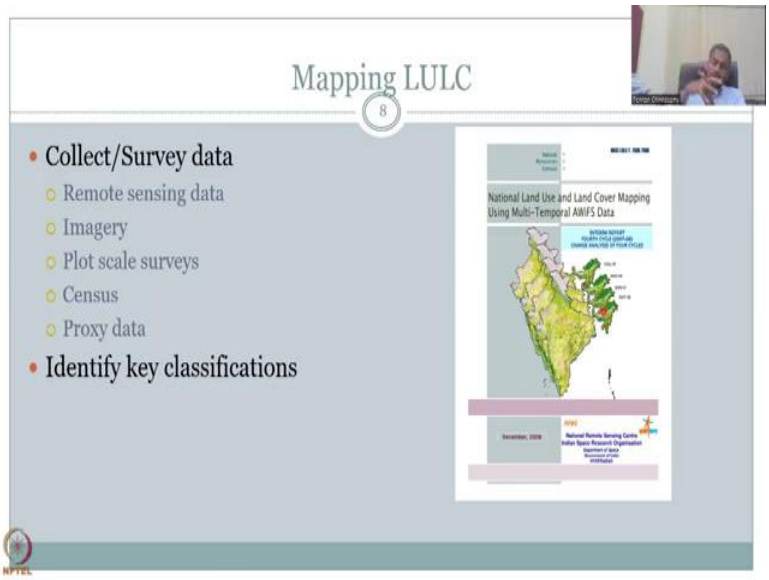
The other thing you could see is here you could see the Narmada's dam across the Gujarat region, SSP command area. And you could see that if the height of the dam is increased the command area gets more water and the command area is also mapped as a land use because initially it was barren land but because of the channelization of water the land has been converted to agricultural use. And you also put water bodies canals in the land cover so now

the land use is very very different because of the more availability of water which is given in the command areas.

Then the next data you can see here is on the x-axis is time period from December 1 to December 13, 2013 and then on the y-axis one it is the groundwater storage anomaly in centimeters whereas on the second y-axis it is the number of wells. You could see that after 2005, West Bengal liberalized the groundwater market and so there is more number of wells which is orange number you can see that the orange number has gone up the line and the number whereas the groundwater which is blue and the primary y-axis is coming down.

So, the hypothesis is as the water now access through wells has increased or the number of wells has increased the groundwater comes down. But what was the water used for? The water was used for irrigation. So, basically your land use land cover is now changing from barren land in rabi to cropland and that cropland is consuming more water. So, you could see that land use land cover plays a vital role in understanding these water recharge and discharge dynamics.

(Refer Slide Time: 29:23)



So, now we know that satellite data can be used widely and so what are the ISRO and NRSC does the national remote sensing centers Hyderabad, Bengaluru, Ahmedabad, all these centers what they do is they collect these satellite data here they are using multi-temporal AWI FS data which is a particular sensor through the ISRO portal and they make maps. So, what do they do?

They collect and survey data, they use a lot of remote sensing data which is satellite based, drone based data, they procure a lot of imageries and then do some plot scale surveys, sensors and then use proxy data to maps of land use land cover for the entire Indian region.

It has very limited key classifications which is generic in nature, however, the data is available, so you can take the data and re-classify. The data is same but for example they have 10 classes let us just take for this example, let us take this example you say dark green is forest, light green is agriculture and white issnow, that is it just 3 land use land covers.

However, the same coloring can be used for multiple more classes, let us say dark dark green is forest and then light green is a forest, deciduous forest, this is western ghat forest, this is the green color is different from this green color so those kind of things. So, it is up to you the user who will tell how many different colors are there or club the colors and then make classes or just classification.

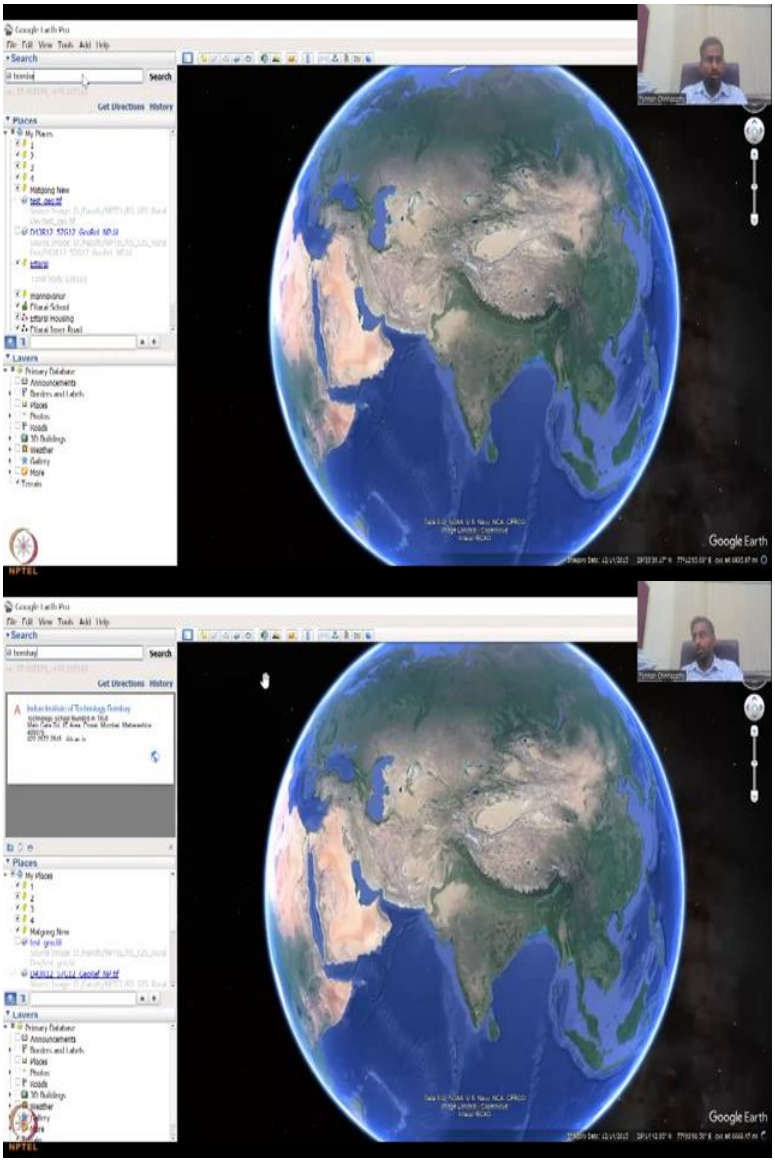
(Refer Slide Time: 31:08)

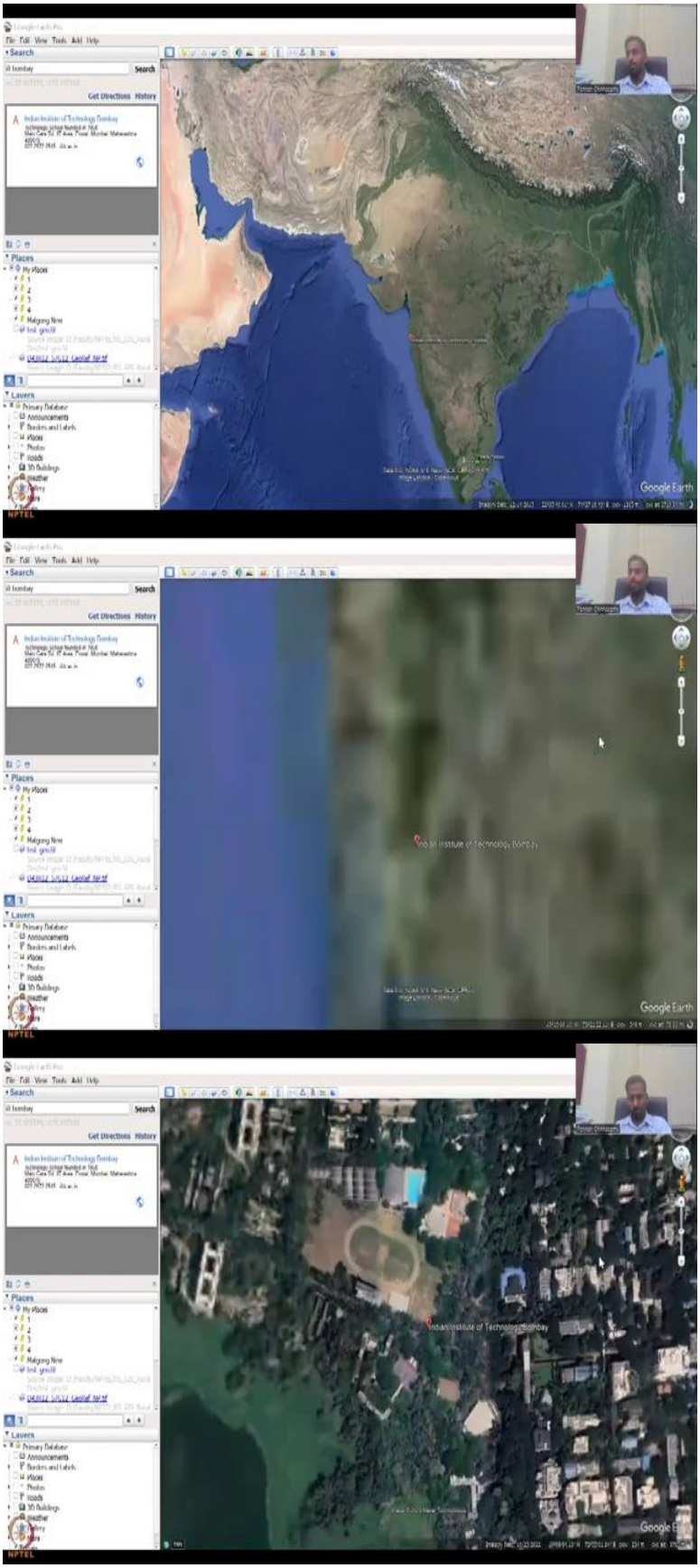
To move on Google Earth Pro has a lot of these data embedded, it can be used on the Google Earth Pro desktop version, mobile version and the online version. We always use the desktop version that we have shown in the previous examples. What we have done is we have demarcated an area for example I have shown IIT Bombay and how IIT Bombay has converted from one land use land cover to the other.

So, I can also show the same content in a different platform. For example, we have we can show how the Google Earth Pro has evolved using a lot of data and dynamics and I also told that you have the time tool that you can use to go back and front in time and space and then

identify the land use land cover. So, let me share my Google Earth Pro and show a small example before we conclude.

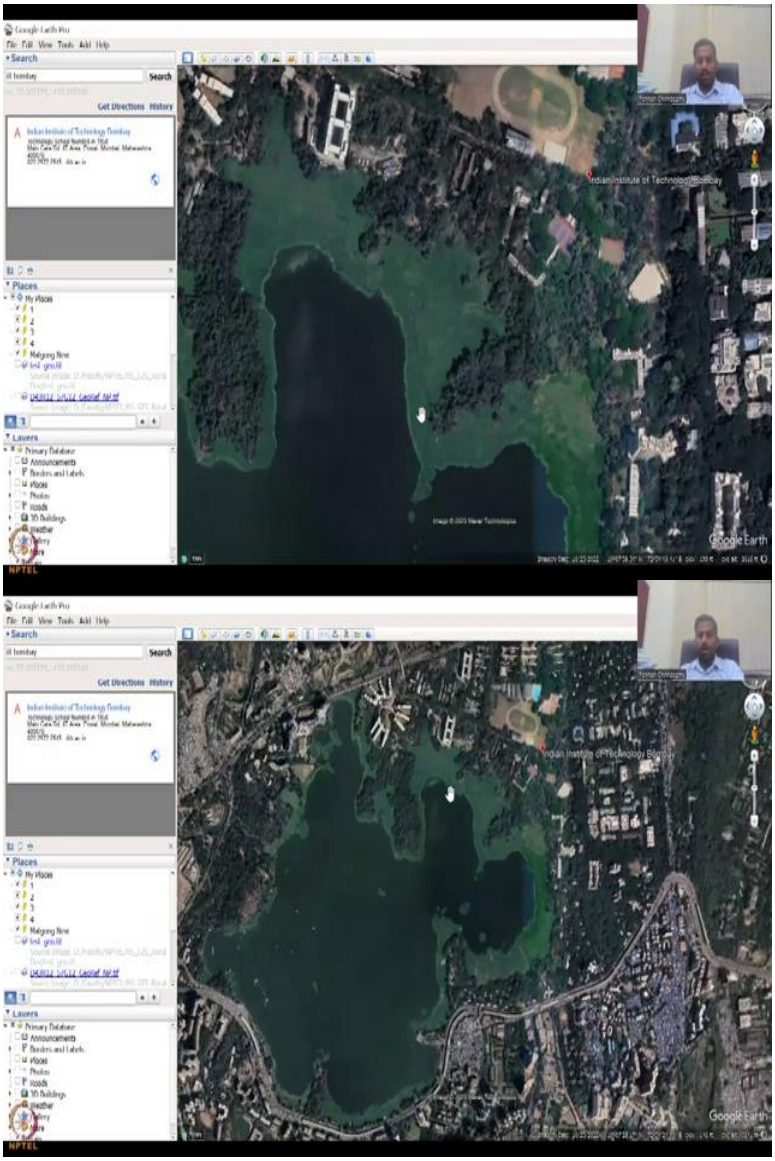
(Refer Slide Time: 32:30)

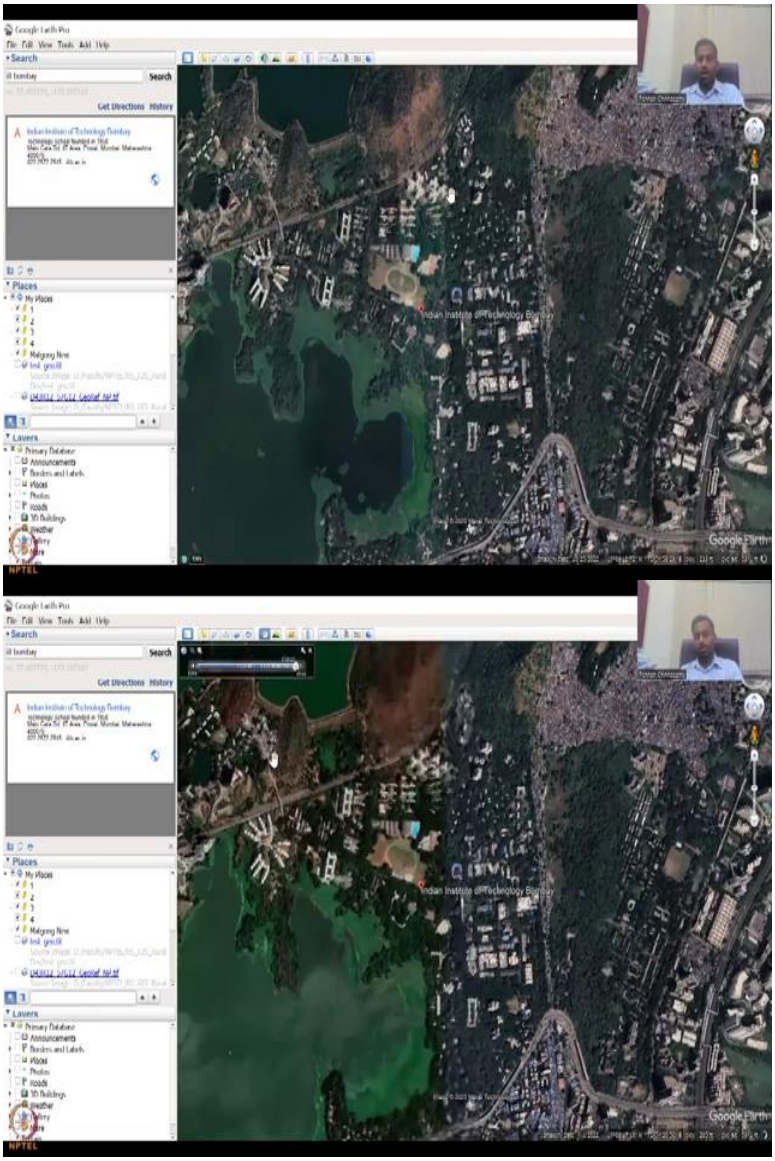




I am going to show IIT Bombay and once we click okay, the map goes in.

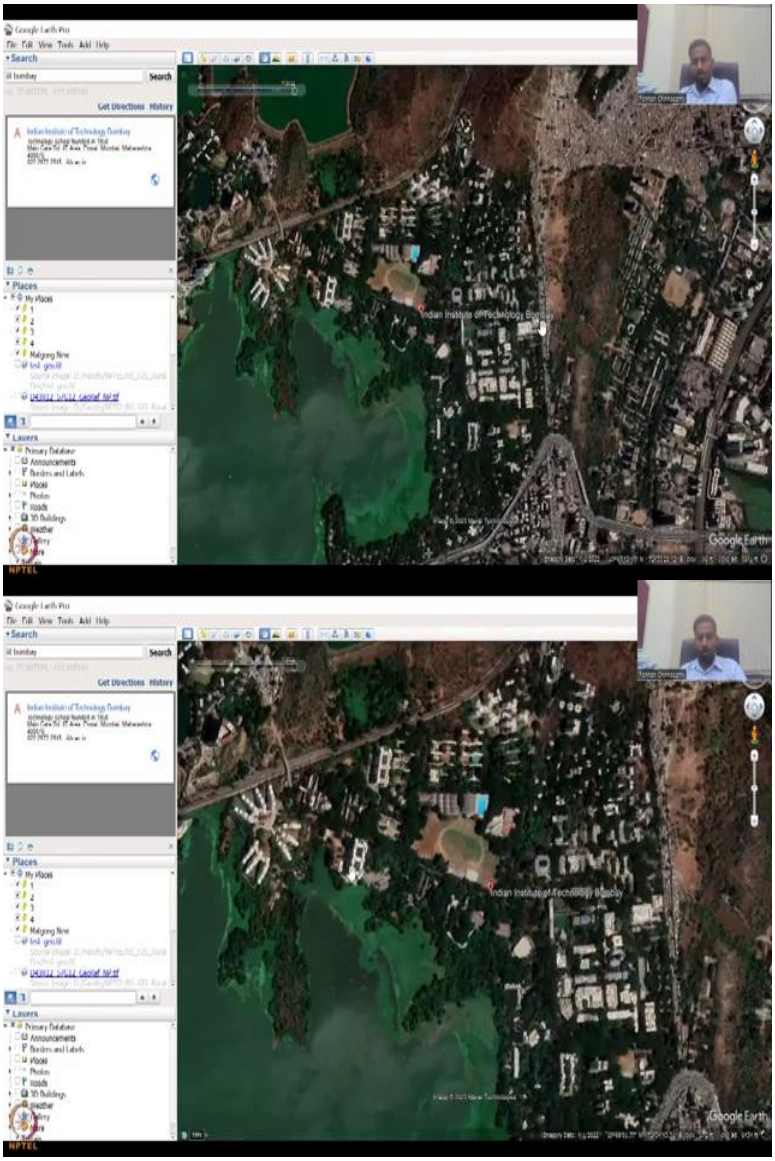
(Refer Slide Time: 32:47)





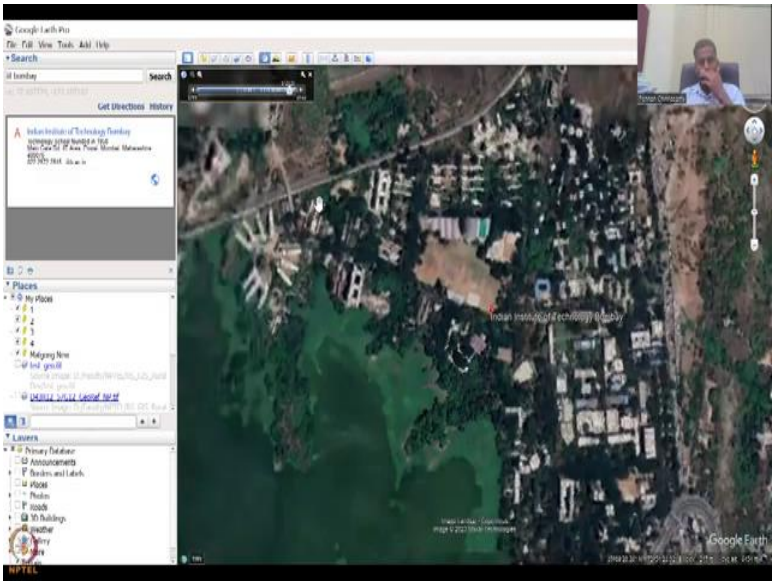
So this area is the lake area the water body area as per land cover and the land use this was initially barren but now it has been used for construction, education, infrastructure, etc. So, let us keep this as a stationary image and then click on the time frame and you could see that now we are at 2023, 2022, 10 the month and then we can go back in time.

(Refer Slide Time: 33:22)



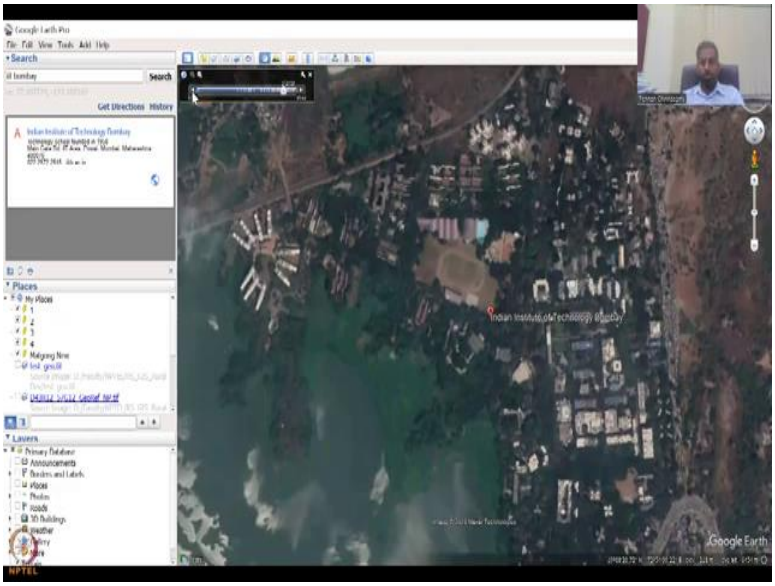
So, this is the fourth month you could see that some land is still under construction, however, this water body, some part of the water body is not water body. Why? Because there is a lot of algal blooms and water hyacinth because of the pollutants because of the non-managing the water body.

(Refer Slide Time: 33:46)



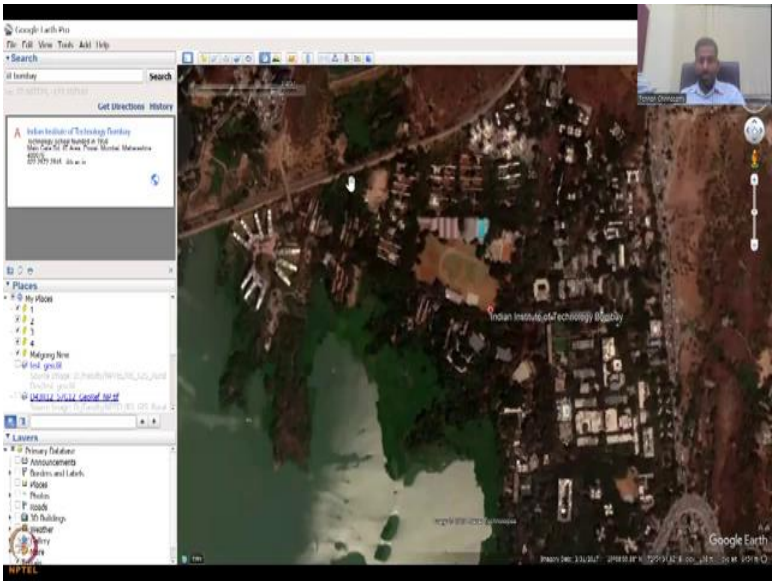
So, now we will go back in time let us go back 2 years and you could see less number of buildings.

(Refer Slide Time: 33:57)



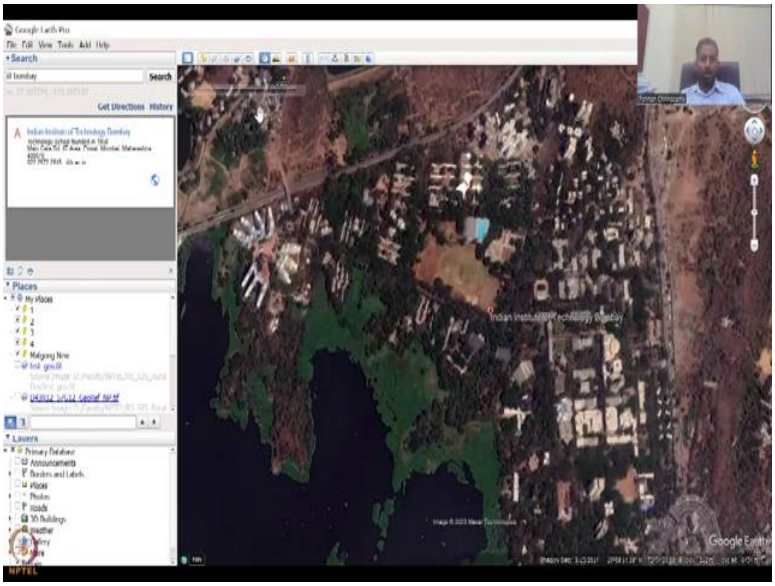
Let us go back in time another 2 years 2018 which is four years before the first image was shown 2022 now it is four years March 2018. You could see around the land also there are some less number of land use land cover. There are a lot of cloud cover and stuff which should not be there in the land use land cover which you will be taking apart.

(Refer Slide Time: 34:20)



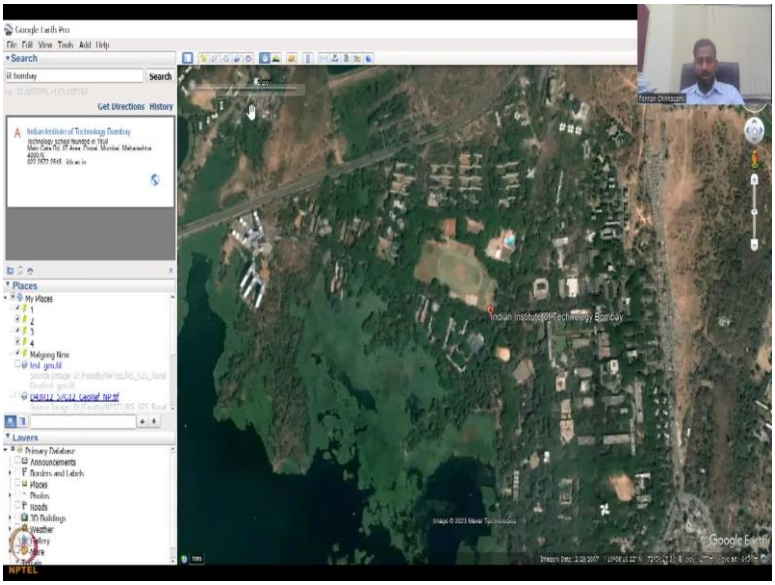
And I am going to 2017 you can see that these fossils were not there, so this was barren land in land use land cover but now these horses are also going to be are going to go off.

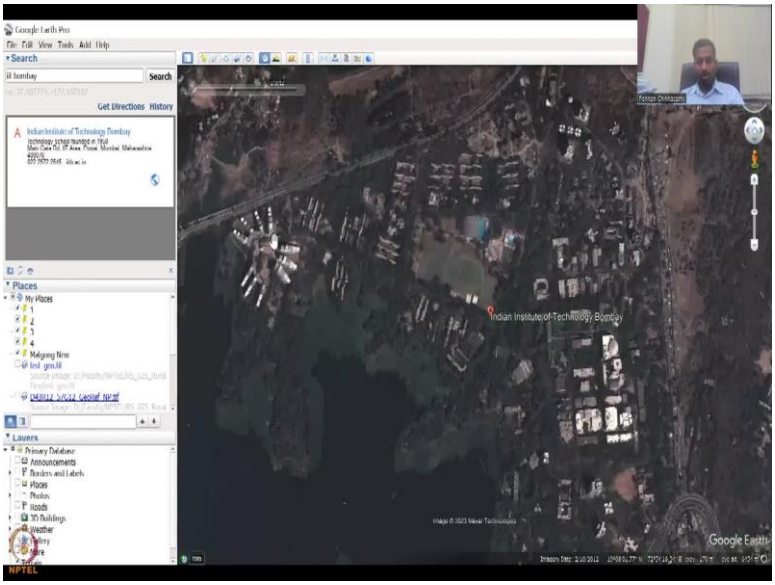
(Refer Slide Time: 34:33)

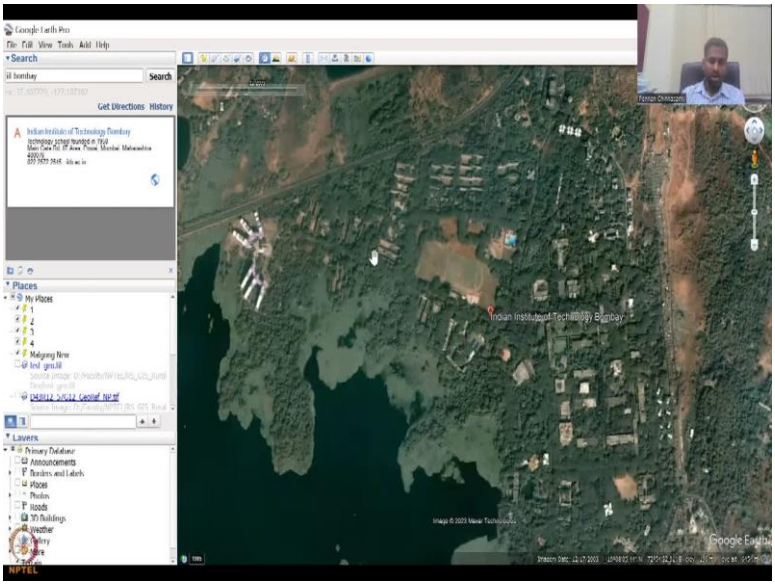


So, I am going to go now eight years from the initial image and you could see that this part is lot of forest cover, lot of tree cover, but it will soon be more relevant in 2018, 2008.

(Refer Slide Time: 34:44)

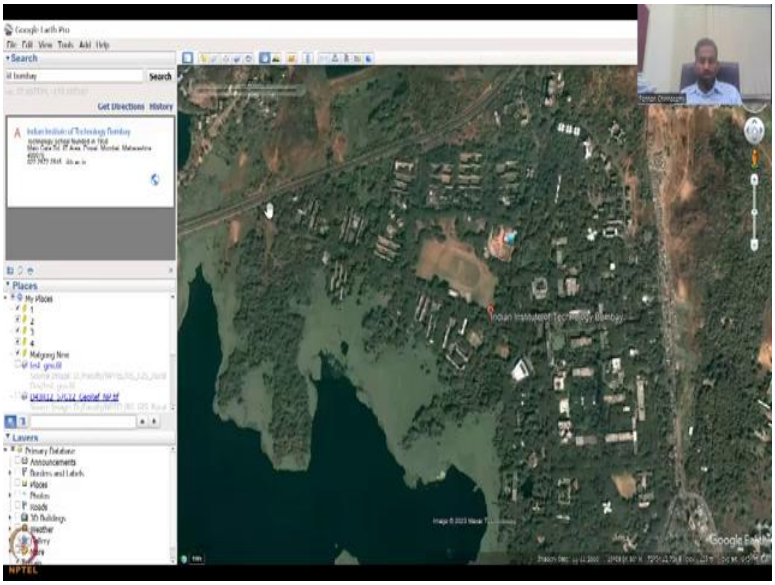


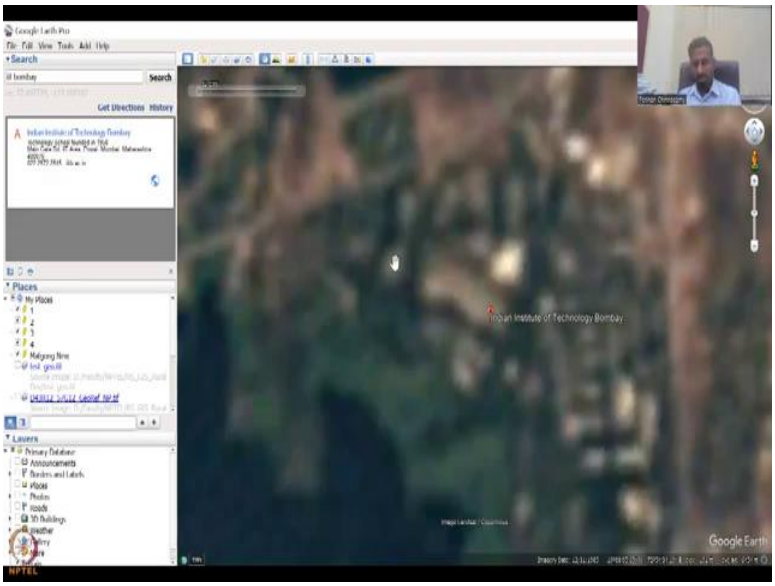


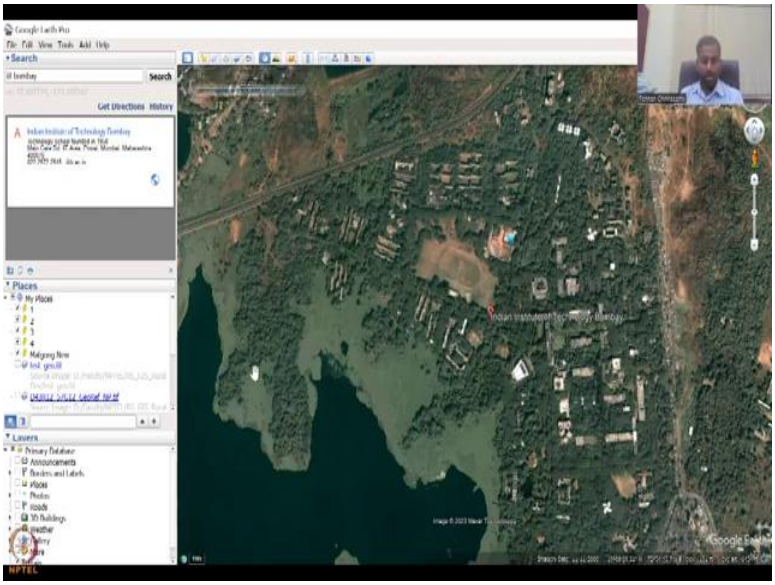


So, 2008, 2007 you could see that only half of this circle ring was there, in this time frame you have a beautiful circle of hostels but in 2007, 2003 let us go back you can see that these lands were still not having much hostels, very very small number of hostels, the size were small there and the land around it was reserved, reserved as green cover and lot of forest entries were preserved like these small small forest lands were still preserved.

(Refer Slide Time: 35:22)



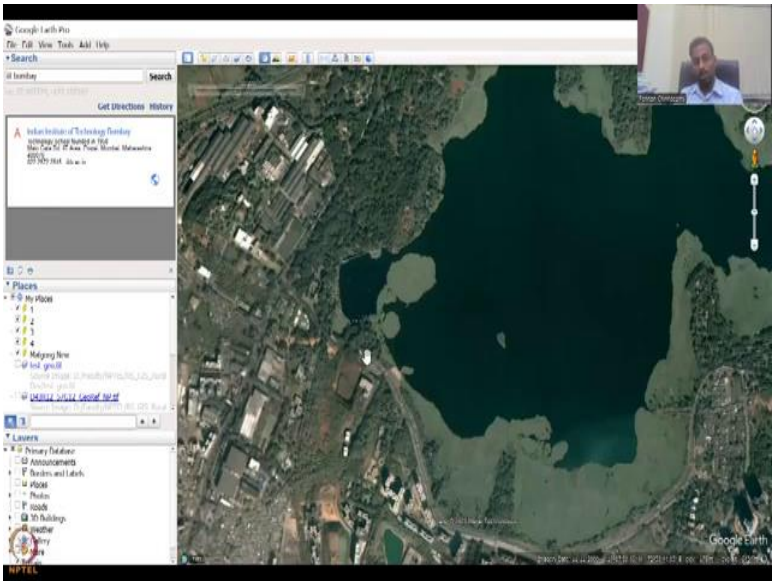


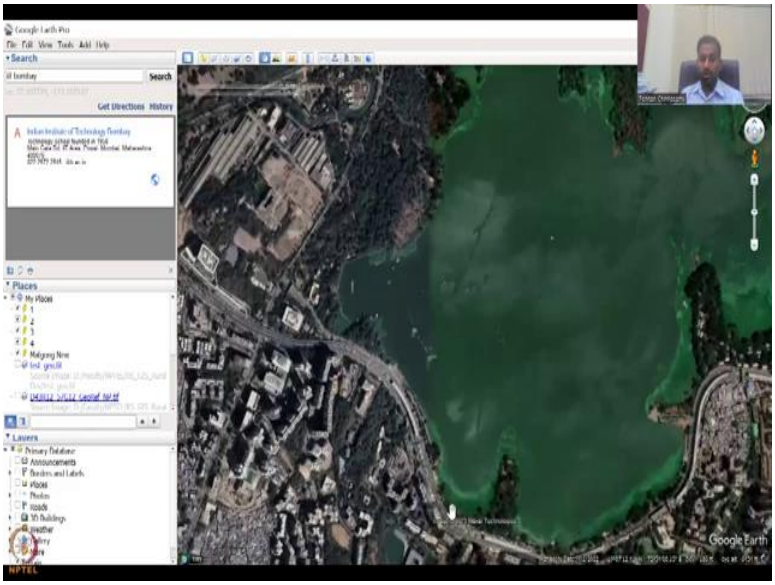


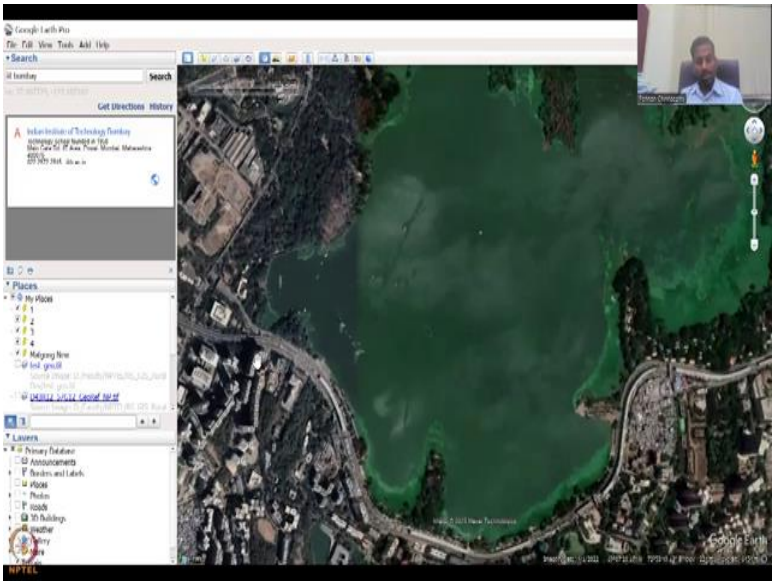
And the earliest we can go is 2000 there is nothing here you can see there is no construction, no hostels, this land was barren with some lot of tree cover. So, now you could see that how a Google Earth Pro you fix it on a single land you can draw the boundary and then within the boundary you can qualify saying that okay 10 percent of this land was under forest, 60 percent was under the institution because IIT Bombay is from 1960s. So, you have a good 60 years of growth whereas this is still 40 years of growth is here.

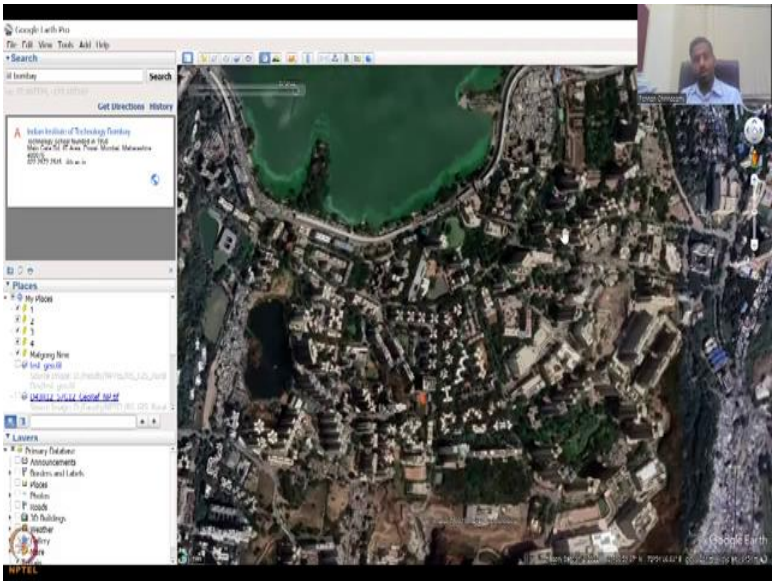
So, the earliest data you can go was 1985 but will be too blurred because the resolution is not good. So, you cannot use 1985 the best data is 2000 you can use and you could see how this has changed.

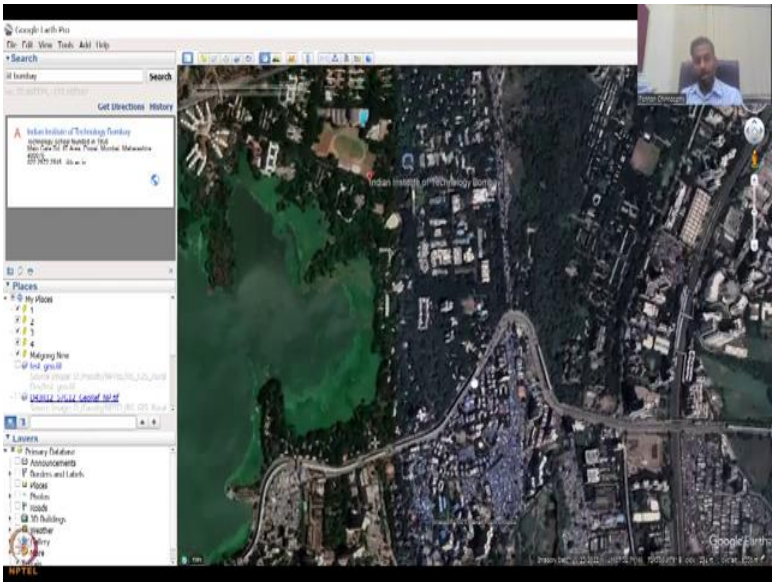
(Refer Slide Time: 36:15)

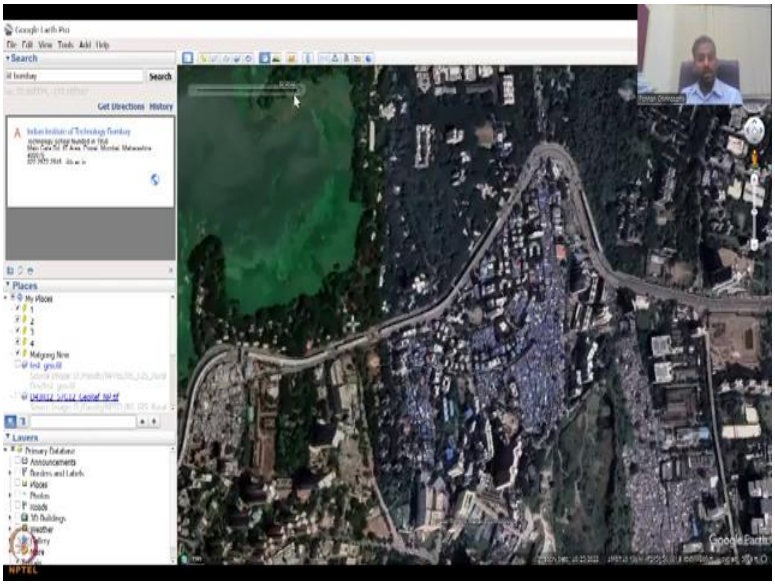


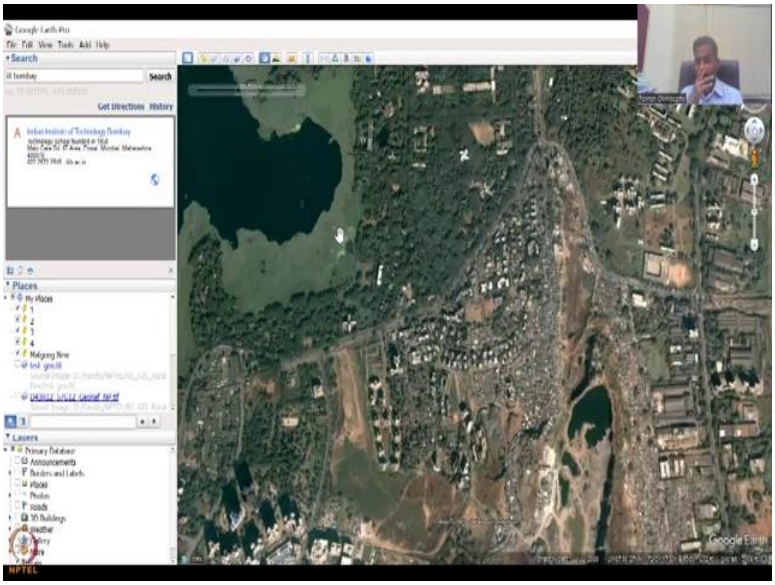












The same thing you can see here this area was totally forested and a lot of water body and the area was very very underdeveloped, lot of barren land and if you now see it you see the metro coming up, you see the good hotels have come up, all these are hotels, Hiranandani complex as I said all this was called was not part of the IIT network, it was all this is IIT and all you could see here is the IIT market and you could see that in 2000 basically 20 years ago it was nothing.

So, there is no, not much development, this water body was there now it is gone. So, it is drained so that this has been converted to land use land recover into barren land and all these rural regions have now developed. I showed this example in my own village also that with Google Earth Pro you can see that before and after and that is basically the land use land cover. With this I will stop today's lecture, I will see you in the next lecture. Thank you.