(Remote Sensing and GIS for Rural Development

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Week - 10
Lecture no. 46

Remote Sensing based indicators for rural development

Hello everyone, welcome to the NPTEL course on Remote Sensing and GIS for Rural Development. This is week 10, lecture 1. The past weeks, we have been looking at various issues in rural development especially data issues to augment and increase the understanding of the rural problem. And we also looked into certain aspects of new development. For example, increasing acreage under a particular crop and crop yield. We also looked at that most of the data are outdated and are from the British era. These need immediate updation however, lack of capacity, time and cost limitations are available. And therefore, there is less data that has been procured for rural development.

On this note, instead of doing the business as usual scenario, we have looked at multiple data sources that can either service proxy data, create new data through data mining approaches and or become augmented to the observed data. So, in that case, we saw remote sensing data as a very powerful tool that can do all these 3 things that I mentioned augment observed data, when data gaps are there, data limitations are there, provide new data as secondary data or proxy data and or can be used for data mining activities. So, where you can create new data.

On this note in the last week, week 9, we stress for the need to understand the land that is available for rural development, not only agriculture, but for example, if you want to start a small scale industry and or a chicken poultry farm, aquaculture, you need land and resources. For that, we have used remote sensing tool to select areas for these data issues. And for new development activities.

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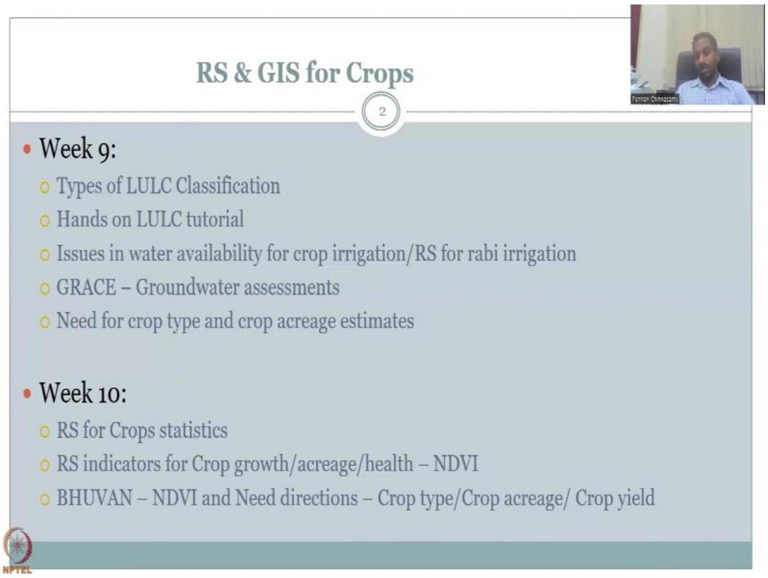

So, let us do a recap of week 9, what we went through in terms of understanding the data needs and how remote sensing can help. In particularly, we looked at remote sensing and GIS for crops. Because rural development is still mostly focused on agriculture. Most of the population works on agriculture. The water that has been given to rural regions around 89 percent is used for agriculture. I would say more because industry is less. So, 90 to 93 percent of the groundwater in the rural area is used for agriculture, if not 100. So, in week 9, we looked at types of LULC classification, which is basically the land use land cover. And we also did some land use land cover change, so that we can look at how the land changes and where we can implement new development activities.

Government activities can also include increasing acreage of farms, grain farming, agroforestry and subsistence farming. We also did one hands on tutorial and you were using data stored in the USGS website. And we were able to quickly do within the 30-minute timeframe. However, there were some errors and fine tuning could have been done. As I said, these exercises were initially master's thesis some 10 years ago.

Now, we can do it in 30 minutes. Thanks to the development of ease to access of data and readily available remote sensing data through multiple platforms. Then we looked at issues in water availability for crop irrigation, we discussed crop irrigation as a particular entity, because during the monsoon season yes, if you have land rainfall comes you have agriculture, but during the non-monsoon season only those farmers who have access to water can do irrigation, which is application of water for crops. So, a farmer sometimes have only one crop, because when the monsoon comes they do the farming.

So, in growing the crops and then harvesting and when there is no monsoon, they harvest it and then wait for the next monsoon. These are farmers who are limited with economic resources and water resources. Whereas, farmers with access to pumps, wells and some budgets can involve in non-monsoon crops. And these are divided as Rabi and Zaid crops and in some locations in India, I will show through the case study, you could also see the same land used four times.

So, one during the monsoon twice during the Rabi and one during the Zaid season, mostly the summer monsoon may take more crops. So, we discussed how remote sensing can help in identifying land and water resources for irrigation, monsoon crops is one but non monsoon crops is what we looked at. And also we discussed the fact that irrigation does not mean that it is only non-monsoon, even during the monsoon when the rainfall is less, because always not the same rainfall occurs. When the rainfall becomes this we can supply excess water through groundwater or canal water.

Then we looked at groundwater as a tool for irrigation. And short case that India is the highest groundwater extractor in the world with approximately 245 kilometer cube water extraction, I say approximately because the data does not fully document all the groundwater use and groundwater access. And that is where we found that central groundwater board data which is collected once every 3 months may not be sufficient to capture spatially, temporally and deep and shallow aquifer connectivity.

So, all these 3 things cannot be done just by using observation data, wherein new data should be augmented and grace data was found. I explained very clearly how the grace data works and showcase some regions in the Ganges and Rajasthan, Haryana, Punjab region where groundwater depletion is tremendously high. This is reflected in the Central Groundwater Board report also, however, a longer time series analysis is absent.

In the grace website, just by a click of a button, we were able to get around 20 years of data groundwater depletion data for the Punjab region, I say groundwater but it is actually total water storage. If we assume that a soil moisture is the same, it just cancels out its anomaly and what you get is net groundwater change, the slope should be the same. And you would see that soil moisture comes in so, the sinusoidal curve was there.

Then we found out that after groundwater, we also need crop type and crop acreage estimates. We discussed who are the key stakeholders that require this data and use it for rural development. And now moving on in week 10 we will see what exactly the remote sensing tools are available for crop statistics which include crop type identification, crop acreage estimation, et cetera.

And there has been many indicators developed using remote sensing data. These indicators serve as a matrix or a baseline from which assessments are done for crop estimation. So, this is very, very important case to understand the remote sensing indicators, which indicators are suitable for Indian locations and look at crop growth, acreage, health, et cetera. One such indicator is the NDVI indicator, which we will focus a lot in this class, it is very easy to estimate and more importantly, now, you have ready made products for NDVI.

So, when I was in school, I would normally download the data, do the subtractions and estimated, but now almost 3-4 platforms have readymade NDVI data, you just have to download it and use it for your reports, will showcase what it means in the coming slides. So, that is where I said as I said, some platforms Bhuvan NDVI, we will check and need directions where is the new crop type, crop acreage, crop yield estimates going to come. All these we will discuss in the week 10 lectures.

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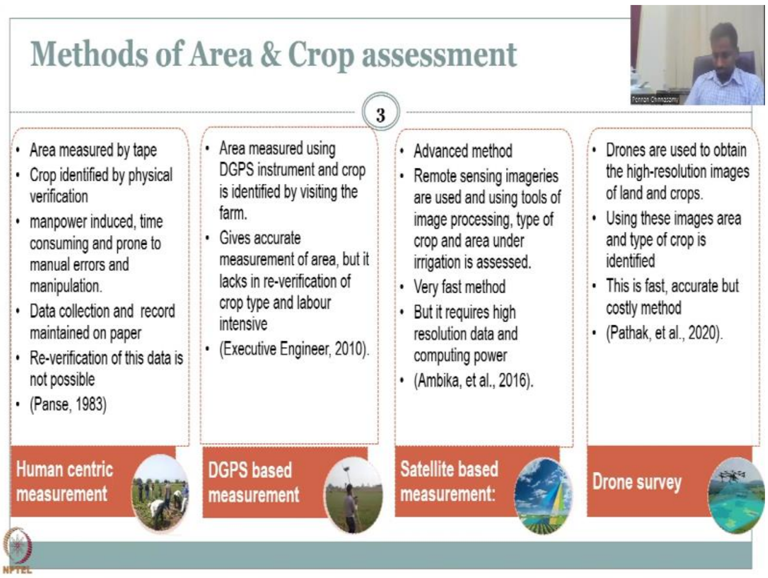

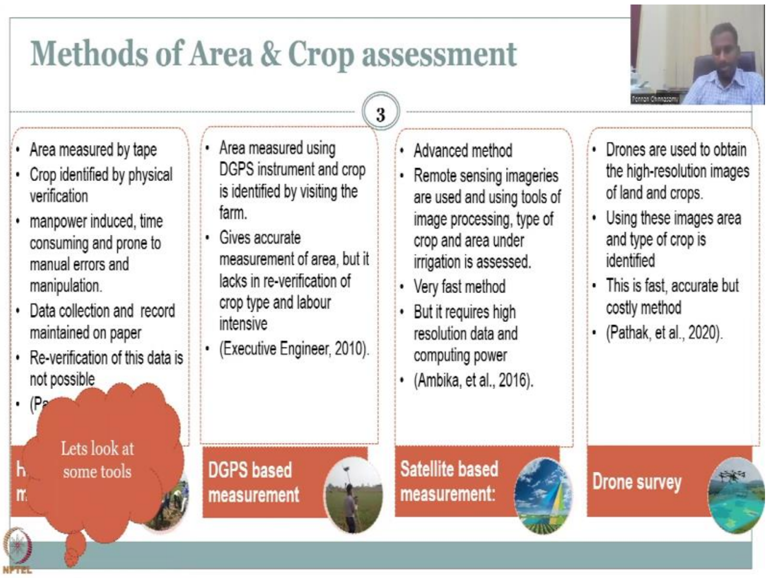

So, we discussed the methods of area and crop assessment and how in the past they have been using human centric approaches, wherein people would use a tape and a scale to measure a particular area for a particular crop. And then slowly there has been some updates in this method. So, even now, people use the physical methods, you would see people going down during the flood season to estimate crop damage and then area not using remote sensing data, which is quick and approximately correct.

And then we have the DGPS method where we have differential GPS measurements taken around. But the most quickest, less costly, or even free open source I will say is the remote sensing based estimates. They are very fast and have high precision and accuracy compared to the other methods. There is no bias error, human error. These are all neglected. Human error can only induce if the person doing the GIS work does not do it properly. But nowadays, as I said, there are platforms that can give this data quick and free of cost. So, you do not have to rely on errors that may happen.

Then the drones we discuss about some drones. Like for example, an average agricultural mapping drone would cost around 8 to 10 lakhs. Not all farmers will have that money. Even if you say a cooperative of farmers can own a drone, let us say a village owns a drone, but who is going to fly it, who is going to get trained in flying, there is a certificate for pilot certification, and who is going to get data to analyze. So, all these are there and still GIS is needed, still remote sensing principles are used. So, why not use the satellites.

One thing I want to stress here is of all the technologies, satellite technology is growing every single year. So, the data which I used when I was in college and school was 90-meter resolution, now you get it at 30 meter and 10 meter resolutions free. So, you can see how the big jump is. And also you get new hyperspectral and multispectral images, which was not readily available in those days. So, I am trying to educate all of you through this NPTEL lecture to spend a lot of time on processing satellite data. Even though drone survey data is also remote sensing data, and pushing for satellite data because the satellite data technology is coming very fast, is growing very fast. Indian Government has relaxed a lot of rules for using satellite data for research and stuff, which means like giving it for free of cost.

So, I would recommend you to focus more on satellites. Similar rules and regulations may occur for drones and the technologies and the steps that you do are same because it is the same GIS remote sensing data that you can see.

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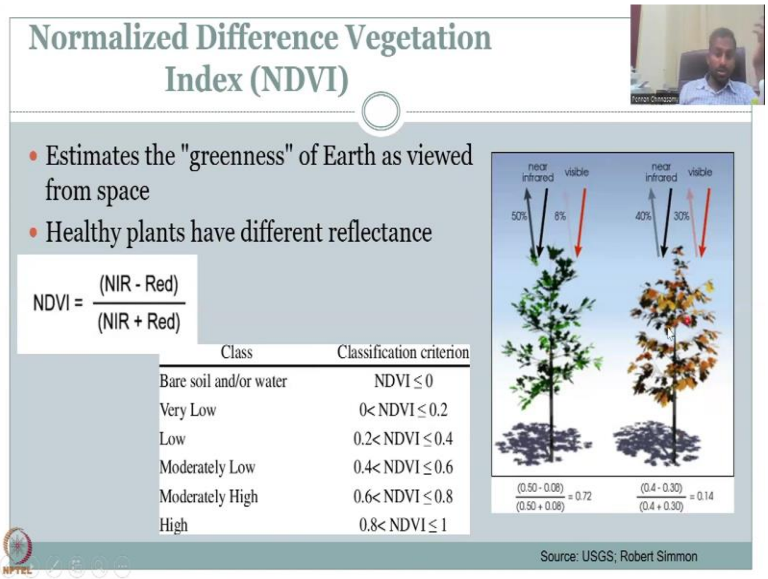

So, moving on, let us look into some examples of the real satellite derived products, satellite derived tools. Indicators are very, very key. There is a lot of indicators that are used for research for especially mapping acreage of crop growth vegetation and the health of vegetation. So, of this NDVI ranks really, really high. A lot of studies will be done if you just Google NDVI in Google Scholar will see like a lot of papers available. And you will also see a lot of papers available for the Indian subcontinent.

So, I would like to first foremost have this discussion on NDVI, and then we will take care of other indicators also. So, the Normalized Difference Vegetation Index NTVI, it estimates the greenness of Earth as view from space. So, basically, if near infrared, or a green light is shined on a particular plant, and a plant is fully grown very healthy, it has green leaves, then lot of green is reflected. The other colors are absorbed.

Same the near infrared is given by plants, and it is reflected by plants, because when it is healthy it as more near infrared. So, basically, a healthy plant has different reflectance compared to a normal or a non-healthy plant or a plant which is ready to harvest. Let us take this example. So, you have 2 plants on the screen with my pointer, so you have 2 plants. So, one is the healthy plant and one is a plant which is about to lose the leaves, it is getting brown and stuff. So, let us look at these 2 colors, near or wavelengths in the spectrum the near infrared, which is not visible to human eye.

So, that wavelength when it comes almost 50 percent is observed in the plant and 50 percent is reflected in a healthy plant in a non or not that healthy plant or plant with brown leaves, a plant which is entering fall season, autumn season or which is dying, wilting because of no water, no fertilizer. So, that actually gets 40 percent reflected, 60 percent is absorbed by the plant. And you could see that that 10 percent difference is big to tell the difference between a growing plant and a nascent plant. A growing healthy plant will have really good green cover and the green cover of the leaves will reflect the near infrared high.

Same the visible light almost all of that is observed because invisible you have multiple spectrums, multiple wavelengths, most of that is observed but the green is reflected. So, the 8 percent is reflected in a healthy vegetation whereas in the visible 30 percent is reflected because it is a mixture of colors not only green is there you can see green, red, brown, orange, yellow, all these colors are there because some leaves will have still some greenery whereas most of the leaves are turning from green to red, brown and then slowly falling down. So, that will give you 30 percent of reflectance.

Now, this difference in the reflectance will be used as a function for estimating the plant health. So, look at this. So, 50 percent is reflected. So, this is how the pixel will give you that pixel will give you value of near infrared if 50 percent is reflected, if 50 percent is stored in the pixel. So, that pixel value is taken here 0.5 minus 0.08, 0.5 plus 0.08. So, the equation is very simple. NDVI is near infrared minus red and near infrared plus red. Since this plant has a lot of red color, red color is reflected. Since it has less red color, red colors is observed in the visible red and then you have the near infrared which is a particular wavelength and that is being highly reflected in the healthy plant compared to the non-healthy plant.

So, this is the equation near infrared minus red by infrared near infrared plus red. So, 0.5 minus 0.08 by 0.5 plus 0.08 is 0.72. Here it is the same thing 0.4 minus 0.3 by 0.4 plus 0.3 that is 0.14. So, now we have ranges and this range is given by a lot of the searches based on the NDVI is a function. If the NDVI is negative or below 0, any value below 0 it can be barren soil or water because there is no life. If there is no life, there is no infrared, near infrared.

So, basically the top will be 0. So, this this part will be 0 then this negative part is there. So, even whatever small parts or let us say minus 2 by 0 plus 2, so, it is 0.5. 0.05. So, all these negative values would indicate that the near infrared is totally observed and not reflected. So, if it is not reflected the satellite will not see it. So, what data we are collecting is the satellite the sun’s energies are coming and it gets reflected back. Once it gets reflected back, the satellite captures it and gives you as an image.

Now, if 50 percent is reflected, the other 50 percent is observed. When will it be negative as per this equation, if NIR is 0, there is 0 percentage of NIR coming all of it is observed then it is either barren or water. So, water observes all the colors, and then it splits because water is colorless, white, et cetera. Barren soil is a lot of there is nothing there to grow. So, there is no green, there is no infrared reflecting agents. So, you will not see much infrared.

Very low is there. So, these are the classes for the plant growth. So, very low, very less plant growth is 0 0.2, low growth moderately low growth is 0.2 to 0.44 to 0.6, high growth and really good cover green cover is vegetation cover is 0.8 to 1. So, the max is 1 and the minimum would say people say minus 1. So, the studies have actually shown that NDVI ranges from minus 1 to plus 1 because the max you can have read is minus 1 if NIR is 0, 100 percent is reflected from red. So, you get minus 1.

So, this range, which has been created for NDVI is used widely. So, all the data is they will get the reflectance. And then multiple bands are there, they take the NIR band minus it by the red divided by NIR plus red. And whatever the fraction comes, refraction is between this range, each range has a particular value. So, from this you can see 0.72 is almost near to moderately high and high. So, which means the plant growth is really good. And 0.14 is very, very low. So, you could see that also the plant growth is not growing well.

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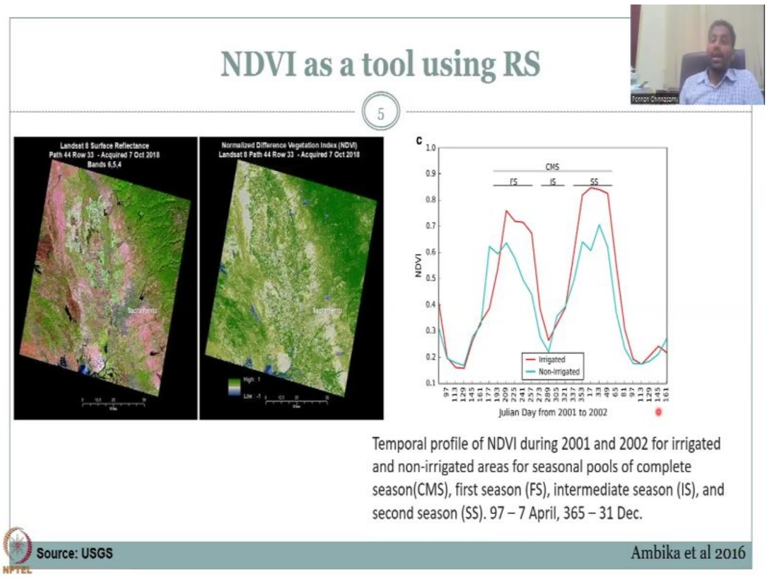

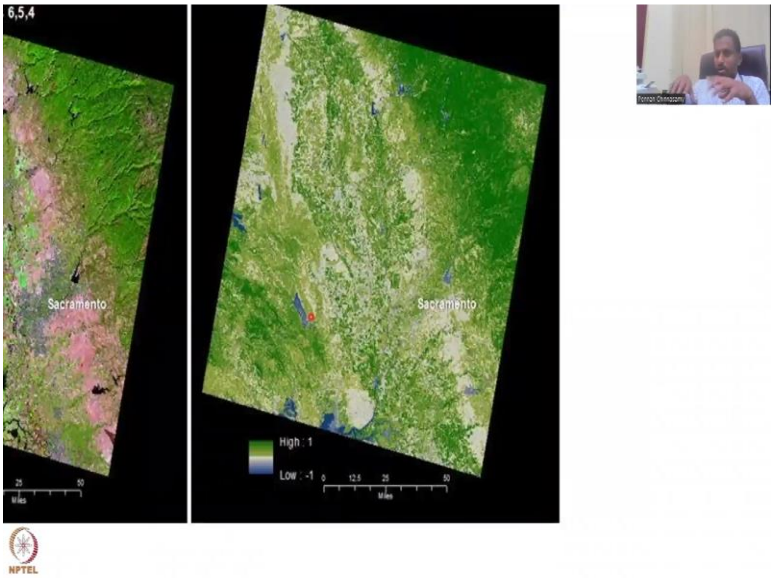

Let us look at some examples. NDVI as a tool using remote sensing. So, this data from USGS shows the recent Landsat, Landsat 8, Landsat 9 is also recent. So, this is this bands is 6, 5 and 4. So, what you do is when you collect this, the difference between the surface reflectance of a normal Landsat and a normalized difference vegetation index NDVI. So, you have taken 654, normally, 6 minus 5 by 6 plus 5, the band number, and the band 6 is near infrared and 5 would be red, or 4 would be red depending on the satellite.

So, here if you see if you merge all the colors in one composite, you have this colorful image. And wherever green is there, you think, okay, there is good green growth, whereas this pink and brown is there, you think, there is nothing growing. But if you do the NDVI color, which is non visible to the eye, 6 is non visible, near infrared is not visible, if you subtract and then do the coloring, then you will see that the range is minus 1 to 1. As indicated the water bodies are minus 1. It is a blue bodies are there.

You can easily determine if it is a water body or not, by zooming into the location, see if you zoom into the locations, normally the water bodies have a shape, round shape or kind of irregular kind of a shape. But you can you can see that the drainage is there, there are some pathways into the water bodies, you do not see suddenly there is blue as a patch. But here you could see these lands are low, there is no vegetation growing, whereas in the northern side, there is a lot of good vegetation growing in the Sacramento region in the US.

So, this is a clear difference between a normal image taken by the same satellite, same sensors. If you use a composite image, Landsat 8 all the bands that you see is this, but if you say no, I do not want all the bands. I am going to take out 6 and 5. Suppose 6 is near infrared and 5 is red. I am going to take 6 minus 5 and 6 plus 5 and there you are, you get the NDVI indicated map. And in the indicator map you can see that clearly a lot of areas are green and there are some nascent growing also happening, which is not shown well in this image.

So, using this many researchers have studied the NDVI as a tool for remote sensing. So, let us look at a temporal profile. Here you have days, the NDVI profile, a particular location 2001 to 2002 for irrigated and non-irrigated areas. So, this is the CMS, which is the complete season, growing season. And then there is a first season, intermediate season and second season. So, this includes the irrigated and non-irrigated so, basically the 3 seasons, and we are going to see for the same location, how it differs between a irrigated and non-irrigated.

So, if you have a land, and it is the integral ranges from minus 1 to plus 1, we just normalized it from 0.1 because there is no negative values, all of the time it is growing something. So, let us say that there is no negative values. So, what is happening here is in this paper, the Julian date is taken. So, some researchers write it as calendar day, or Julian day, in Julian day, 97. So, Jan 1 is 1, and then you just keep on adding, so Jan 31 is 31, Feb 1 is 32. So, if you do that calculation, 97th day in the Julian calendar, or Julian Day is a seventh of April, this is 365 days 31st of December, if it is a normal year, in a leap year, we will have another.

So, here, what is happening is in the irrigated area, you always see a higher NDVI, a slightly higher NDVI correct, you can see that 0.3 to 0.4 and then it grows, the peak is different, the peak does not happen on the same day. So, in the non-irrigated the peak happens, just after the rainfall, a day or 2 after the rainfall, the plant is happy, it turns a lot of green, whereas in the non-irrigated, sorry in the irrigated what happens is, there is good supply of water. And so, what happens is there is a higher peak, just look at how much difference this is, this is pretty significant, this is significant in terms of a plant being declared good or high.

So, this is almost highly very, very high or high growth of the plant and this is normal growth of the plant and this is because higher water is given irrigated. So, irrigation actually helps a lot of times to increase the plant growth needed or not, that is a different story in this scenario, it is helping and you can see that you can differentiate based on just the NDVI data for a particular location, if it is irrigated or non-irrigated.

So, you could see that to see 3 seasons are there. In the IS season which is the intermediate season nothing has grown much. So, almost barren land almost 0, but in the 2 cycles when the water is applied, and 2 monsoon because some areas have 2 monsoons like Tamil Nadu et cetera, they are 2 monsoons, northeast and southwest. So, what will happen is, you will have these 2 monsoons that provide some relief and some water for the crops and that is why you see a bigger peak and here you have the second peak higher. So, the second monsoon is the highest, the first season is not that big.

So, you can see that two of these same location the NDVI estimate gives you the difference between a healthy plant and a non-healthy plant and the healthy plant can also be because of irrigation.

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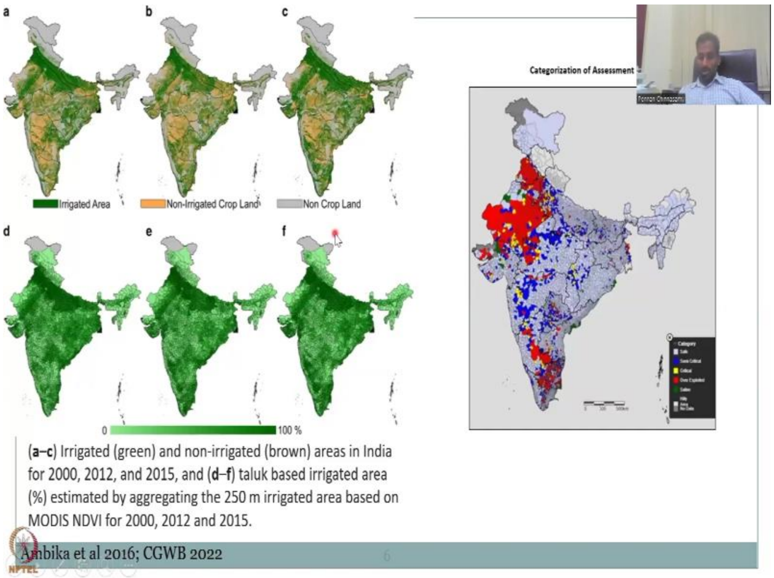

Here there is the same paper there is also multiple images done for entire India where a to c is given as indicated green color non indicated as brown. So, they have taken the satellite data and converted it into irrigated versus non-irrigated, the irrigated is green and non-irrigated is just when there is rainfall it happens and then there is crops, more cropland is also given and then in the, from 2000, 2012, 2015. So, you could see that in the 3 time periods 2000, 2012 and 2015 considerable increase in the irrigated area, the barren land, no cropland and the non-irrigated brown land is almost the same see the central parts, but there is considerable increase in the green area that is because of access to groundwater most importantly.

Then the d to f it is percentage taluk based irrigated area percentage estimated by aggregating 250 irrigated area based on models NDVI for 2000, 2000, 2015. So, just aggregating the 250 meters, what color is coming, is it 0 to 100 percent irrigated. So, 100 percent irrigated would be almost the NDVI very very high values and you could see that along the Ganges this high irrigation happening because of Canal irrigation and groundwater irrigation.

So, now, if you compare this to the data set we already have, which is the CGWB data, you could clearly see that this increase from 2000 to 2015 and this data is also 2015, you can see that there is multiple blocks that are converting into red in the areas where there has been an increase considerable increase in irrigation, which definitely depicts that it is converting from a non-irrigated area to irrigated area, like these areas, for example, now, it is turning green, whereas, these areas are now turning red in terms of groundwater.

So, groundwater has a definite relationship to the irrigated and non-irrigated status. And remote sensing is the only tool that could capture at India PAN India scale the changes in vegetation due to access to irrigation.

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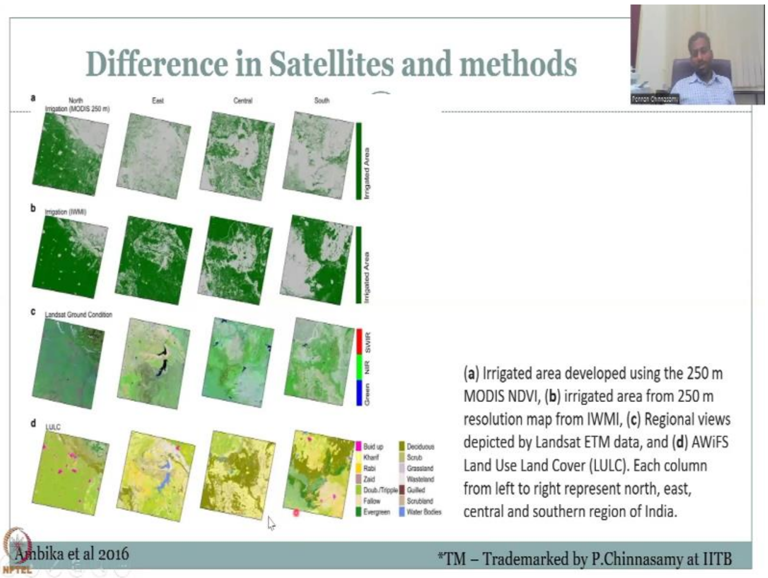

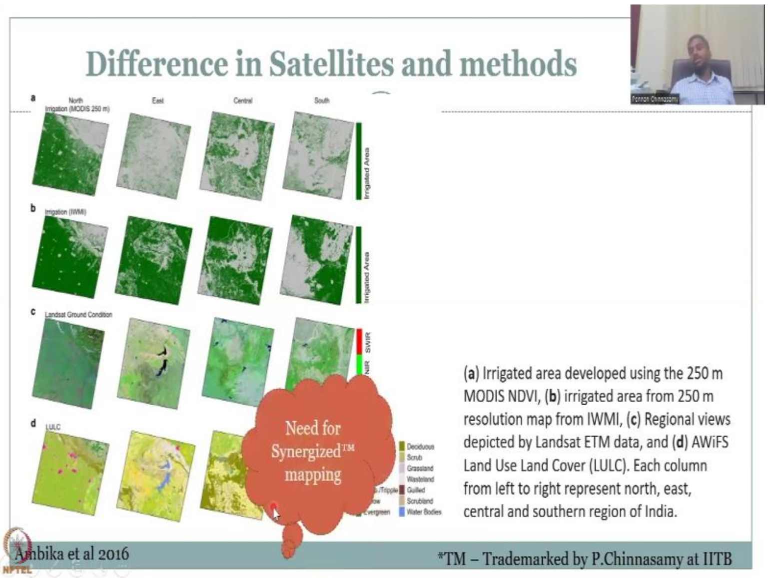

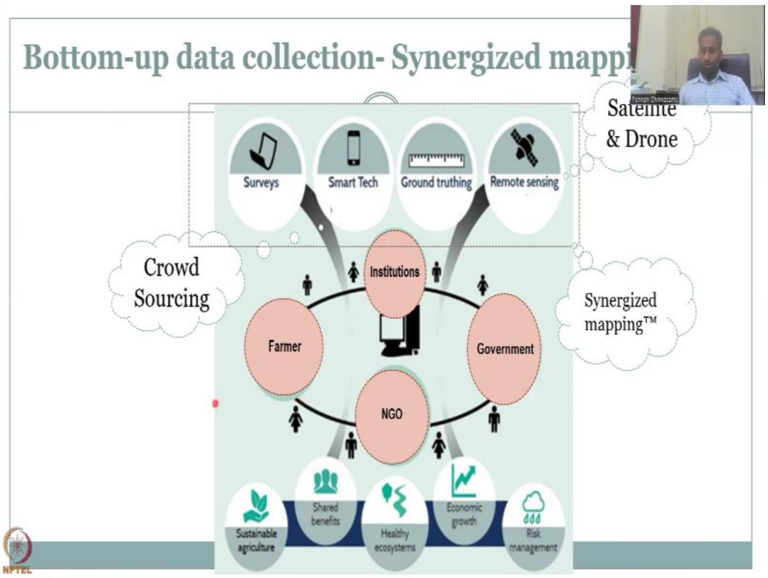

So, now, there are different satellite methods I have already explained the Lonare et al paper, which is authored from my group Chinnasamy's group, what you could see is there is different tools, different payloads, sensors and different AI ML techniques that can be used. And we came to a conclusion that the Sentinel 2 data with higher resolution was better for the Maharashtra location.

Similarly, this study has also done a comparison of irrigated areas based on 250 meters which is modest. So, look at modest which is very, very coarse resolution Sentinel is 10 meters to 30-meter resolution. And then you have northeast, central and south of India irrigated area how it changes then you compare that with INIS, International Water Management Institute's irrigation maps. This was the NGO where I also worked for three years when I was in Nepal and you could see that there is a considerable difference between the models. It is the same year, but same location east central and south.

But there is the green color which says irrigated is different between the methods, then the lands have ground condition is different. You can see that the Landsat regional view is depicted by Landsat ETM data and AWiFS Landsat land use land cover. Each column from left to right it was north, east, central and south region of India, you could see that yes, if we use just the landset ground condition, you could see multiple images of irrigated and non-irrigated areas with water bodies and then the land use land cover based on the AWiFS data showcases that the Kharif and Rabi season. The kharif and Rabi are along the south and central regions when compared to the north and east regions.

So, basically, what I wanted to tell you here is the accuracy of your NDVI will also depends on the satellite, the location you use and the methods, some people would have another formula for NDVI which is called a developed NDVI, we will look at it in the following lectures.

So, here is the question when all these different colors are given. So, the c is not a NDVI. It is just a normal image green, red and blue, green, near infrared and shortwave infrared. So, you can see that all these composite images somewhere give the picture but it does not tell you the difference between irrigated and non-irrigated whereas, the land use land cover done cover can give it based on the crop type.

So, what this tells us is there is a need for augmenting remote sensing data with observed data and other data to get at that particular understanding, which we will cover in next class, but I will stop here in terms of what is synergize mapping, it is already that we discussed in very brief terms, but I will be happy to discuss this more in the following lecture, where we will look at what are the different tools that can be used to bring data together into remote sensing platforms and then use it for rural development.

So, this is a trademarked name synergized mapping, it is trademarked or IIT Bombay through Assamese group again, but anyone can use it as just a concept. Why we trademark this we wanted to show that this can happen and when you trade market then there is the framework is trademarked so anyone who is using it in their publications can be acknowledged by us. So, with this I will stop today's lecture. I will see you in the lecture 2, week 10. Thank you.