Remote Sensing and GIS for Rural Development
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Lecture – 2
Raster Data Type Formats and Uses

Hello everyone, welcome to Remote Sensing and GIS for Rural Development. This is the NPTEL course focusing on rural development using remote sensing and GIS-II. We are now at week 5, lecture 2. In week 5 lecture, we have been looking at specific data types in GIS, of which vectors were discussed in week 4, and week 5 we are looking at rasters. There are only two types of data vectors and raster; and we are looking at each one specifically for each week. And in the last lecture, which is week 5, lecture-1, we define what raster data is supposed to have. The specifics and properties of raster data and we also looked at the formats in which raster data is stored.

We also looked at the difference between vectors and rasters. In today's lecture, we will look into more specifics about using raster for rural development. What we see here is some examples are going to be very specific for rural development; whereas, some have to be tailor-made into your objective. As I said, satellites are collecting some physical properties as data, and it is converted to remote sensing image or information after some post processing.

This post-process data which is still raw data for you, because you are going to take the data and process it in GIS, has to be worked upon in different objectives, so that we know what objective we are going to have and what data we are going to use. So, let us look at some raster data for rural development. And I am going to revisit this slide which I used in the introduction lectures, however, with more specifics.

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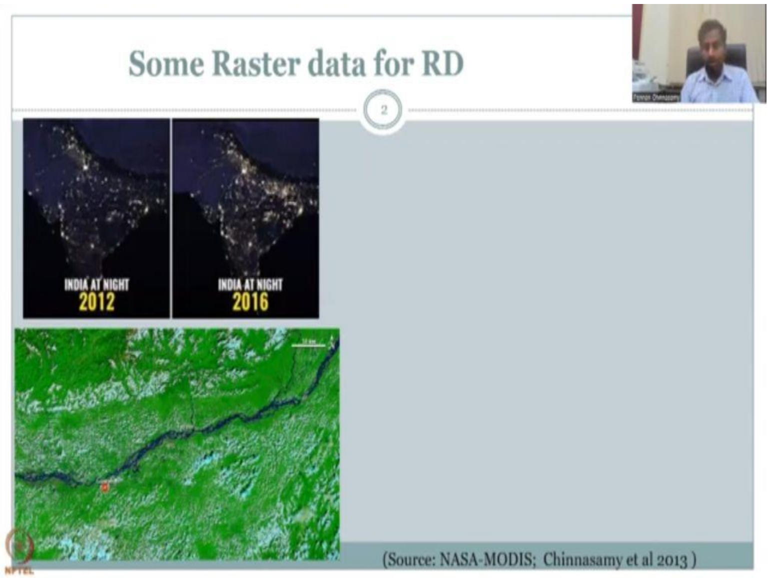

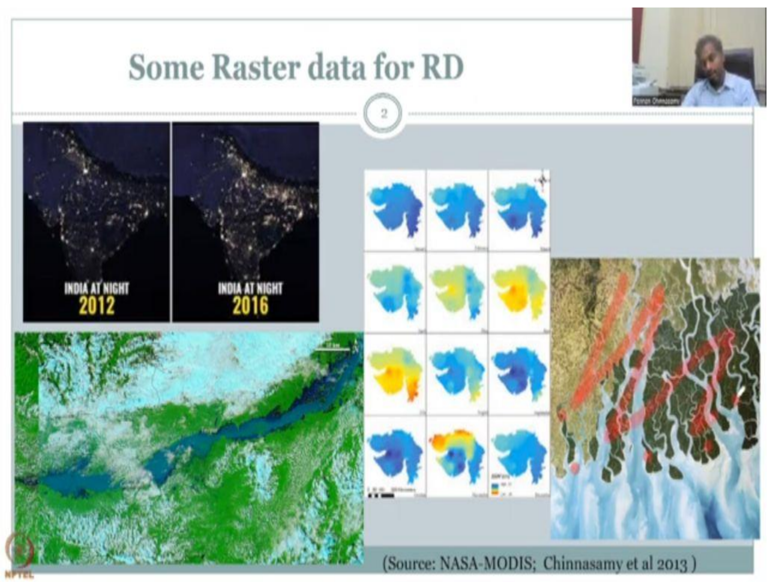

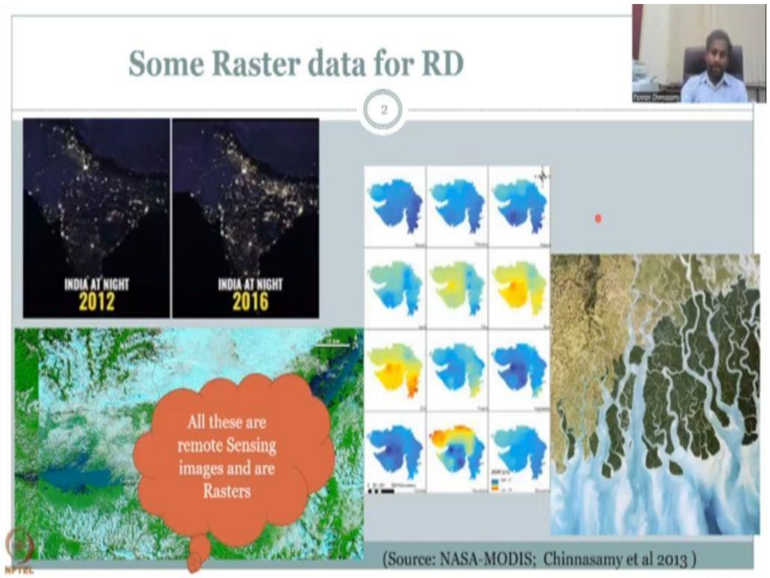

So, this is the luminescence image taken for the Indian region by a NASA satellite in 2012 and 2016. So, how can we use this for assessing rural development? We have defined what is rural development earlier, and one key aspect is connectivity and rural electrification. So, this image, while it does show that the urban centers are expanding, you can see the bigger dots. In both the images are expanding, the bigger dots Delhi, Chennai, Mumbai; all these major metropolitan cities are expanding, it is called spidering effect. However, we also see some positive rural development because in the central part of India and around the major cities, you see some small lights also popping up.

And you see also a road kind of a network connectivity, which is the highways, over the four years between 2012 to 2016. There has been tremendous growth of highways, thanks to the different schemes of the government that we looked upon, and also rural electrification has been happening at large scale. So, these also can lead to access to electricity and power which in turn can be converted to a livelihood option. Shifts that can be operated shift as an morning shift or night shift for running cottage industries; and most importantly, storage and processing hardware can run on power. So, these can be installed in villages now, because there is access to rural electrification programs which is evident from this image.

So, this is one that we would revisit. The other is the image taken by a satellite of a river. This is before flooding that I explained earlier; but, let us look at it per se for rural development. Once we have a water network, we can also assess where the fertile land is. Again, agriculture is the key livelihood option for rural regions and for agriculture water supply is key. Not everywhere we have irrigation through groundwater because it is expensive. However, we do have surface water irrigation. Surface water irrigation can be through rivers and channels, mostly gravity fed.

So, now if we know where the sub streams go through, the land near the substreams can be managed to support agriculture; this is what this image can tell. But, as I discussed earlier in the introductory slides, this also helps in assessing the damage after a natural calamity. These natural calamities are known to impact mostly the rural regions because they are more vulnerable. And for example, let us look at the image after the flooding has happened. You could see that the banks of the river has swelled; Guwahati is here where you could see a lot of swelling happening. We call it swelling or the wetted perimeter is increased.

Now, the lands which were under the swelling are going to be flooded and or sedimentation would have been split; so, the sediments soil would have been spilled across. So, these are not fertile soils, some of them and can impede agriculture development. So, for rural development, one key aspect is resilience, climate change resilience, which means how does the system bounce back from a natural calamity; how fast or how, what is the investment needed these kinds of things. So on that note, this image plays a vital role in assessing the rural infrastructures land and housing locations where the floods could have damaged, thereby letting officials to support these regions through a satellite data, which is a raster.

All these are rasters because as I said satellite data is mostly rasters. We are looking at some rasters that can be applied. So, now if the blue color is only going to be taken out as water and then the rest green is going to be converted as lands, so the raster is going to have only two values suppose; blue for water, green for land. In this first image, you have blue at a certain location; the rasters going to only have blue here; whereas, in the second location, some land parcels have been converted to water. So, these were initially land; now it is water. So, you could see that these raster cells, which have been converted to water cells are the inundated cells; water inundation, which is affecting rural development.

As I said earlier also access to water is key and initially groundwater was a point data. It was at a point how much ground data is available, and that is catered to the local land around the well. It was good assessments when groundwater was less used. However, India becoming the leader in using groundwater, over extraction is reported in many regions across India. And this could be because of climate change, because of overuse of pumping et-cetera etcetera. However, it is important to monitor groundwater levels and with the current point source. So, what is the point source? This is the vector data; whereas here you have raster data.

The point source will only give the groundwater level in a particular location; so we have location specific groundwater data. However, in a raster image, so this is a very specific satellite called grace. In this image, you could see that the coverage is continuous; so not giving groundwater at a point, but across Gujarat. And that helps because we understand where the regional pumping is happening, not a point pumping. The point pumping can have impact only in the location; whereas, a regional pumping can have impact across the region. We could see that here there is more pumping happening during in the Saurashtra region, central regions. But, after the water has been supplied, there is a lot of recharge; groundwater recharge happens, and so there is groundwater recharge in these regions.

The other thing that we would like to discuss is the inundation of the land. So, land inundation happens because climate change creates water level increase, a sea level rise happens; and that can impact the low lying areas. Most of the low lying areas are rural regions, except different cities like Chennai, Mumbai, Kolkata; most of the other regions are still under rural entities. Why? Because these support predominant agriculture plus fisheries, occupation; and there is a lot of people who are dependent on these for their livelihoods. So, now if you look at this, the level increase can only be looked upon as a climate change impact. How do you create early warning systems by using these kinds of satellite images? And you could see that it is a pure raster and a raster, which had land in some spaces, now has water.

So, this is where pixels that had land has been converted into water, because of sea level rise and sea level inundating the land. So, both you saw this, the water in the river coming out because of floods, and the sea level rise increasing because of snow melt; and more water joining the rivers, the sea level rise increases; mostly global warming has been linked to the sea level rise. We are now going to talk about the processes that happen, but because of the process the impact that is affecting the rural regions can be studied on a raster scale. Can this be studied using vectors? It is possible, but not at this high coverage.

You may have a point here I am going to put some points, a point data which is vector data point here point here. We can make it big. So, let us say you have a pointer, a sensor here sensor here to collect a point data of the water level rising. How does it show the entire coverage, it cannot.

So, you need a surface to show the entire coverage; and that is what this satellite image is giving us. All these are remote sensing images and are rasters. In some cases, the rasters can be converted to points, and the points can be smooth to a final resolution of rasters along with observation data. But, again this is kind of a data less intensive course. So, we will not be getting into high processing of GIS and remote sensing, but introducing methods and tools that can be used for rural development.

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One of the most important application of rasters for rural development is mapping, mapping the land cover acreage; so there are multiple terms that can be used. Let us stick with the agriculture and agricultural allied livelihoods; for example, grazing of animals dairy, all these require land. Land as in not just a plain barren land, but a land that needs cultivation water; and after that there is a harvest and then post production. Cows need grazing, cows need food for dairy industry to flourish; if you try to bring the food from other resources, it is going to be expensive.

So, there is a grazing land. And then you have goats and these are predominant livelihood options in the rural regions which are allied to the farming. Farming is key but then the these are like; poultries also there chickens, ducks et-cetera. Mostly it is agriculture followed by dairy and poultry. In agriculture, you have different types of agriculture, horticulture, cash crops, food crops, etc. Knowing the spread, knowing the acreage of this helps in understanding the natural resource requirement for optimum yield. Let us say you have a one hectare land which is growing sugarcane and another one hectare land which is growing cotton.

You are not going to apply the same resources to the land, which means same water, fertilizer, pesticides; these differ because of the land use cover. So, this land use cover is very important for attaining sustainable rural development. And other sustainable development goals, you have food security, poverty reduction all are linked to the optimum use of the land. So, here in this map, what you can see is which is produced using the European Space Agency's satellite data, GlobCover Version 2, 300 meters per pixel. You could see that the land has been colored based on the type. Here we are, we look at multiple coloring that has been used this; I am just zooming in, I am just zooming in this region for you to see.

And you could see that a lot of cultivated and manage areas rainfed areas are orange in color; and the dark greens are more the forest. So now, if you have a time lapse image, which is an image taken in 2004, for example, and the current image that is taken in 2022 or 2023. If you can assess the difference, the difference in forest cover, the difference in the agricultural land cover all these would provide the assessment of resources that are needed for rural development. Let us take some more focused angle on this.

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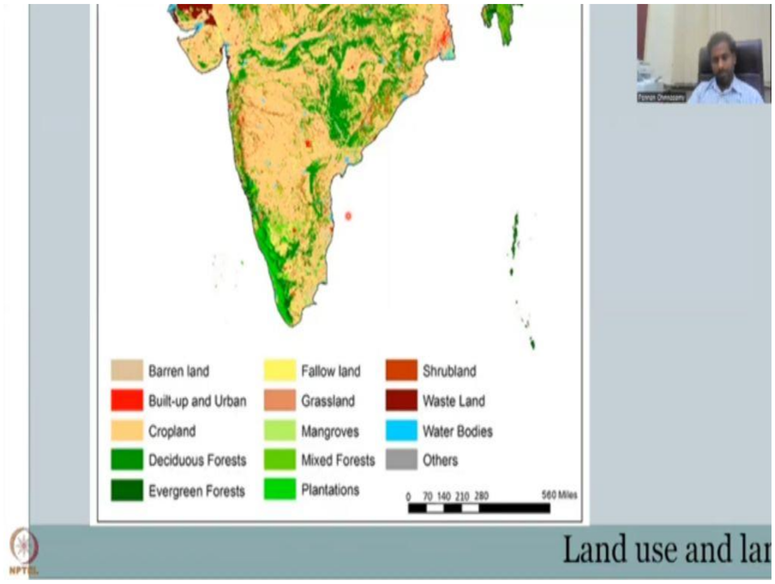

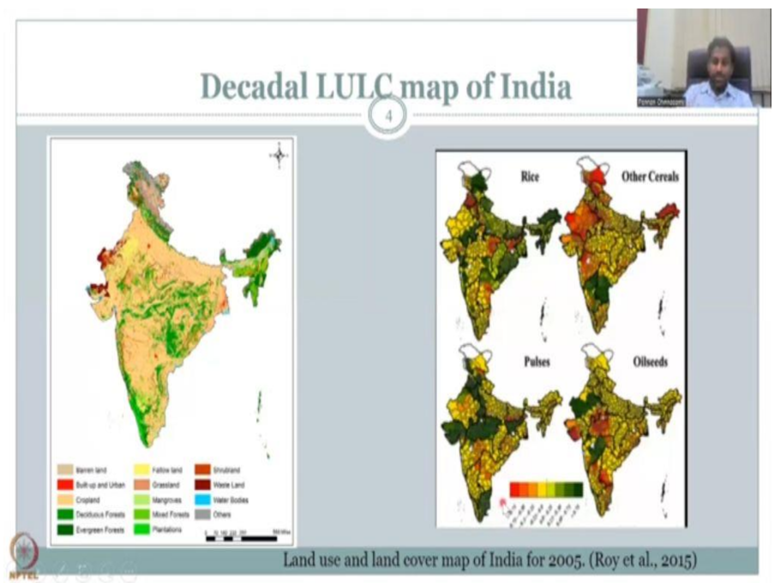

We have the decadal land use land cover map for India; so, decadal means in 10 years over 10 years. So, you can see that a land use land cover map of India for 2005 versus 2015, which I am going to pull up. But, before that this is a raster see how the data is continuous. I have clipped the boundaries out, so that you can only see the data for India. There is because the discussion is going to be on India; we are not going to look at the other regions of the world. So, we are going to look at here for example. You could see here, you are looking at the colors which are red for built up area, and then fallow land.

So, this is very important to understand where we are having built up area, and where the land of rural land has been compromised or changed into multiple different land use types. So, let us look at what the land has been used for. What the land has been used for is it has been used for rice production, other cereals, pulses and oil seeds. So, this is a spread of land use land cover across India. The top Kashmir parts do not have much agriculture because of the Himalayan region. But, if you look at here, let us say for example Rajasthan, it was growing rice but not high.

So what what, where was the rice growing regions, it was here. So, just looking at this rice image, you could see that most of the rice is grown in the Chhattisgarh, Odisha belts and the southern regions a little bit. But, cereals are grown mostly in Karnataka, Andhra, Telangana; and pulses in Tamil Nadu, Madhya Pradesh and Gujarat; whereas oil seeds are in Rajasthan. Wheat is still there, but we are not having it in this paper; so, all these are done. So, these are extracted first as a generic cropland. So, if you could see cropland is given in brown color in the left image, and then the cropland is divided into multiple crop types.

I gave the example of a person who has two hectares, one is sugarcane and one is cotton. So, if you look at the top image, the initial image of a raster, you will combine both the one hectares as cropland; because it is used for agriculture. However, in the second phase which is the second level of raster estimation raster classification, the cropland area is converted or classified into rice, pulses, oilseeds, horticulture, whatever it is for that location. So, you could see here, initially this image just shows it as cropland; but what crop? So, that can be answered by here which is pulses and rice. These are taken by high resolution satellites, which can capture the difference between the green color of sugarcane, and the green color of a soyabean.

From the top, it might look all green; but the satellite can differentiate between many multiple green levels. And based on the green level, sugarcane has a signature green; whereas, soyabean has a or cotton has a different color of green. So, those both the greens are not the same. So, once you know the signature of sugarcane and the signature of cotton, you can easily divide it and make these kinds of maps which says that the land; yes, it is cropland in Maharashtra, eastern side of Maharashtra. But, we also see the type of cropland; wherein, you could see, let us take Madhya Pradesh. In Madhya Pradesh, you have some cropland here; but most of the cropland which has been aligned is having pulses. Same for Tamil Nadu, we have a lot of cropland which, which part of it is oil seeds; part of it is rice and most of it is pulses.

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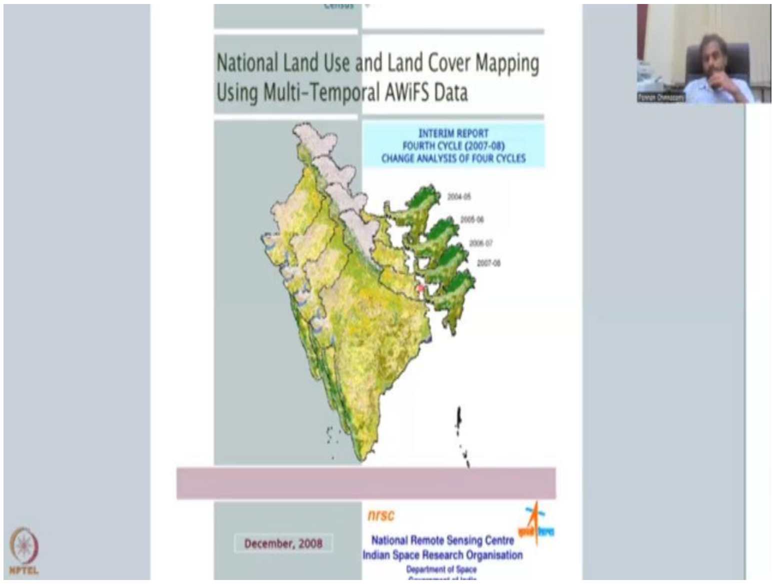

So, in this image you could see that you have multiple land use land cover done by ISRO. So, knowing the importance of this land use land cover for Indian rural development ISRO produces these land use land cover maps at different temporal scales. So, they aggregate the data and then they make 2004-2005 example till date; so, they are publishing it. This book is 2008 book, so that is why you see the image of 2008. However, you could see clearly how the at least here because the other reasons are overlapping, the image is overlapping; whereas, here you could see 2004 to 2007, how the green color in Assam region the Northeast region has changed. Is it good or not? Will that kind of assessment will you will have to go to the ground and assess the benefits, and impact for rural regions.

But, mostly it is how the land has been converted to industry or over production, which leaves the land as barren. So, if you too much exploit the land for water and nutrients, it becomes barren thereby not supporting plant life for a couple of years. And that is where rural development requires resilience mapping and land use land cover mapping.

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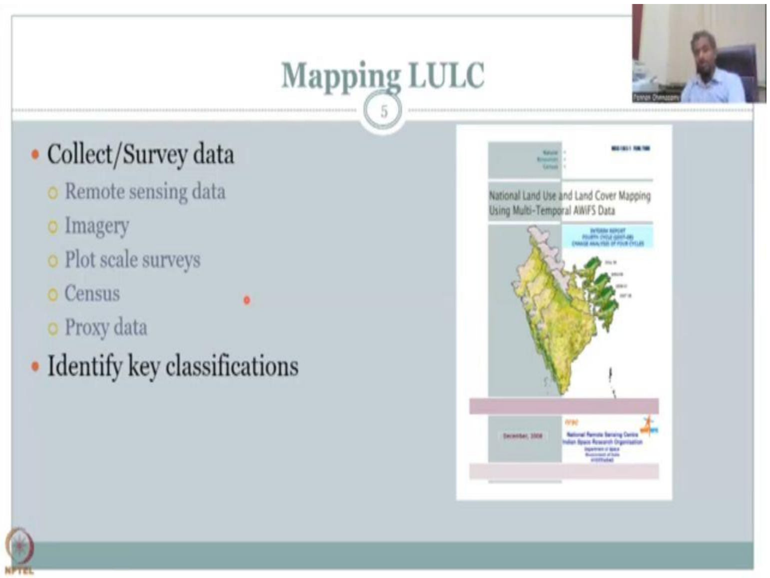

How is this done? They first collect data which is of two types. The first data is your remote sensing data, which is your satellite raster data. The raster data is classified into different colors and each color is given a particular land use land cover type LULC, which stands for land use land cover. And the remote sensing data is both imagery or satellite data and then some surveys are done, wherein, people go down and look at each pixel in a region; and then report the pixels color to the satellite data. So, now you have a same location through the satellite, you assess the green color; but you do not know what that green color refers to. So, you send people to collect one or two points in the pixel to show what color that is.

For example, the green color could be sugarcane or soyabean; from looking on the top view, you cannot differentiate it. But, if a person goes down to the survey and then assess it, we can be taken on. So, that is called ground truthing plots through plot scale surveys. Then, you have census data which can give you a data on yield agricultural census yield, or agricultural crop production data; these can also reflect the land use land cover change. We can only know that one hectare there is rates; one hectare can produce a ton of a particular crop. You would expect 50 tones, 100 tones suddenly; so that is where the census data can play a vital role.

And then proxy data, other data that you can use to map land use land cover. The key here is to classify your satellite data, the image the rasters into multiple colors; and the multiple colors should be given names as an labeling of what that color means. So, identification of key classifications is very important.

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Now, let us look at in other regions and in other scales how a raster image, a satellite image can help. One is the cropping calendar. And in this you can clearly see that an image an infrared image that has been taken by a satellite, some pixels are red; whereas, some pixels are brown in color. The red indicates a healthy growing green crop. So, if you look at the trees, the trees are also red. So, this is an infrared camera in the satellite, which is picking the green color a lot. And you could see that green because trees are always green; it is not red in color. So, green has been picked up, which means the winter month wheat crop; because this was taken October or early November that period.

So, in between maybe early November, this image was taken. And you could see that the winter wheat, the winter sowing of wheat is happening in the same image; and some land is ready to be harvested. Because the green color is gone, it is turning brown. So, the plant when it starts, it is green in color. Slowly converts to dark green and then the green color comes down thereby converting to orange, brown; and then the plant is wilted or the plant dies, so or harvested. So, this is where the coloring of the plant through a satellite imagery can give you the cropping calendar. Each pixel takes a color and that color can be represent when the crop was stoned, was sowed and harvested.

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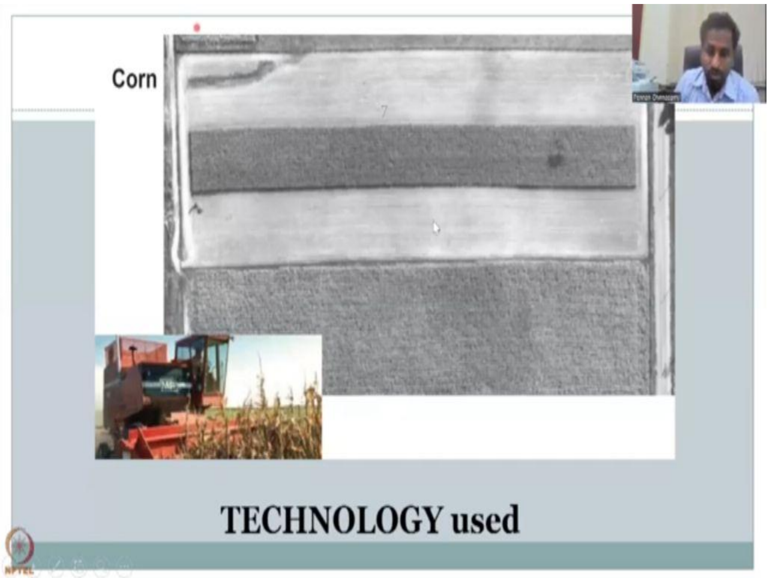

Also it can be used to assess the what kind of technology has been used; let us say for example this. This image shows clean cropping boundaries and also the harvest has been very clean. So if, if it is done manually, you will see some one or two not correctly harvested; or it will not be smoothly harvested because people they cut on the top, cut on the bottom. So, the height of the stub which is remaining back in the land will have different colors, whereas this is very smooth. This smooth color comes back because it is almost unique. And that unique comes because of a machine like this harvester, which actually cuts through the crop line at a particular height.

So, you have a clean image; and this image reflects the technology used. So, now farmers can know that what technology is used in the neighboring farms, the neighboring rural areas; and those technologies could be brought in for their use also, instead of them going and looking at it. These images can help and also help the rural authorities. This is corn crop. So, you can help the rural authorities to put budgets for farmers because these technologies are actually help. And you can also see a river which is going across a water drainage that brings water.

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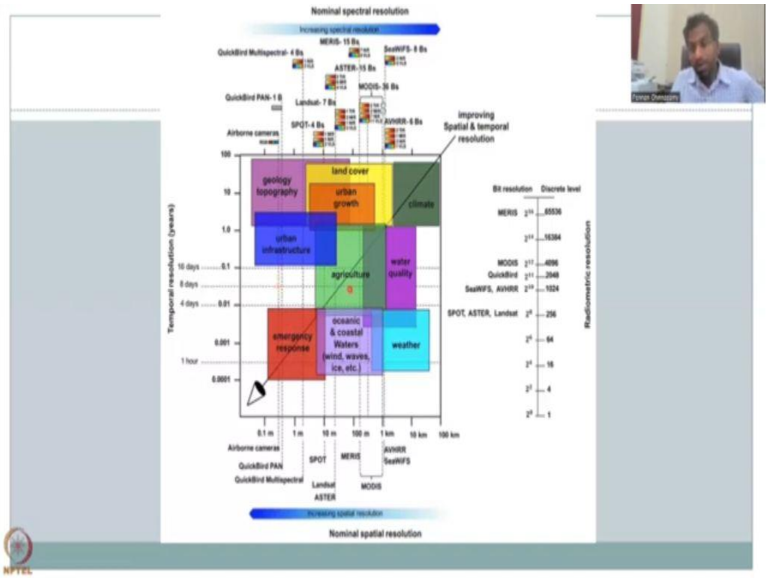

So to conclude, there are a lot of satellite data, which are raster images; and each data differs in spatial and temporal resolution. Spatial resolution is the pixel size, whereas temporal resolution is how often does the satellite come to the same location to collect the data for the pixel. In this graph you would see that the temporal resolution increases from top to bottom; because 100 years is low resolution, 0.001 years is high resolution. The same thing you have 100 kilometers has a high space high spatial coverage, but low resolution; because at 100 kilometer pixel, you cannot find what crop it is. You cannot find your road; it just takes the dominant color.

So, if that 100 kilometer pixel most of it is let us say a forest, you will lose the housing, you will lose the agricultural land, and only forest color will be there. So, 100 kilometers is coarse or and 0.1 is fine or hyperfine resolution. So, now what you could see here is the linear point of collation is right there, the 45 degree angle; and this is where improving spatial and temporal resolution happens optimal range we can say, because at this point it is very expensive. If you look at which satellites are giving these kinds of data, these are not free data; you have to pay a lot of money to get it. These are private data collection agencies like for example, airborne camera through your drones and small airplanes.

Whereas quick bird is a commercial satellite data agency where it collects data at very very high resolution, and sells it for optimal views. So, now where does rural development come? Fortunately, the rural development mostly comes in this part; emergency response is there during floods and droughts. And the geology and topography is also a one time investment. But, mostly the land cover agriculture, water quality all come at a not to find resolution or to course resolution, but somewhere in the middle.

And those middle ones are dominated by satellites which are open source. So, you could see that the bands are given; and mostly these are also temporal resolution is 18 days, 8 days, 16 days which are okay for agricultural development work. You cannot have 100 years data it is of no use, or one year data. One year data how do you accumulate? So, if you remember the groundwater map I showed, it was monthly. And now this image in the center says by monthly, every 15 days, every 16 days, if you collect data that is good for rural development. We will revisit this slide more after we discuss the satellites and the processes involved in accessing the data. With this I conclude today's lecture. Thank you.