Remote Sensing Essentials
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Lecture - 41
NDVI and other Indices

Hello everyone and welcome to new topic today we are going to discuss and normalized difference vegetation index and other indices. Earlier very briefly we have touched and NDVI when we have been discussing or started discussing on multispectral analysis and along with the band ratio and decorrelation is stretch principal component is stated that time very briefly I have mentioned about and NDVI.

And today we will have a complete exhaustive discussion on NDVI and it is applications basically applications are in vegetation related to studies. And these are 3 next this slide and next 2 slides are repeat of our earlier discussion just to connect with previous discussion.

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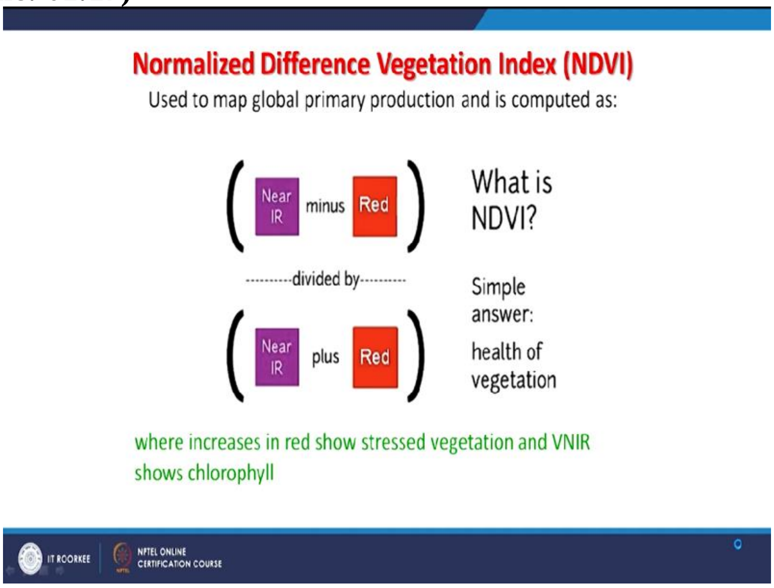

I am using these slides and that is normalized difference vegetation index. As you know that you know the near infrared band minus red band divided by a near infrared band or NIR band plus red band and this will create 2 things one is it reduces the number of bands 1 and also it gives the index for the vegetation, because we are using and near infrared and then, and that red band here and then near infrared plus red band again here.

So, using this kind of indexing and we can know not only about the condition of vegetation, but if vegetation is suffering from some kind of stresses. Because we are using red band and if vegetation is suffering from some kind of stresses, there will be a shift from infrared towards the red and that means from longer wavelength to shorter wavelength and that will give us an indication or index about the condition of the vegetation.

Especially the changes in the chlorophyll content. So, that is why these vegetation indexes becomes very important the example also we discussed very briefly I will touch here again that if in see if in near infrared.

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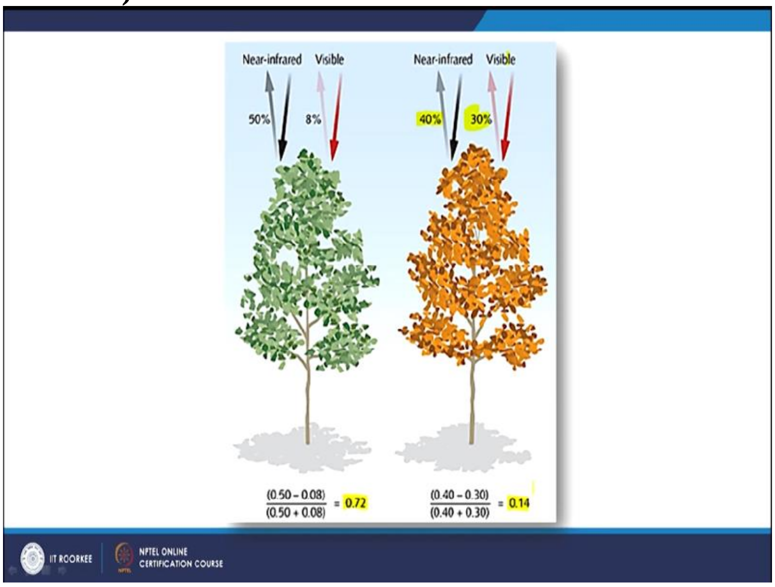

If it is giving 50% component and then invisible part we are having just 8% component in case of a healthy vegetation, but and if we see that index what would happen the NDVI would be 0.72 whereas in case of vegetation, which is under stressed or drying up and because of lack of water or maturity or any other reason, then this visible component has increased very significantly and at the same time this near infrared.

Because chlorophyll content has reduced and therefore, the glow this near infrared reflection in near infrared by the vegetation will reduce and therefore, our NDVI are the index becomes only 0.14 and that we can assess the conditions of vegetation. And basically these changes are because of changes in the chlorophyll content.

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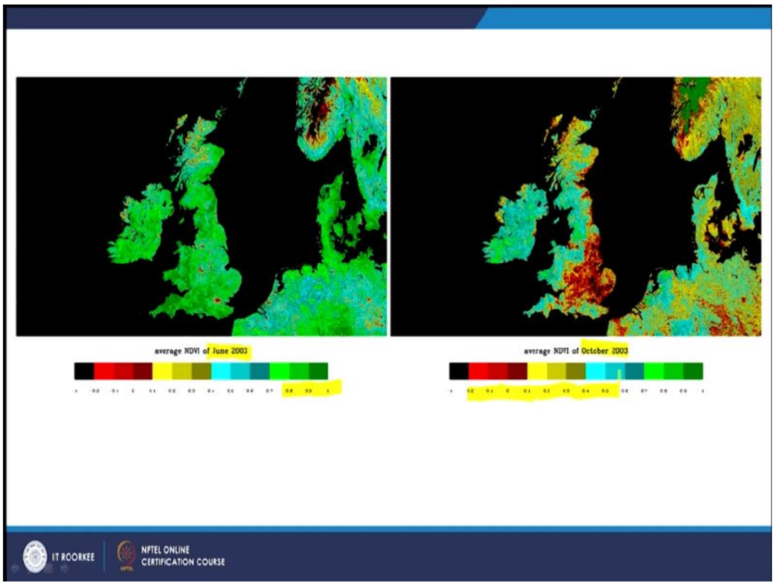

Example if we see here that NDVI in the month of June of 2003 of UK United Kingdom Island in some parts of Europe, and do the summer time is there and the we are seeing and this and NDVI values are quite high, as you can see around 8 9 or 1 and whereas in the month of October, that means the winter is approaching the vegetation is getting dried, and the result of this, the NDVI values are really getting very low.

And some in some parts they are a near 0 or 0.1 or little bit up 0.5 or 0.6. So, that way, the conditions of vegetation can be assessed very quickly in blind these 2 channels that is near infrared channel, which gives the best reflection if vegetation is healthy and the red channel because if there is a change in the chlorophyll content, the reflection will shift from near infrared.

Towards the red means from longer wavelength to sorter wavelength and this you know shifting the red edge can give us a lot of clues about the vegetation condition. So, when we say index what basically means is a sign or measure of something. And here what we are measuring is that chlorophyll content in the vegetation and these indices.

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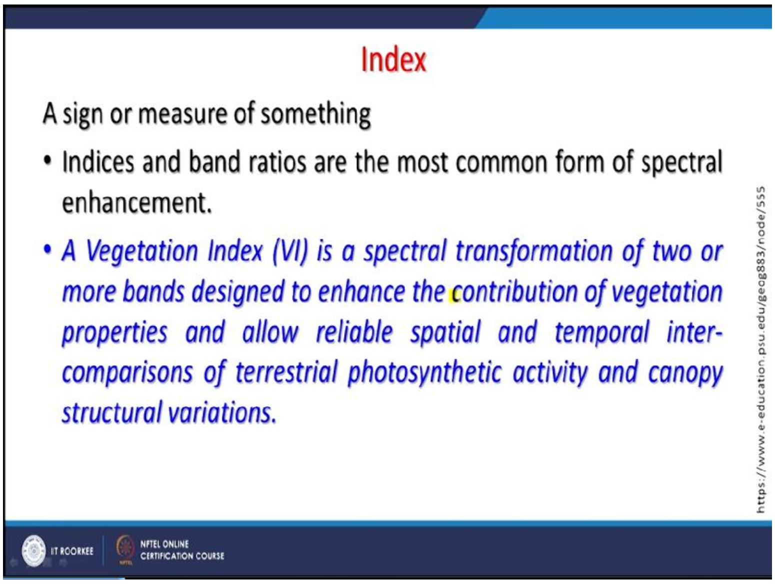

And band ratio we have discussed extensively. So, these indices and band ratios are the common form for spectral enhancement, because there might be many bands and we want to enhance and the way by which we can you know assess the condition of vegetation that is the contribution of vegetation properties and also at 2 or more bands can be used are used basically in and NDVI or in vegetation index.

And then it allows us to reliable spatial and temporal inter comparisons of terrestrial photosynthetic activity and canopy structural variations. So in that way, especially when people are working on global climate change and other things, and especially focusing on vegetation related changes, NDVI has become vegetation index has become a very powerful tool to assess the changes, which might be occurring due to changing climates or global warming.

So, there are many variations variants of these vegetation indices, and many are being functionally equivalent may not give sometimes different results. But nonetheless, people have developed a very variant of variations within this fundamental vegetation index that make use of basically inverse relationship between red and near infrared reflection.

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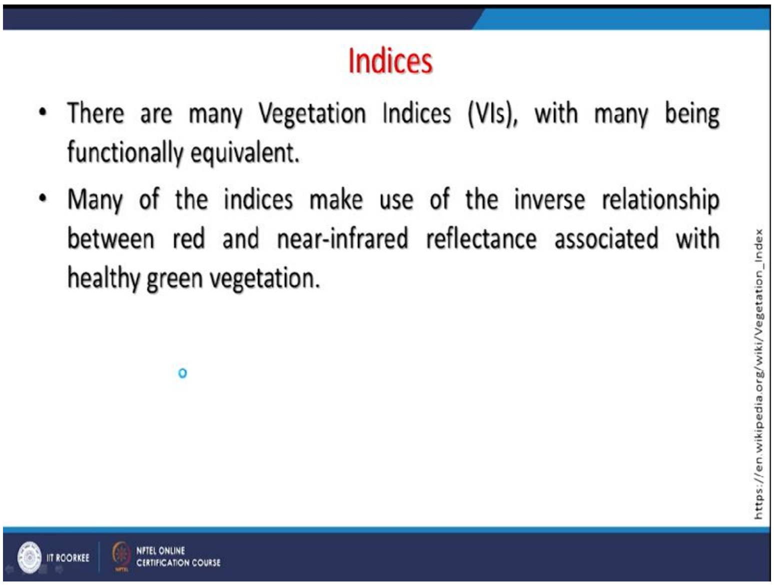

Because associated with the healthy green vegetation or chlorophyll content, and why inverse relationship here that Because, as you know the healthy vegetation will have the maximum reflection in near infrared or infrared part of EM spectrum, there is a vegetation which is heavy lack of chlorophyll content or less chlorophyll content, because of some of that some reason, then it will have more reflection in the red part of EM spectrum.

Then in near infrared and therefore, and this is inverse relationship has been identified and exploited and vegetation indices. So, after once we started getting satellite data maybe earlier, not a lack Landsat, but before that, also there were many other satellites not that operational in the data were mainly in the scientific domain. Nonetheless, in a later part of 60s people have used those scientists have used these satellite remote sensing data to monitor the fluctuations in the vegetation at the surface or the changes in the vegetation.

So, fluctuation when we say it changes with the season or changes in the vegetation might be because of some other regions for example, global climate change another. So, what basically we are doing through these indices is the measurement of vegetation attributes that includes and the among many attributes that it is one is the leaf area index LI very common derivative. Then percent green cover how much green cover is we are in an area chlorophyll content, green biomass.

And absorbed photo synthetically active radiation a part so, many such products are being generated through different calculations, but the fundamental remains same that because the vegetation healthy vegetation

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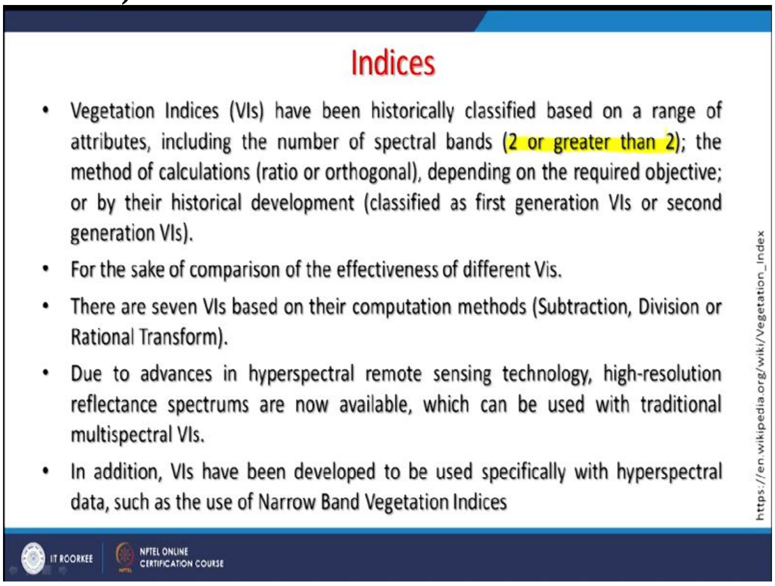

Have the maximum reflection in an infrared channel and therefore, that can be exploited. So, basically, these indices historically have been classified based on a range of attributes including number of spectral bands. So, generally 2 or greater bands are used like near infrared and red and the method of calculations that is ratio or orthogonal which depends on the require and what kind of objectives are there and why there are historical development classified as first generation VIs vegetation index or secondary generation VIs.

So, for the comparison purposes of these effectiveness of different vegetation indexes, there are 7 VIs and based on their computation methods and like subtraction, division or rational transform. So, the basic remains same that you know you are having near infrared minus red over and near infrared plus red, that is the basic 1, but then there are variations. So, due to advances in hyperspectral remote sensing, because in hyperspectral remote sensing you are having more number bands and very narrow bands also.

So, therefore, only taking 2 bands and creating an NDVI is not really well, because, since the options of many events are there and therefore, we can imply more than 2 bands to create vegetation indexes and also and higher resolutions especially in terms of his spatial resolution, which is also increasing. So, that we can further use and this vegetation indexes or indices and little differently as compared to earlier.

When we had only say, NOAA data or AVHRR data, a AVHRR data Landsat based data at that time because of lack of number of bands we were restricted to use only 2 bands to develop these vegetation indexes. Also these vegetation indexes have been developed to use, especially with hyperspectral data, such as use of narrow band, vegetation indexes because earlier the bands were quite wide, but now we are having options through hyperspectral remote sensing about narrow bands.

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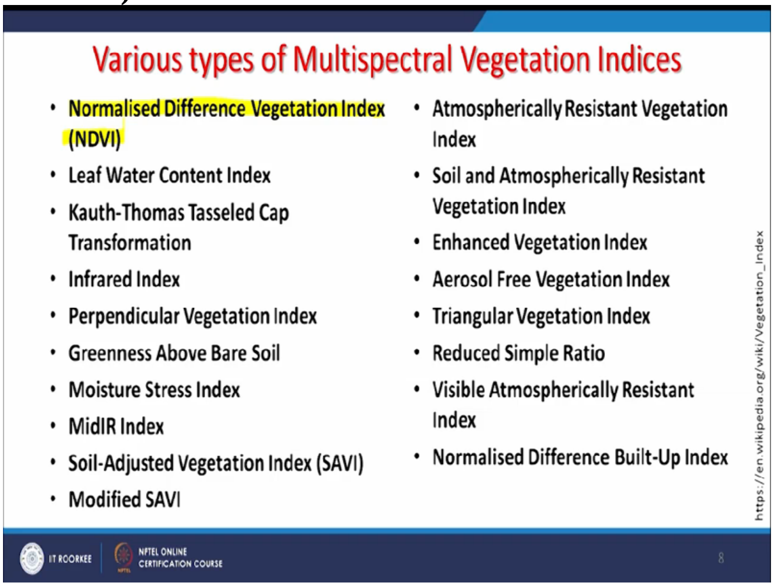

So those can also be used. Now, because there are various types of multispectral vegetation indices are there the most common one and most reliable and have been tested extensively globally? That is normalized difference vegetation index. Then there are leaf water content index. Then there is a Kauth Thomas Tasseled Cap Transformation and then infrared index and then perpendicular vegetation index.

Greenness above bare soil index soil moisture stress index and mid infrared index and soil adjusted vegetation index various indexes are there, but the most common one is NDVI rest are the variants from the original because of availability of and more number of bands, with the narrow band width and higher spatial resolutions people have been trying to develop newer vegetation indexes also a modified shabby is there.

And atmospherically resistant vegetation index soil and atmospherically resistant vegetation index, enhanced vegetation index, aerosol free vegetation index, then triangular vegetation index then reduce simple ratio and then visible atmospheric resistance index and then normalized difference built up and because the area might be having vegetation and built up land. So, he normally difference built up index and has also been there various such indices are there, but the most common one as we are going to discuss now in detail is the normalized difference vegetation index that is NDVI. So, this is a simple graphical indicator.

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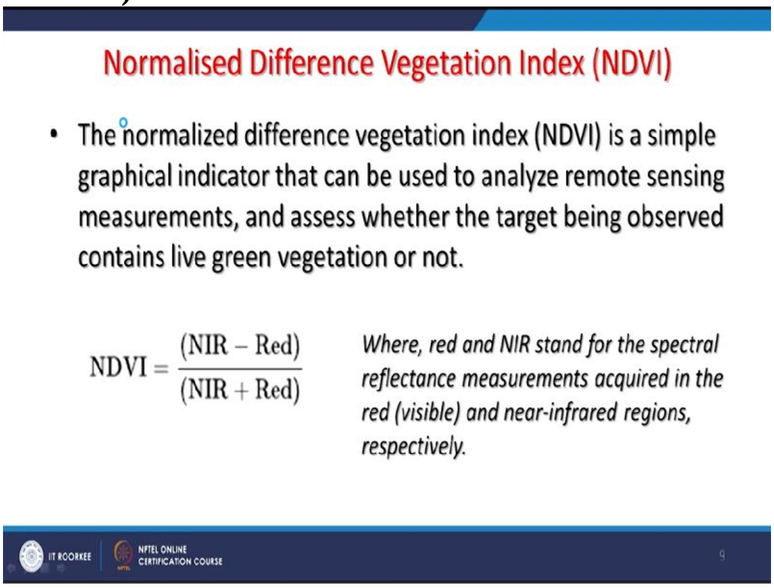

And NDVI which can be used to analyse remote sensing measurements multispectral data and assess whether the target that is the target in our case is the vegetation being observed contains live green vegetation or not that means, it contains good chlorophyll content good amount of chlorophyll content or not that it allows us to create index So, NDVI as we have discussed and NIR minus Red over an NIR plus Red. And that gives so where red and infrared stands basically for the spectral reflectance measurements acquired in red visible part of EM spectrum and near infrared regions respectively of EM spectrum.

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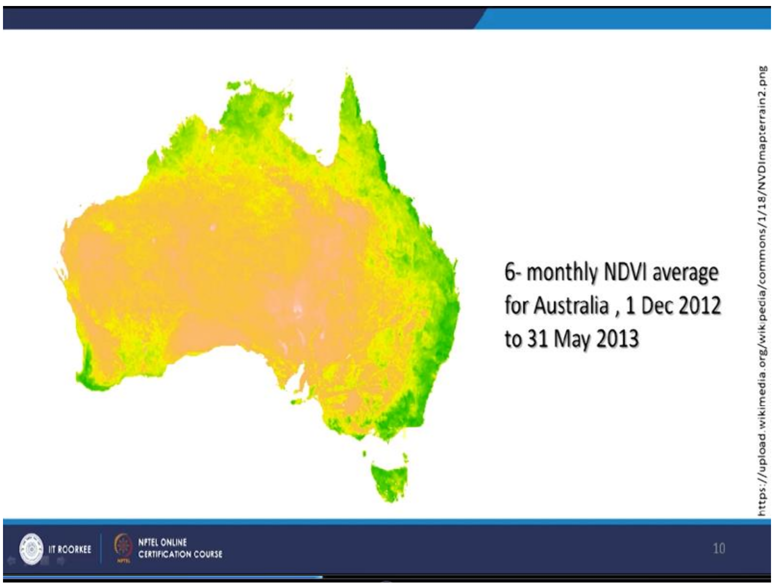

And if we see some products which have been generated by the people, then this is from NOAA AVHRR data 6 months average NDVI average for Australia between 1st December 2012 to 31st May 2013. So, for individual day, it is might be possible to create NDVI or an average of also can be created. So, by looking such product, we can clearly assess that on the coast, North Coast and the East Coast Australia we are having good amount of vegetation or healthy vegetation.

In remaining parts except in the southwest corner, remaining part is almost desert and the whatever the variations within those 6 months have been incorporated here because seen average NDVI of those 6 months.

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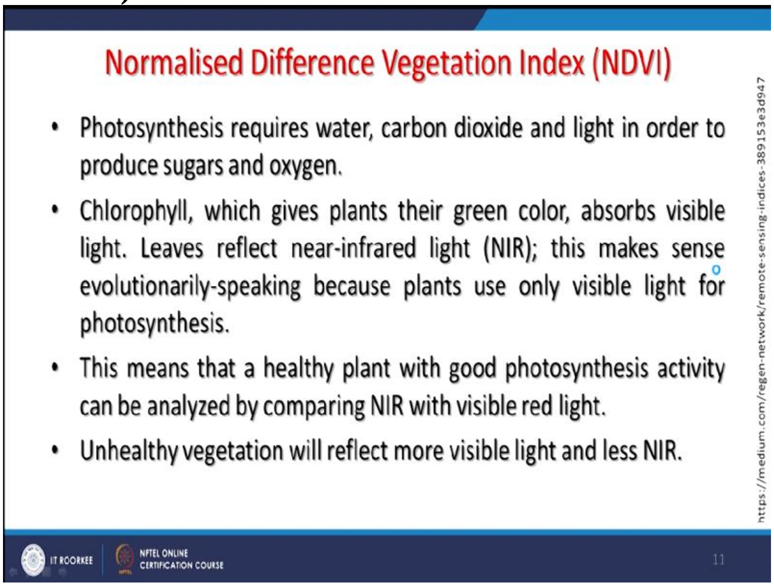

In normalized difference vegetation index basically this you know, it includes the photosynthesis, which requires water, carbon dioxide and light to order produce sugar and oxygen in the plants or in the trees. And this chlorophyll, which gives the plant their green colour, absorbs visible light. That is why we do not have much reflection in the visible part of EM spectrum, but at the same time it leaves the leafs or vegetation reflects more in the near infrared part of EM spectrum.

And because of this inverse relationship between visible and near infrared of vegetation reflection, and this makes us you know, evolutionary speaking, because plants are only visible light or photosynthesis. So, this means that a healthy plant with good photosynthesis activity can be analysed by comparing NIR and visible red light and this is what it is done in normalized difference vegetation index.

Whereas the same time, unhealthy vegetation, vegetation suffering from stresses or some, you know, problem related with water or some other issues, then will reflect more in the visible light and less in the near infrared. So, this inverse relationship is basically exploited extensively in these indices and healthy vegetation will absorb most of the visible light falling into it and that is why when you see the visible bands from any of these sensors on board of different satellites, we find that vegetation will generally will appear dark, whereas in infrared channels vegetation will appear very bright.

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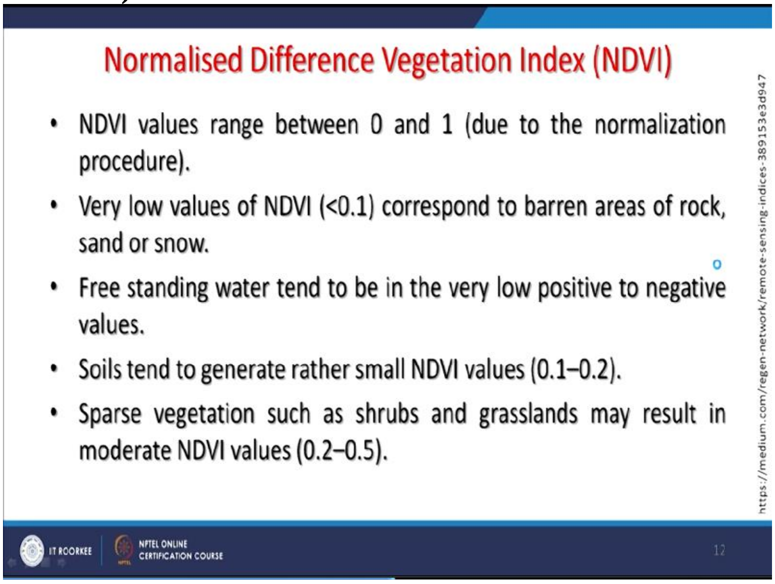

Now NDVI values range basically 0 to 1 because we really normalize and normalize these values. So, the values varies 0 to 1, and we can of course, then maybe 0.1, 0.2, 0.3 depending on what kind of precision 1 is looking for and a very low NDVI value. That is, for example, maybe less than 1 basically corresponds to barren areas of rock sand or snow. That means there is hardly any vegetation or vegetation is having almost no chlorophyll content.

So dried up vegetation may give you the NDVI value of less than 0.1 and free standing water tend to be in the very low positive to negative values. So, this water sometimes may get a little confusion about that part, soil tend to generate rather small NDVI values of 0.1 to 0.2 also and a sparse vegetation such as shrubs and grasslands may result in moderate in NDVI values are 0.2 to 0.5 these are in ideal conditions, but these conditions vary season to season and location to location. So one has to be little careful while interpreting NDVI products. Now there are known NDVI.

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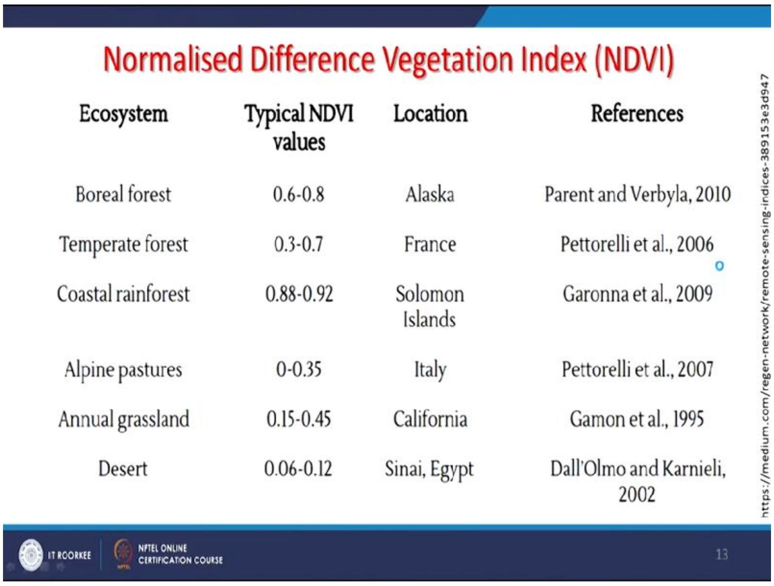

Like Boreal forest and which is vary and say in this example is of Alaska is maybe having an NDVI will between 0.6 to 0.8 relatively quite high and NDVI because of this kind of ecosystem that is boreal forest, dense forest and good chlorophyll content in that among the leaves, then a temperate forest, you may have 0.3 to 0.7 for example, in France, coastal rain forests given by different collected 2 different publications. Coastal rain forest and Solomon Islands 0.88 to 0.92 very high and NDVI values then Alpine pastures, a very low.

NDVI values then Annual grassland and California is 0.15 to 0.45 and in desert conditions obviously, hardly you are having vegetation and vegetation if you are having might be having very little chlorophyll content and therefore, you might be having very low and NDVI values. So, NDVI values are getting very high in case of coastal rain forest and in reverse be in desert conditions they are getting very low of 0.06 to near 0 in part of Sinai, Egypt or many other desert areas these might be there.

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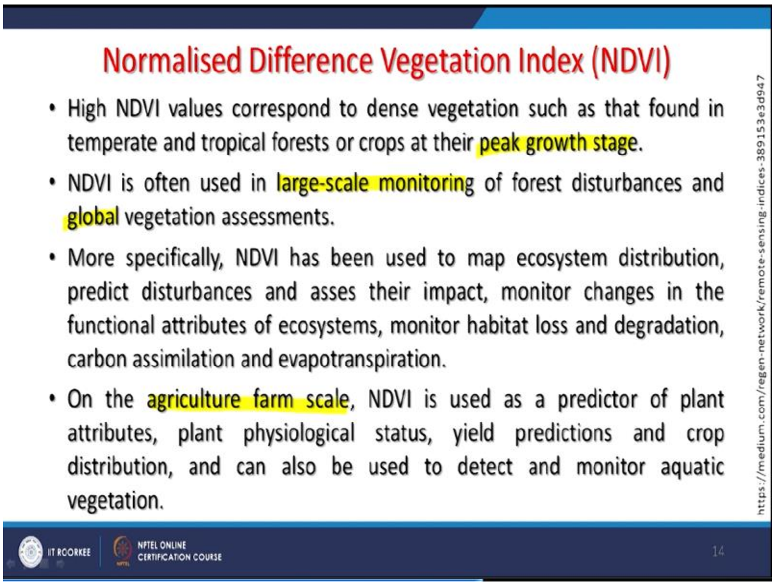

Now, high how to interpret these things. So, we will discuss a little bit of that part, high NDVI values basically means that there is a dense vegetation and there is that kind of a vegetation we find basically temperate and tropical forest as you have seen in the coastal region and that when the images are used or the of that area that is having the peak growth stage and the peak growth stage means at that time the leaves are having the highest concentration of chlorophyll and therefore, you may get a very high NDVI values.

NDVI as I also mentioned earlier, and this index is used for large scale monitoring of forest disturbances and global vegetation assessments, whether there are some changes with time which is occurring due to some reason maybe climate change or you know, because of human interventions, those things can be assessed are being assessed. When we go for a globally scale vegetation assessment of course, a very high resolution.

Satellite data not implied then relatively coarser resolution data like from NOAA, AVHRR or MODIS are imply to cover at globally scale and more as physically the NDVI has been used to map an ecosystem distribution predict disturbances and assess the impact monitor changes in functional attributes of ecosystem, few functions, attributes we have already discussed and monitor habitat loss and degradation of carbon assimilation and evaporation.

All these things evapotranspiration all these things can be assessed through NDVI or the changes which are might be occurring in an area. But at a larger scale monitoring is the most common application of NDVI not at a very, you know, in the detail or in a very highest spatial resolution. And if we want to use for agricultural related thing, then agriculture farm scale. NDVI is used to as a predictor of plant attributes and plant physiology status yield production

And crop distribution and also can be used to detect and monitor aquatic vegetation. So, lot of applications that farm escape is also possible, but this farm scale if it is too small farms or their agricultural lands are there then things may be completely different.

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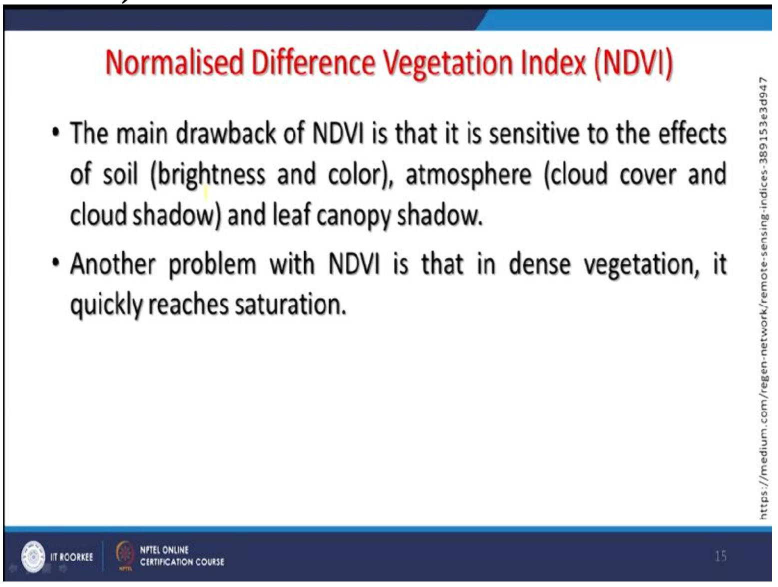

So one has to be careful while using or that level and how there are no technique is perfect. So, NDVI there are also drawbacks for NDVI and because it is sensitive to effects of soil because all the time you do not have when the satellite records the images, it may have you also having mixed pixel kind of situation where vegetation is there and bear or the soil might be also getting.

So, brightness and colour of the soil. They might play very important role in your images are in your different bands, atmosphere conditions, maybe cloud cover cloud setup may create some problem in the NDVI products and of course leaf cannot be shadow because there are plants and trees and they will have their own shadow on other trees also. So, this leaf cannot be shadow can also affect your NDVI values.

So, one has to be a little careful this is one of the drawbacks of NDVI. Another problem with NDVI is and that in dense vegetation it quickly reaches saturation that means is reaches to value 1 or 0.9 and therefore, assessments are the variations and in case of dense vegetation and to assess that variation becomes difficult and this may be due to the fact that the NDVI index is nonlinear see, that is the issue here with NDVI.

One of the drawbacks also so in and I what I can say that NDVI is good to study large areas and get a rough sense of photosynthetic activity or a rough sense of chlorophyll content. So, if a plant which is going through which is having going through a good growth having good leaf area index and having high content of chlorophyll, then we will be getting a large or a high NDVI value and also it gives us a sense and formation that what kind of activities are going on within the plant and it is a sensitivity to soil and it also means it has limitations.

So, soil part has already and has discussed and also that atmosphere conditions, cloud cover clouds or maybe aerosols. So, these may create some changes in the values of NDVI if these situations are prevailing in that area for which we are using the images now, I take example from India.

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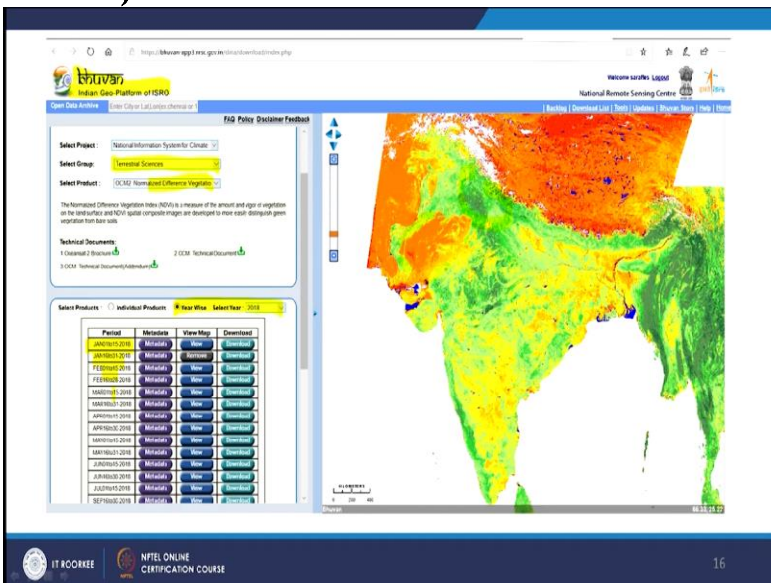

And this is from our bhuvan portal, if any one of you so far has not visited and please go in this one and here you can choose like group is terrestrial sciences and normalized difference vegetation index from a satellite which is OCM. And here what we are seeing for the land part the what is the condition of vegetation is there based on this and NDVI value and the dates are also giving here and the January February March, April and all those and dates are there.

But here, year wise what we are seeing for 2018 the entire year average and vegetation index of over India and in surrounding countries. So, mainly if we focus over near what we find that in the northeast part of India, we know it is highly forested and therefore, we are getting a very high NDVI value whereas, a desert part of Rajasthan we are getting very low in NDVI value and rest are in between and forested part of Himachal Pradesh the Uttarakhand also we are getting good NDVI value.

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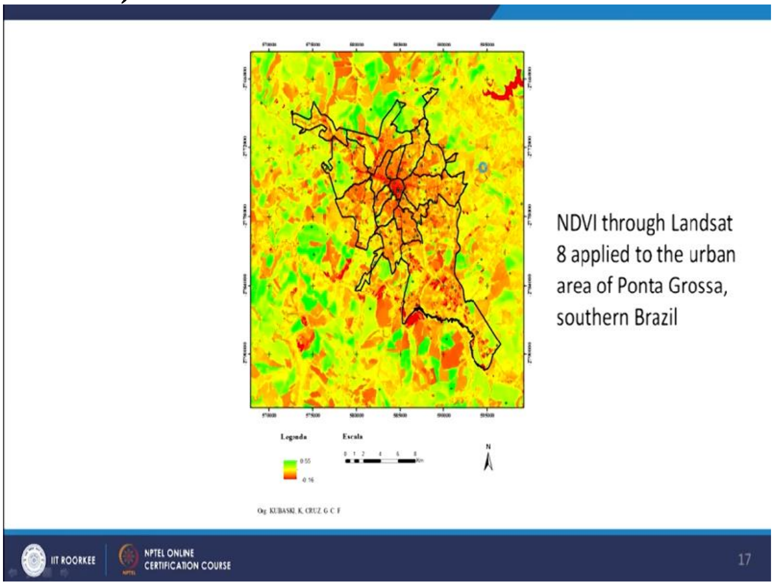

If we go for you know, at farm level or broad level then we have been implied high resolution satellite images from Landsat maybe 15 meter or 30 meter and spatial resolution data and in urban areas we can develop NDVI like in this case Ponta Grossa of Southern Brazil it has been used there, so NDVI values here it is giving - 0.162.55 to green part are having 0.55 NDVI value.

So, from a country scale one can assess depending on the sensor and of course, the coarser resolution will give you a country level coverage or continental level coverage and high spatial resolution satellite images like Landsat it can give you a farm level or regional level local level of that thing. Now, instead of NDVI we can have some other indices as we also discussed like for example, enhanced vegetation index. So, what is basically enhanced vegetation index?

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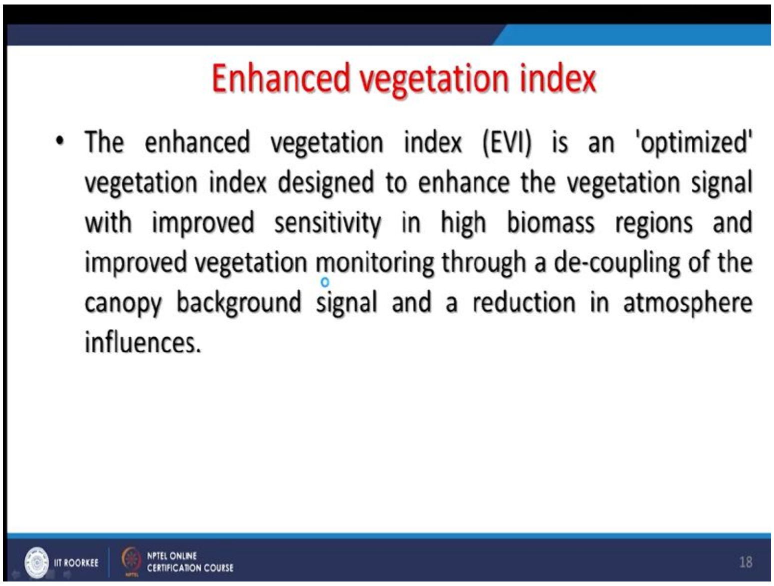

Is an optimized and vegetation index, which has been designed to enhance the vegetation signal with improves and sensitivity in high biomass region, because we as we discussed that when you are having dense forest or high chlorophyll content, then the saturation reaches very quickly. So, in those areas, there is enhanced vegetation index for in high biomass region and improve vegetation monitoring through a decoupling of cannot be background signal and a reduction in atmosphere influences.

So, in normal in this NDVI and we were not able to handle the atmospheric effect. So, you easily or significantly but in this enhanced vegetation index, these things are possible to handle or be coupled with that. So, NDVI that is enhanced vegetation index is computed by this equation is

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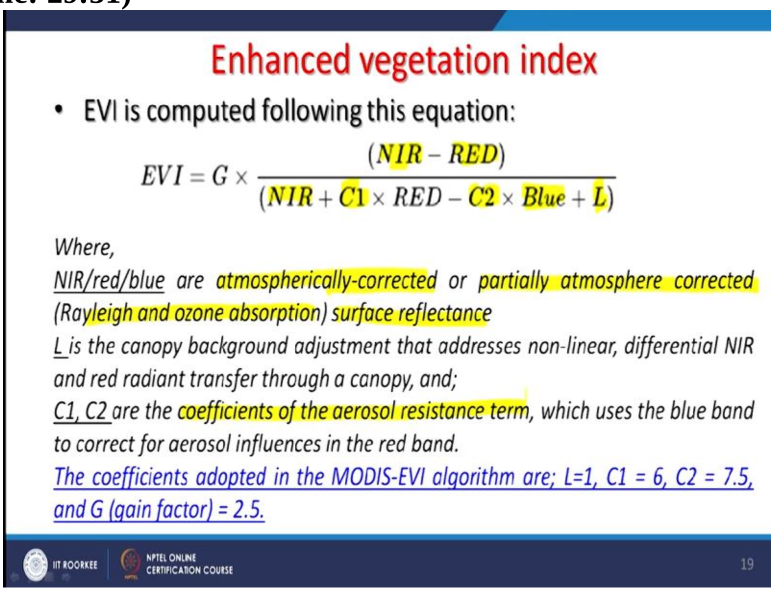

Near infrared channel minus red channel and then near infrared plus C1 plus red channel and then minus C2 blue channel and then L. So, where this say near infrared red and blue as you know different bands, which are atmospherically corrected in earlier discussion in NDVI we did not go for that kind of correction, atmospheric correction or partially atmospherically corrected and based on Rayleigh and ozone absorptions.

And of course, surface reflection and bearer L is the cannot be background and which is adjustment that addresses non-linear and differential NIR and red and radiant transfer through a canopy and C 1 and C 2 are the coefficient of aerosol stand up. So, in an enhanced vegetation index if one would like to develop, then lot of inputs are required. The first and bigger biggest one is the correcting these channels red infrared and blue channels atmospherically corrected or partially atmospherically corrected.

And that requires lot of efforts and these coefficients of aerosols resistant terms, which are also blue band to corrected for aerosol influences in the red band and then the coefficient adopted in the like MODIS provides and with MODIS it is possible and to some extent to create enhanced vegetation index and these are L1 L is taken as 1 C1 is taken as 6 C2 is taken as these coefficients are taken as 7.5 and G which is here in this equation the gain factor is taken 2.5.

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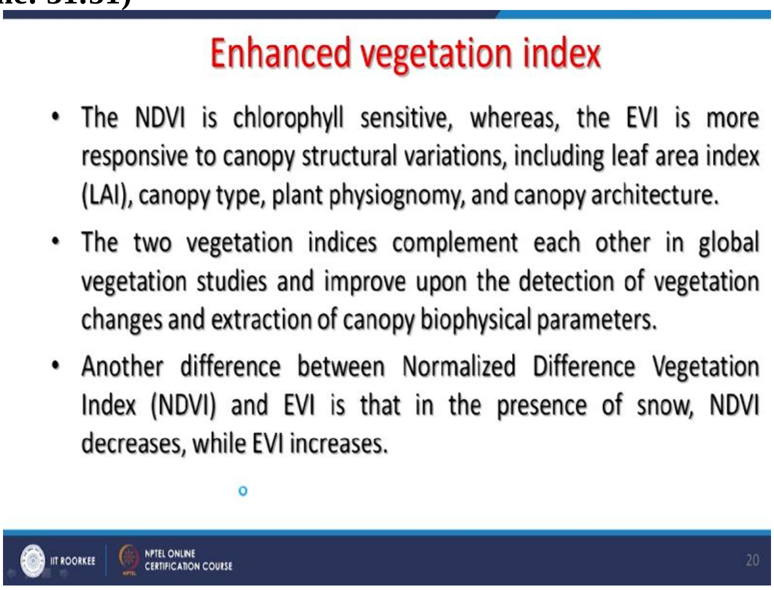

So, by which we can have enhanced vegetation index, what are the advantages with enhanced vegetation index over the convinced NDVI that is because NDVI is chlorophyll sensitive because it assesses basically and the chlorophyll through the and this differentiation with or this inverse relationship between infrared and red channels whereas EVI is the more responsive to canopy structural variations.

And including leaf area index canopy type and plant physiognomy and canopy architecture. So, it brings a lot of other attributes of vegetation into the calculation and that is why it is considered as enhanced vegetation index. So, 2 vegetation indices complement each other that is NDVI and EVI in global vegetation is studies and improve upon the detection of vegetation changes and extraction of cannot be biophysical parameters.

And other difference between NDVI and EVI is that the presence of snow there are some areas may be like in a Himalayan conditions, you are having forest any zone and then you know NDVI decreases by EVI increases. So, in that sense, it may be very useful in case of such situations. There are very various types of hyperspectral vegetation indices which has been developed or are being developed because as more data as also in the previous earlier discussions.

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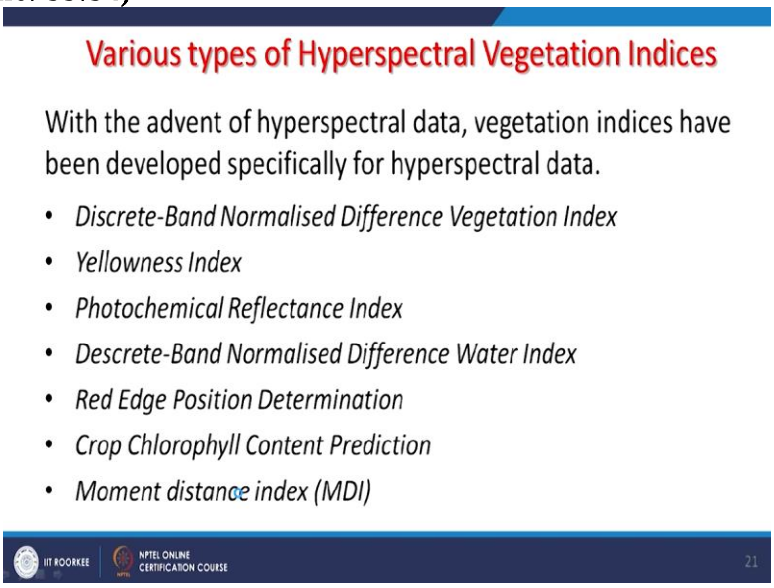

We had specifically on hyperspectral remote sensing at that time we discussed that the now the data is becoming available to the satellite spaceborne hyperspectral data is becoming available though maybe having a narrow swath and may not be having a regular coverage nice and that temporal resolution may not be high. Nonetheless, data is becoming available so people are has started developing or has already have developed these hyperspectral vegetation indices.

With this say and what are those indices are discrete band normalised difference vegetation index, yellowness index, when it is getting in a mature and photochemical reflection index and discrete band normalized difference, water index, red edge position determination and crop chlorophyll content prediction and moment distance index. So, various types of indexes are for indices are possible with hyperspectral remote sensing data because you are having more number of bands there available to analyze and that is why is there so, what are the applications and many applications we have already touched

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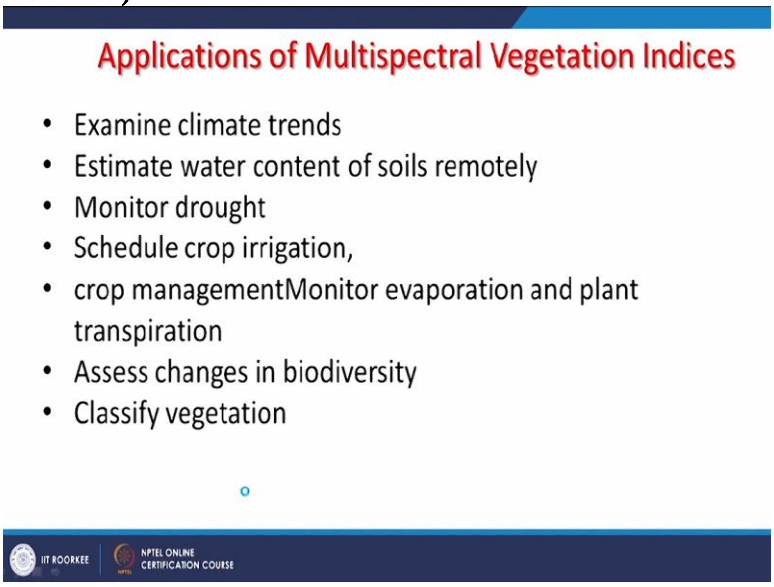

But for completeness we will go through once application of this multispectral vegetation indices, which we have been discussing examine climate trends, climate trends when we imply that means we have to have coverage at global scale or at least at continental scale, then only we can use that and that means, resorting to coarser spatial resolution data for example, NOAA AVHRR data or MODIS data, which provides even coverage almost every day.

So, in that way, these globally scale and climate changes climate trends can be studied through these multispectral vegetation indices and estimated water content of soil and that to remotely monitor drought so, if we can monitor the water content or moisture we can also monitor the droughts and schedule crop irrigation and crop management Monitor evaporation. And plant transportation assess changes in biodiversity and classify vegetation and lot many things can be done with these NDVI values or vegetation index. So this brings us to the end of this discussion. Thank you very much.