# Remote Sensing and GIS

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## Lecture – 10
## Digital Image Processing (DIP) - IV

This is the fourth lecture on digital image processing. Here we will start where we left in the previous lecture which was principal component analysis. So we have covered the normal PCA how to apply this on our remotely sensed image and what will be the product and how to interpret those products. So there is a concept called FPCA. So before I start that 1, let us again refresh our memory.

This Eigen decomposition of covariance matrix is basically your PCA right and here what we do is we decompose our covariance matrix and in terms of eigenvectors and eigenvalues and then you might remember like what was the table and where we had all the eigenvectors elements and for each principal components, the elements of eigenvectors are very, very crucial.

So if you want to highlight some X component or X target in your given image, then you should look for those wavelength in which that material is sensitive and to which particular principal component their weight is or the loadings are more or less. So do you remember loadings, so basically loadings are the elements of eigenvectors. So that is nothing but the weightage is assigned to all the input bands right.

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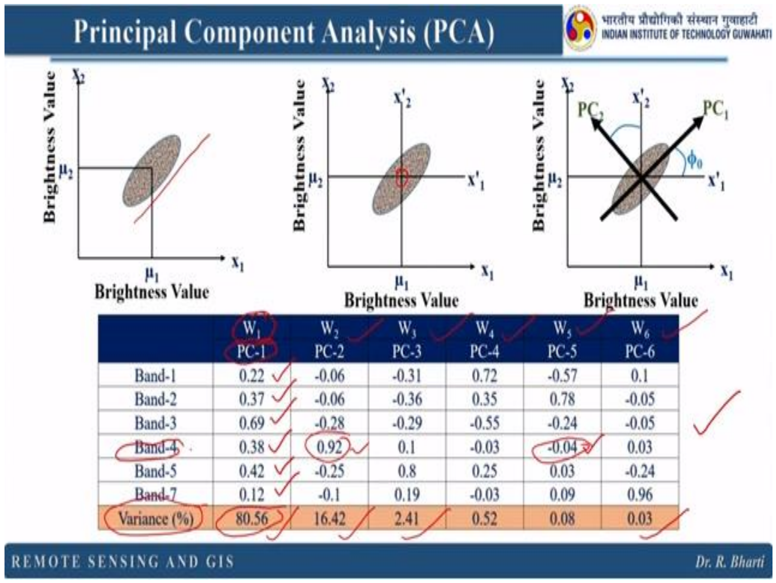


| | $W_1$ PC-1 | $W_2$ PC-2 | $W_3$ PC-3 | $W_4$ PC-4 | $W_5$ PC-5 | $W_6$ PC-6 |
|---|---|---|---|---|---|---|
| Band-1 | 0.22 | -0.06 | -0.31 | 0.72 | -0.57 | 0.1 |
| Band-2 | 0.37 | -0.06 | -0.36 | 0.35 | 0.78 | -0.05 |
| Band-3 | 0.69 | -0.28 | -0.29 | -0.55 | -0.24 | -0.05 |
| Band-4 | 0.38 | 0.92 | 0.1 | -0.03 | -0.04 | 0.03 |
| Band-5 | 0.42 | -0.25 | 0.8 | 0.25 | 0.03 | -0.24 |
| Band-7 | 0.12 | -0.1 | 0.19 | -0.03 | 0.09 | 0.96 |
| Variance (%) | 80.56 | 16.42 | 2.41 | 0.52 | 0.08 | 0.03 |

So you remember this, this is basically your band 1 versus band 2 and this is the correlation plot. Then next we have sifted our origin from this to here right and then we rotate with some angle and so that our data will be uncorrelated. So we basically what we are doing here? We are decorrelating or we are identifying the unique information from the inputs. So suppose if you have like 7, 8 or 10 bands in multispectral remote sensing data.

Then what we do? We apply this PCA and we identify maybe few bands or few output principal components in which the informations are very unique. So that will be independently used for identifying some X, Y, and Z material right. And you remember this table from my last lecture. So here basically you can see the variance. So for first principal component variance is 80.56 remember this is variance, not covariance.

So variance is variance among the data sets. So here this is highest then it is decreasing and it is decreasing very low. So it says what kind of information or how much different information is available in your principal components. And this is basically your W1, W1 is nothing but the PC-1 and here these are basically loadings. So in this we will identify suppose if you want to identify some material which is sensitive in band 4 right and then you have to look for those PC which is having minimum or maximum weightage of band 4. So here it is maximum right and here it is minimum.

So you have to find out those PCs where it is minimum and maximum with respect to other available loadings. So suppose if the other available loadings are also in the same range then probably your target will not be enhanced. So in that case that principal component will be not of use. So here you have to be very careful while identifying or selecting the principal component for your objective that which band you are looking for and what is their loadings with respect to others and then whether it is having some contrast or not. So here in feature oriented principal component analysis.

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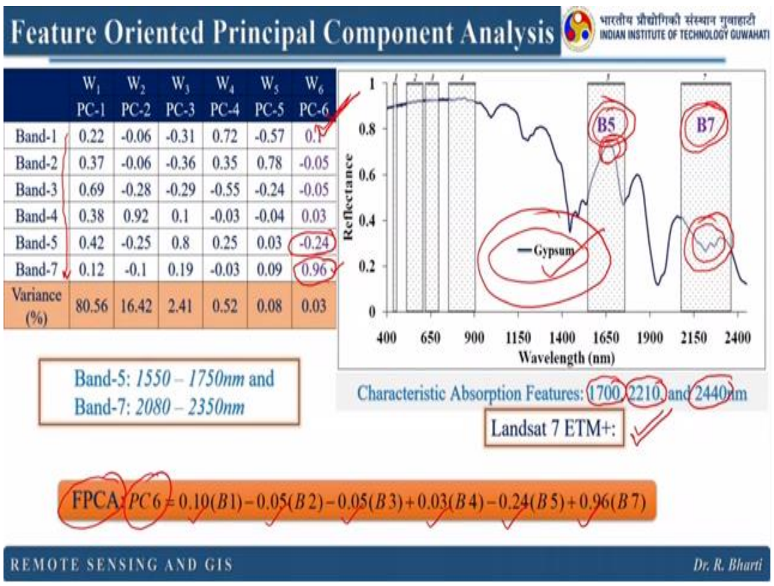


You can see I have taken the Landsat 7 ETM+ data and this is the Wavelength and the band distribution in this 0.4 to 2.5 micrometre. And here I have highlighted this band 5 and band 7 right and this is these are other bands. Now this is in the case of gypsum. So here for gypsum characteristic absorption features are located at 1700 nanometre, 2,210 nanometre, then 2,440 nanometre.

So here basically what we do is we use this principal component analysis to highlight our target based on their loadings or the weightage of the individual band. So now if you have calculated the principal component 1 or 2, 3, 4, 5, 6 and here you see we have total 7 input bands. You can see here right. So out of 7 we are interested to find out which principal components having more or less weightage of band 5 and band 7.

So here can you find out which principal component is having maximum weightage of band 7. So it is easily visible here right. And band 5 is basically here. So you can see that band 7 is having absorption feature right. Absorption feature of my target and band 5 is having peak of my target. So in case if you have high weightage for this absorption feature that means this is 0.96 and low weightage for band 5 that means for this particular peak that is -0.24.

So what will happen to your output? If you have this principal component 6. Your target will be having high value right because weightage is more. So basically we are bothered about this absorption feature and somehow we want to highlight this. So we have used here band 7 and band 5 and this Landsat ETM+ is freely available data. So one can easily download and use it in their application.

So here you can see this is the FPCA, this is principal components 6 and these are weightage for different bands right. So here we are doing nothing just simply we are analysing our eigenvector matrix and then based on our target right. And then we analyze and we say that this particular principal component is suitable in my study. So running the principal component requires the basic knowledge how to run this principal component, what we do in principal component, how we treat our data.

But in feature oriented principal component analysis basically this tells you about the which principal component is suitable for your study. So I hope this is very clear right.

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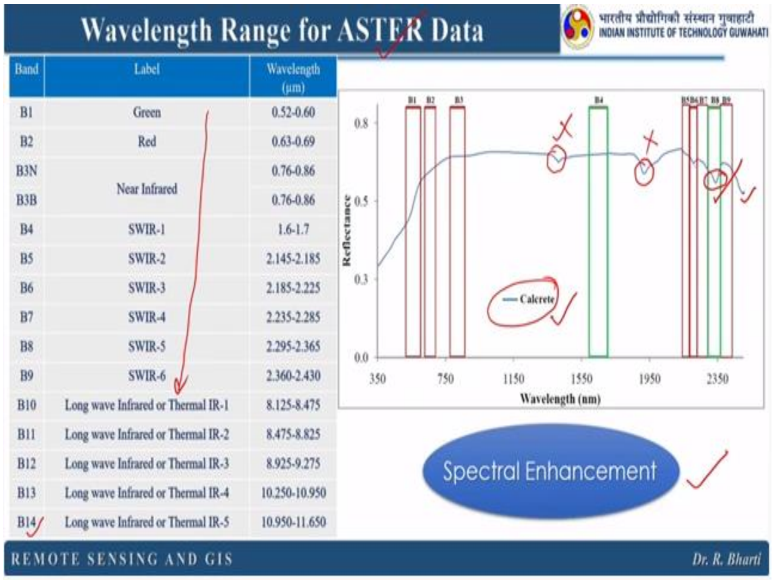


Now if you see this wavelength range for ASTER data. So you can see here for ASTER we are having 14 bands right starting from band 1 to band 14 and these are the different wavelength ranges and here are the numbers. And if you see a calcrete like forget about calcrete, you can imagine it is having similar property of calcite. So what you can do is for calcite this is the spectral behavior right.

You can see this right. Now these are the wavelengths available from ASTER data. Now what we can do is we can enhance or we can do the spectral enhancement why? Because I told you that in the beginning that we are bothered about the absorption feature produced by the material why? Because that tells about the chemical composition and bonding arrangements right. So here if you see this is a absorption feature right.

And this is another absorption feature, this is another absorption feature. But we do not have band available for this particular absorption feature. We do not have band for this right. But we do have a band for this which is band 8 and this is another, this is band 6. So you can see if you want to highlight this particular material then you need to find out which wavelength band is available for a given sensor.

Then only you can use the other spectral enhancement techniques. So here what does it mean spectral enhancement. Basically we want to enhance our feature based on the spectral information available from the remotely sense data right.

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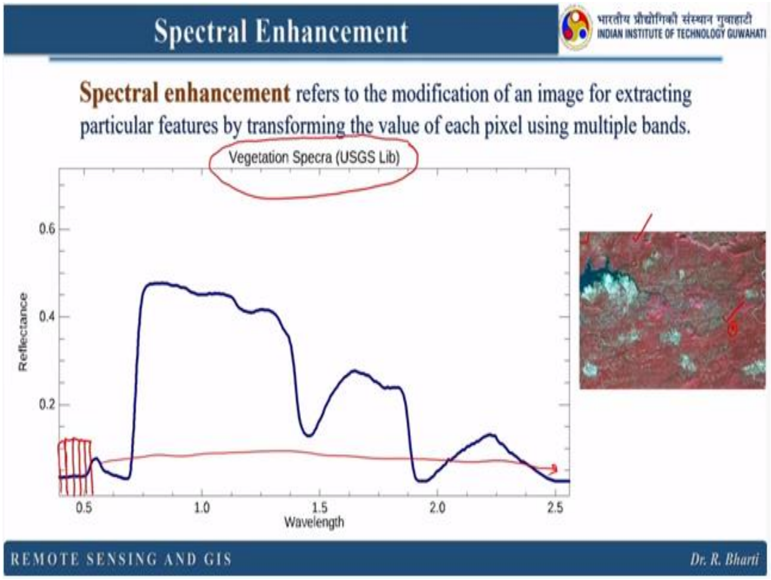


Now there is the definition of a spectral enhancement. It refers to the modification of an image for extracting particular feature by transforming the values of each pixel using multiple bands. So here basically multiple band means we are using either multispectral data or hyperspectral data. So I hope you remember this curve right. This is a standard curve for vegetation and this is spectra I have taken from the USGS right.

This is from the USGS library and if you remember that you can display any given data provided that should have blue, green, red bands available. Then you can display them into standard false colour composite. And in standard false colour composite, all the red colours and dark red colours are basically they represent vegetation. So if you see this particular spectra is derived from, let us assume from this right from this particular pixel.

So here assuming this as a hyperspectral data what you have, you have many bands like one here, second, third, fourth, fifth like that you will have for the full range. Then only you can produce this kind of spectra. Now if you extract one-pixel value so if you extract from here what will happen? You will have DN number or reflectance value or emittance value for this particular band.

And in the background you have hundreds or thousands of bands then you can produce this kind of spectra right.

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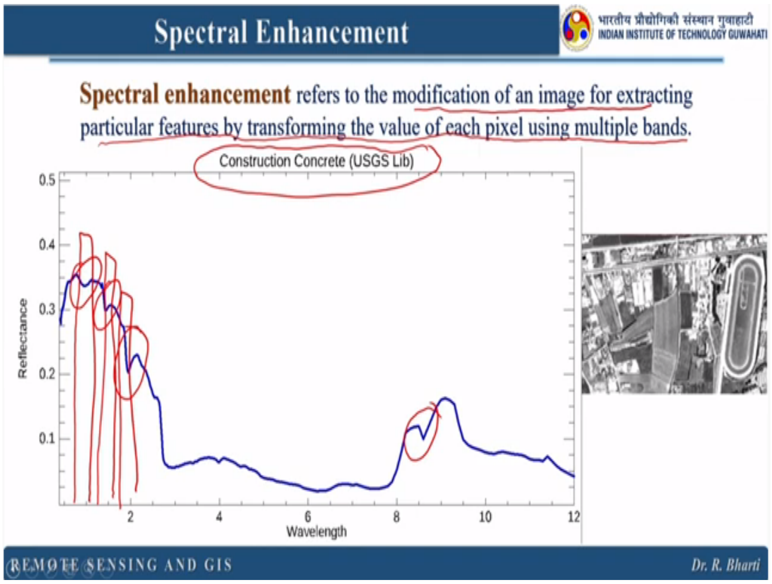


Now next is from a building. So you can see here, this is for the construction concrete. Again it is from USGS library. So basically what we are doing, we are modifying the image for extracting particular feature by transforming the value of each pixel using multiple bands. So once you have multiples of band, you can easily find out in which wavelength you are having absorption features right.

And if your satellite image is having that particular band right. Then you can easily use them to enhance the material property and you can easily track them on the image. So this is the beauty of spectral enhancement. You can easily find out what is the area occupied by concrete right in the given image or vegetation or any other material. Because all the material is having characteristic absorption feature and that is fixed right.

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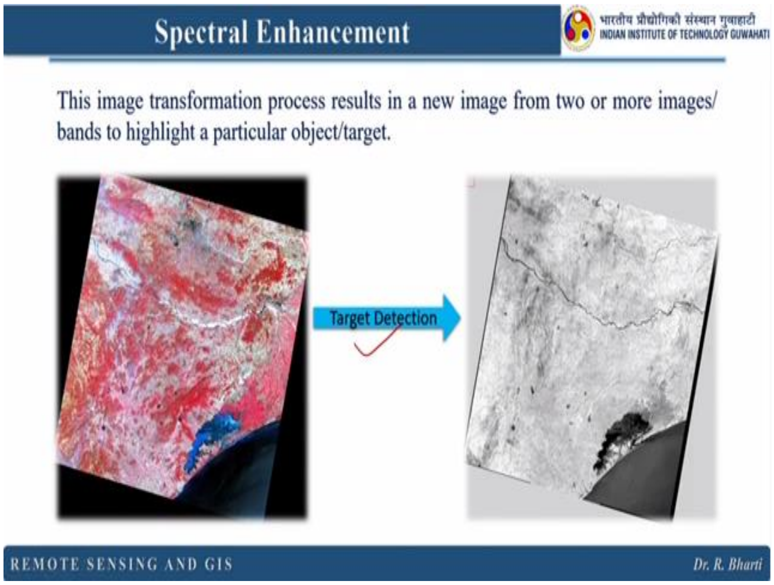


Now in the spectral enhancement, this image transformation process result in a new image from two or more images or bands to highlight a particular object or target. This is in the very simple language. So here you have a input data and you run the spectral enhancement and then you can find out what is or where your target is lying. So it is very easy. You have already seen a example with PCA.

So using PCA you can derive the eigenvector eigenvalues and then based on their loadings you can find out where your targets are lying. So that process is known as feature oriented principal component analysis. Now here we will see few more techniques.

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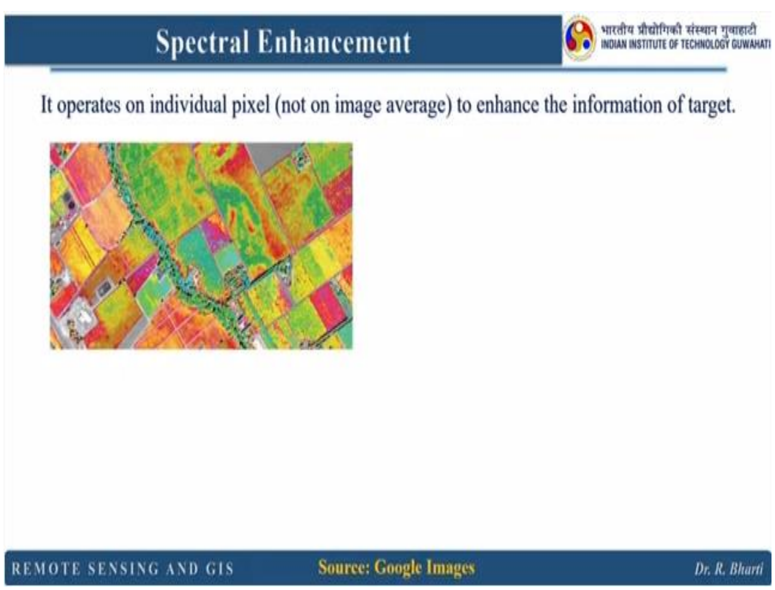

That are used in this spectral enhancement. So basically in a spectral enhancement it operates on individual pixel and not on image average to enhance the information of target. So basically if you see this image. So basically it is a DN number in the background you have always DN numbers. This is only for the representation. So you can perceive the information right. So once you have the digital number what happens?

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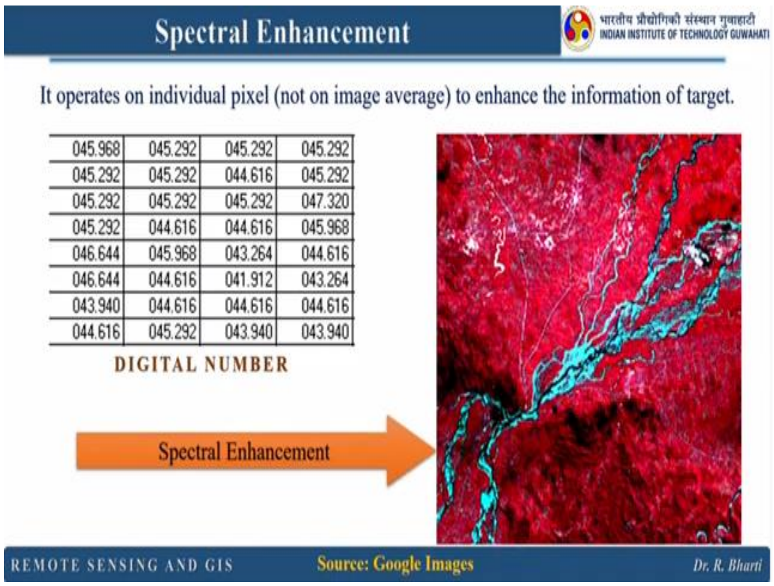


You can always play with them. Because you have the number, you have the matrix, then you can use average mean, median mode, you have already used in the previous lectures right. So here we will use few different techniques to enhance the spectral information of the target right. And we will suppress the other targets. This is the beauty of this spectral enhancement. So in this spectacle enhancement it is important to note that it operates on individual pixel not on the average value.

That means you cannot take a average value of this whole matrix and you can say I have divided or multiplied or I have run this function right. So whatever function you are using that has to run on the individual pixel then only this is going to give you a sensible result.

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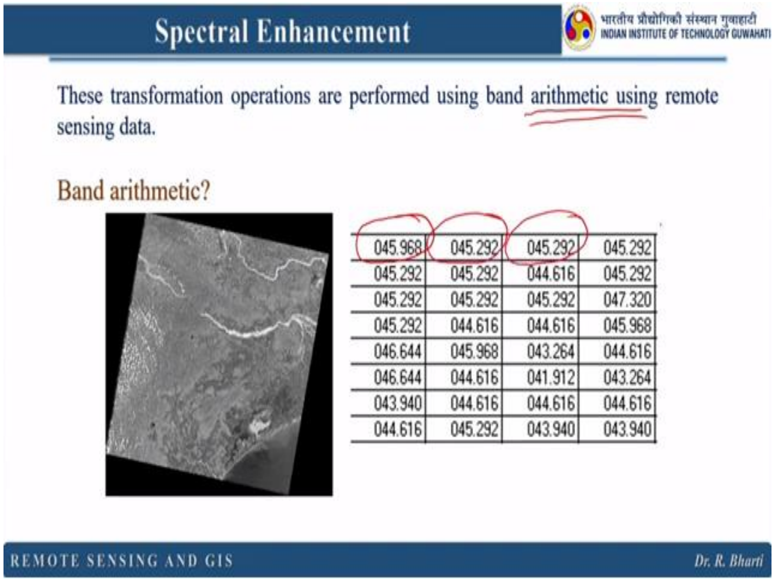


Now these transformation operations are performed using band arithmetic using remote sensing data. So here basically I am going to start with a very basic method and these are arithmetic. And band arithmetic means either you have to add, subtract, multiply, divide, or you can use some ratio and those will be known as band arithmetic methods right. So here you have a band and you have pixel values and then you can easily find out or you can easily use some logic here to individually run those arithmetic functions here right.

And then that will be known as spectral enhancement method. So there are few fundamental questions like what I would like to ask. Like first one is what could be the possible benefits of band arithmetic in remote sensing data right.

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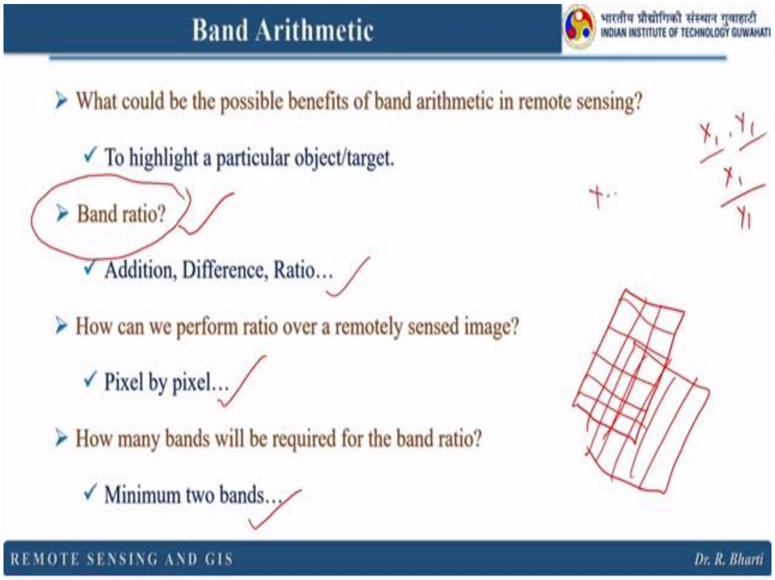


So the simple answer is to highlight a particular object or target that we have already seen in spectral enhancement. So basically band arithmetic is the way how we achieved the spectral enhancement. Then there is a new term called band ratio right. So what do we mean by band ratio? So here either ratio is normal ratio. So you have 2 values X1 and Y1. Then band ratio will be X1/Y1 or Y1/X1 right.

So here what we can do is we can add, we can subtract, we can do the ratio, we can multiply some values. So those are actually included in this band ratio. So next question is how can we perform ratio over a remotely sensed image. Because normally when we see it is a image right. But we know that images are nothing but the set of values and which is basically nothing but matrix right.

So we can easily identify a pixel value and we can always run this addition difference ratio on this pixel by pixel basis. Next is how many bands will be required for the band ratio. Because you cannot do ratio or this band arithmetic operation if you have only one band right. So for this you need to have another band and then only you will have this X1, Y1. So these are few fundamental questions which has to be explained.

Now here the answer is minimum 2 bands are required. Now we know except panchromatic data we always have more than 2 bands right. So once you have 2 bands you can find out suppose if you have X1, Y1, X2, Y2, X3, Y3 then you can always combine these or you can perform the band ratio right. So this is how we are going to enhance the information about our target.

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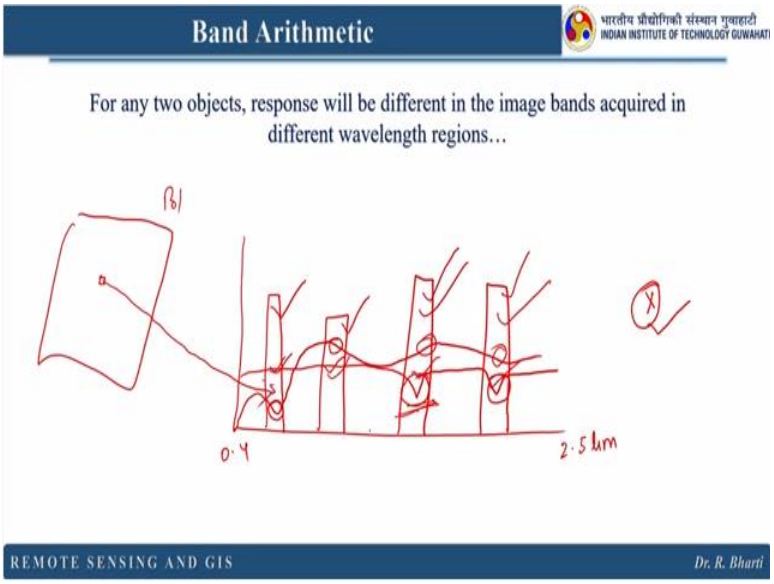


Now for any 2 objects response will be different in image bands acquired in different wavelength region that we have already seen that if you have like I will draw this 0.4 to 2.5 micrometre right. And your bands are like here, here, here and here. So this is in case of broadband and multispectral data. Now if you want to identify vegetation right. So it will be like this suppose for another X material you have this kind of response right.

So if you see this available images or available bands from a particular sensor. You can see in case of vegetation this draft is captured in this particular band and then this peak is also captured in this particular bands. So in this case all the bands can be used to enhance this right. But in case of others right here you have absorption feature, here you have absorption feature. So these 2 bands are very useful.

Just to see you will find the darker portions or darker pixels are basically highlighting this particular X material. But for other wavelength it is straight line. So it is having comparatively high reflectance or emittance. So what we can do here, we can combine all these band so if you divide this particular value. So this is basically from one pixel of this image right. So in this band

1 this is the value, for band 2 this will be the value, band 3 this will be the value, band 4 this will be the value.

So if you compare with respect to spectral information, you can easily find out responses of the target is different in all the bands. So can we use this fundamental information to enhance our target? Yes, right.

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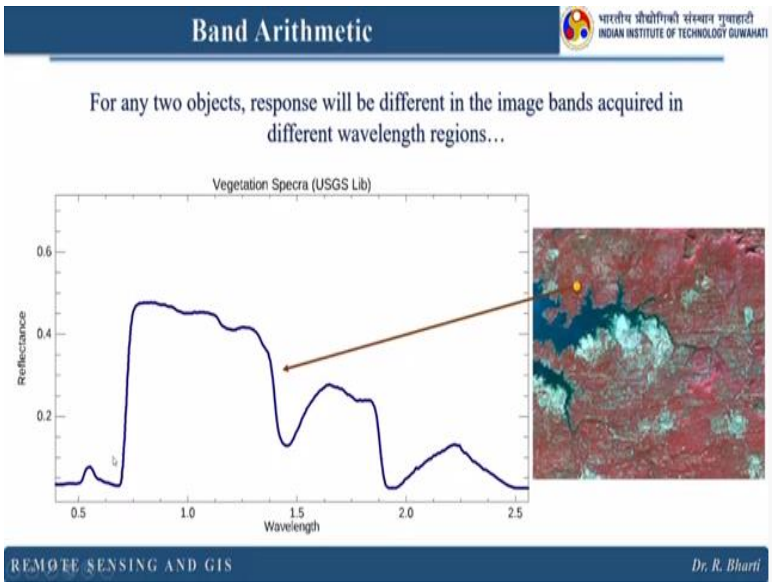


So this is from this image.

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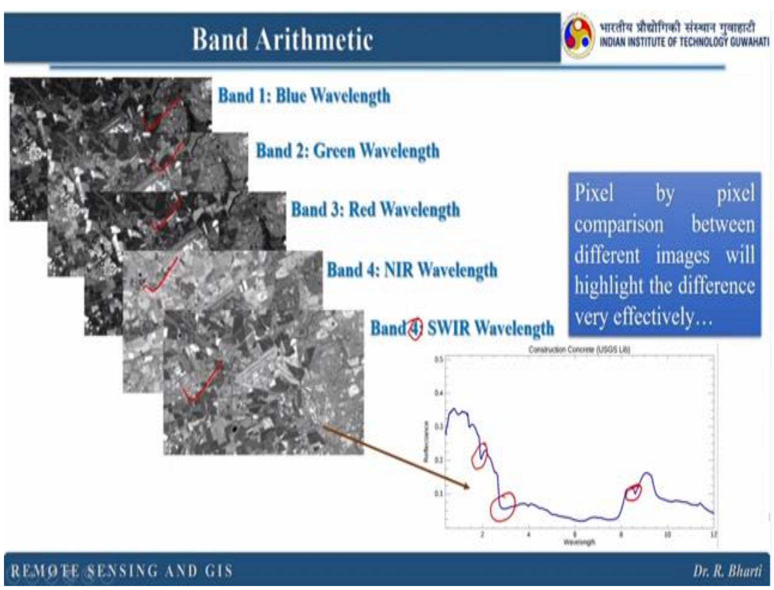

Now in band arthritic what we do? Pixel by pixel comparison and why we do? To highlight the differences very effectively. So here you can see we have band 1, band 2, band 3, band 4, band 5 right. Sorry this should be band 5 right. So here basically what we want to do? We want to identify the material response from this image and we also have some standard library. So you can easily find out that whether these bands are having those information characteristic absorption or not right.

So these are the characteristic absorption features right. So if your band is having that information, you can always go for band arithmetic or band ratio. So to enhance our target. So there are few functions we are using.

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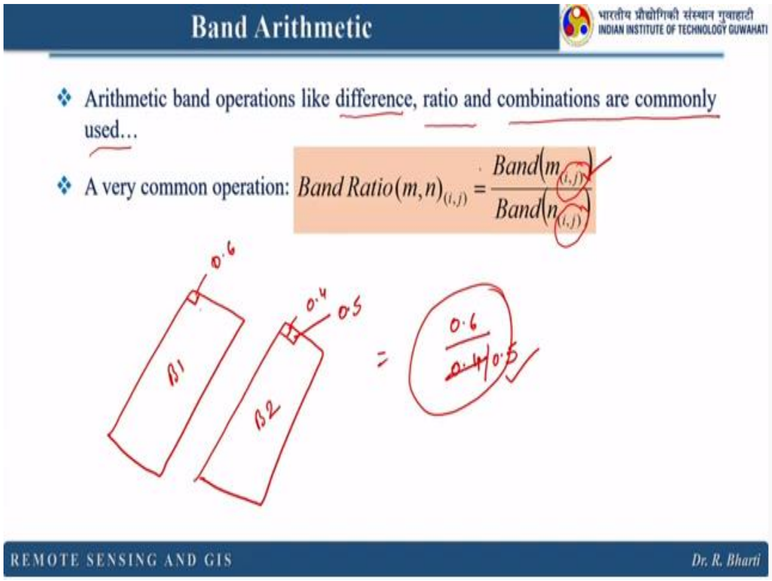


So this you can see here the difference ratio and combinations are commonly used. So this is to enhance our feature and a very common operation is Band ($m_{i,j}$) divided by Band ($n_{i,j}$). So i, j is basically highlighting the location of the target right. So this value will come here but the location is attached. So this means if you are going to use this 3 bands or maybe let us consider these 2 bands.

And the first pixel value you have extracted and let us say this is maybe 0.6 and this is 0.4 right. And based on your logic you are going to divide band 1 divided by band 2. So your band ratio will be 0.6/0.4. So this will highlight your target. Now it is important to note that we have to take care of this i, j. So in case if you are going to use this first pixel value of this band 1. Then you have to use first pixel value of band 2. Then only this is logical.

If somehow if you have mistaken use this value to divide this band 1 first pixel. Then this will get changed. Let us assume this is 0.5. So here you have 0.5 and you have not used this you have wrongly used 0.5. Then that result will be invalid right. Because that will enhance something else not your target. So it is very important to take care of the location of the pixel.

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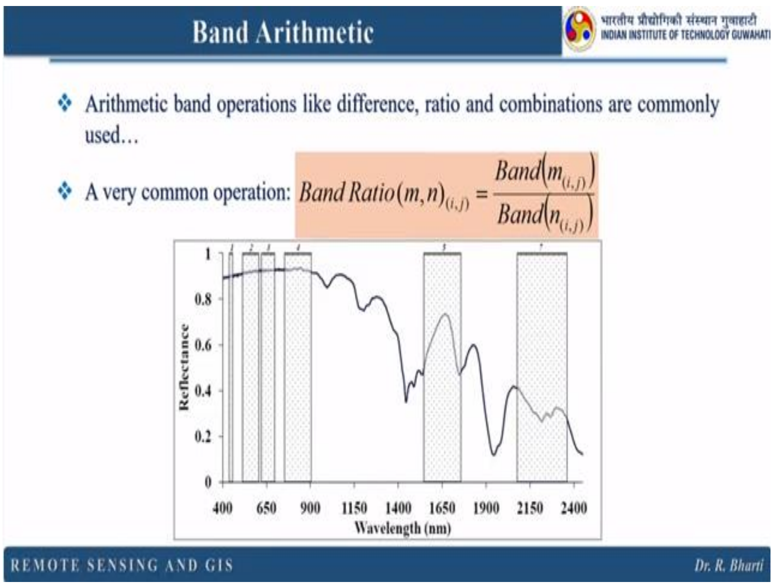


So this is again the repetition. So here you can see so these are the positions we want to highlight and these are the highest value. So you can use some logic here. So in case if you divide minimum value/maximum value, what will be the output? This will be very, very low right. So if you divide this by this, then the lowest value will represent your target right. But in case if you divide this by this, then the highest value will represent your target.

So you have to understand this fundamental and subsequently you can apply this in your application right.

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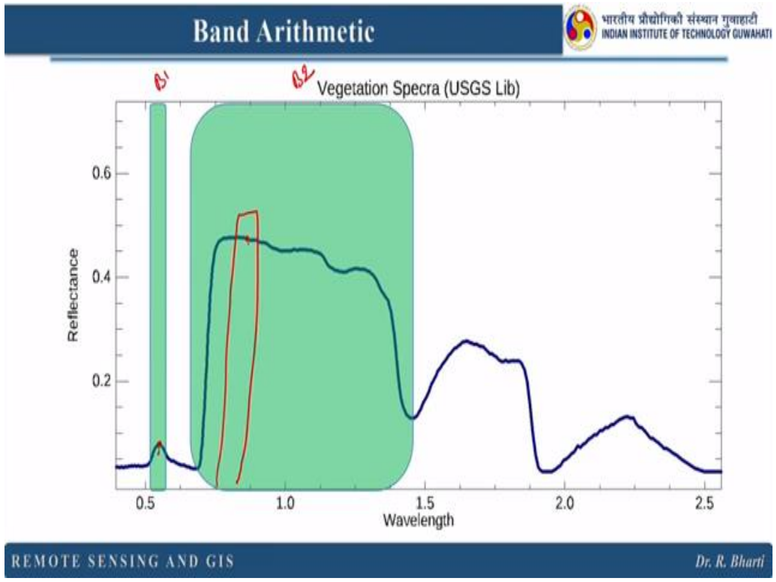


So here this is another example. When you have vegetation spectra and these are the 2 wavelengths like this is band 1 and this is band 2. And you have these 2 bands available with you or you can reduce the width of this band 2 and let us assume this is here right. So you can use this value and this value. So if you divide this by this then your value will be high for vegetation. If you divide this by this, then the lowest value will be your vegetation.

So this kind of logic, this is for example only but this kind of logic can be used to enhance any given material right. So provided your band should cover that absorption and peak of that particular target.

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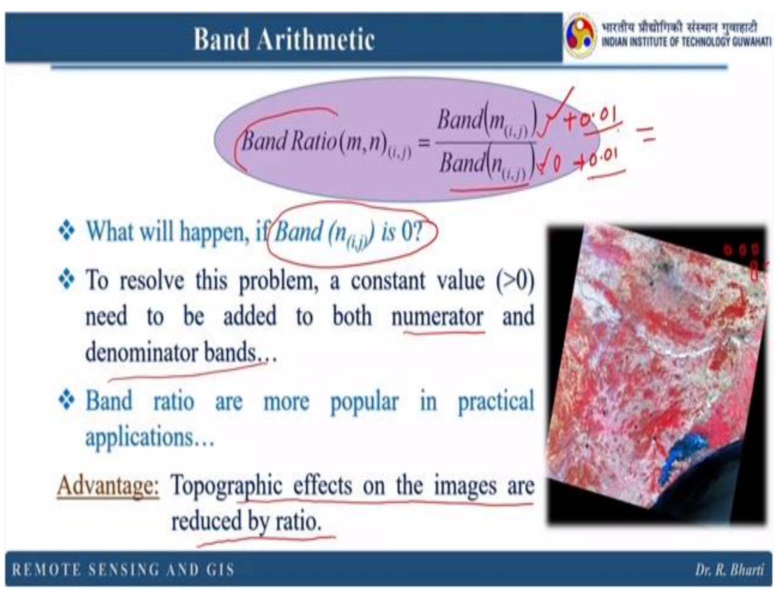

So in band arithmetic you have already understood this part. So what will happen if band ($n_{i,j}$) is 0. Because you have seen there are different errors or several error attached with the remotely sensed image. Now suppose you have 2 bands and you are going to divide or you are going to use this particular band ratio. So if this pixel and this pixel you are using correctly right but because of some errors this value becomes 0 right.

And because of the random bad pixel it may be you might not have corrected this one. So this is still zero. So here you have some value X and you divide X by 0, then what will happen? Your output will be invalid. So these are few practical problems but how do we tackle them. So this is very important to understand the error that is why I have covered all the errors in the beginning. Now you can see that this particular image if you consider these corner pixels and these are dark.

So that means the value is 0. Because this is 8-bit data. So 0 to 255 is the range. So 0 means this $n_{i,j}$ if you are using and somehow if you have changed the location of the pixel in the previous image you have considered this pixel. But here by mistake this pixel have been taken. Then your previously explained problem will occur. But for the correctly used position or correct pixel values, if the numerator is okay it is having some value but denominator is having this 0. Then your output will be invalid.

So what we can do to resolve this one. To resolve this problem a constant value greater than 0 need to be added to both numerator and denominator right. So what happens if you add 0.01 and here also 0.01. Then your here 0 will be replaced with this and you are adding the same value in numerator and denominator. So there will be no effect of these values. But the output will be sensible right. So band ratio are more popular in practical application why because here you are dividing band 1 and band 2 or maybe band 1 band 5 captured by the same sensor at the same time.

So what will happen? all the errors introduced by your atmosphere topography that will be removed. So that is the advantage with band arithmetic and especially with the band ratio. So topographic effect on the images are reduced by ratio. This is the best advantage of applying this band ratio over your image to enhance your target right.

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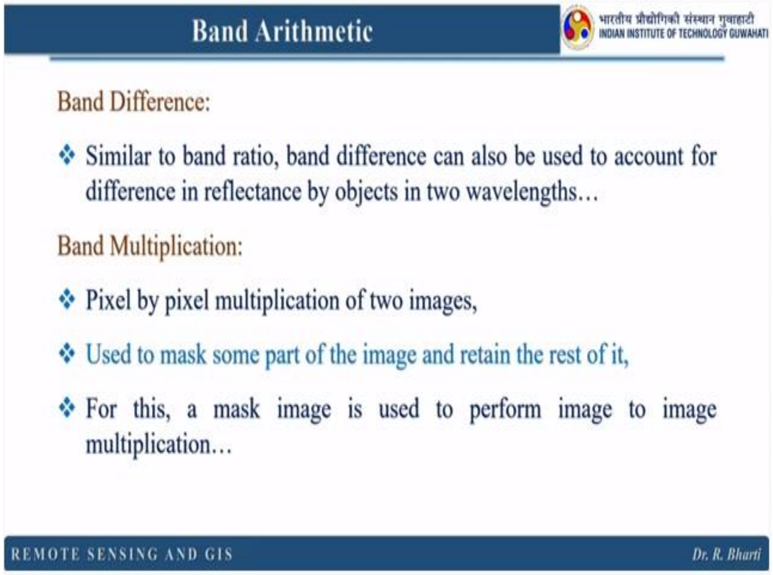


So next one is band difference. So it is similar to band ratio, band difference can also be used to account for differences in reflectance by object in two wavelengths. So you have seen the spectras so if you want to highlight based on the difference that is also possible. So you simply run this band 1 minus band 2. So that will give you this band difference. Then band multiplication, so pixel by pixel multiplication of 2 images that results in band multiplication.

And used to mask some part of the image and retain the rest of it. How we do this? So basically what I am trying to explain here, suppose this is your input and let us assume you have only one band image and you want to retain only certain portion of this image and rest is actually not your study area. So how we can do this we can make a blank image and for this particular circle or for your study area, you assign the pixel value of 1 right. So all the pixel values are 1.

And rest are 0, 0, 0, all the other pixels. So what will happen your output will have only this with the original DN value and rest will be dark. Like you have seen in the previous image. So that is the importance or that is the advantage of band multiplication. For this, a mask image is used to perform image to image multiplication. Again remember that location is very, very important. You cannot change the location.

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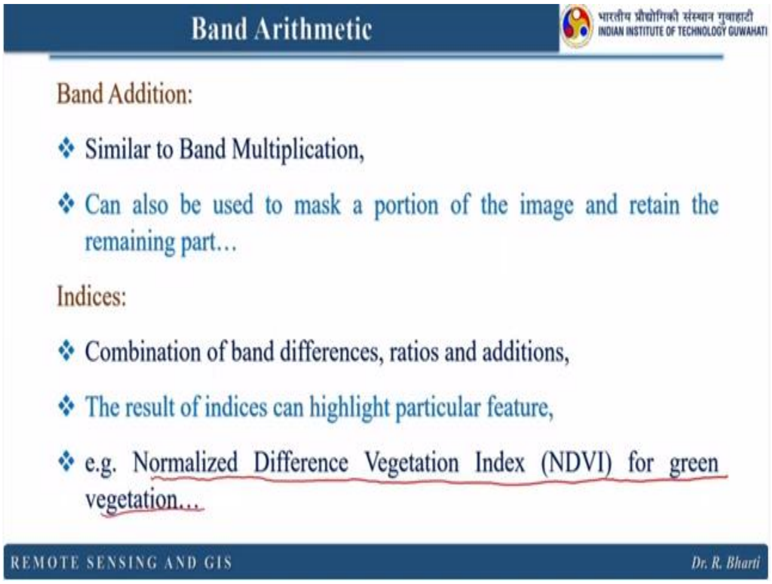


So next is band addition. It is similar to band multiplication and can also be used to mask a portion of the image and retain the remaining part of it. So suppose in the previous one you have used 0 value for the other, other than your study area and you have multiplied so it is very easy. But here how we can do, we can use some very high value or very low value. So that all the values will be suppressed apart from our study area that can be done using this band addition.

Then there is a new term called indices right. So this is actually the combination of band difference ratio and addition. Now individually we have seen band ratio, band addition, band, subtraction, band difference then band multiplication, what is their advantage? But can we use the combination of all of them, yes. How we can do? so I have given you some hint X1, Y1, Z1 these are the 3 values you have got from 3 different bands right.

So now can we use this X1, Y1, Y1-Z1 or +Z1. So like this you can perform the band ratio. But they are called indices right. The result of indices can highlight particular feature. So based on their or based on the your logic which you have generated based on their spectal response right. And here this is one of the very commonly used indices. This is known as normalized difference vegetation index and this is for the green vegetation right. Let us see some examples of band ratio. So far a real objects.

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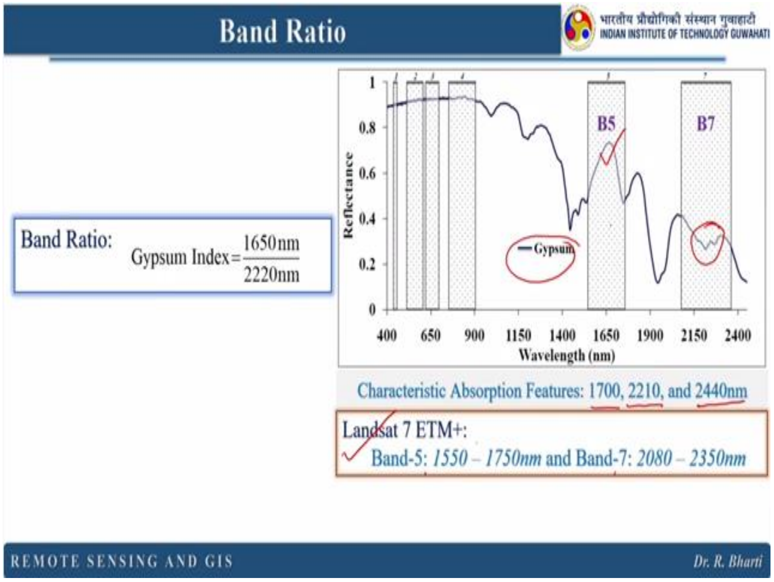


So in geology what we do, we identify minerals and rocks, vegetation, water right. So based on this spectral response. So you can see here this is for the gypsum and here the characteristic absorption features are located at 1700, 2210 and 2440 nanometre. So here in case of this particular material we have used Landsat 7 ETM+ data where band 5 and band 7 are used because they are actually capturing these 2 phenomena right.

And if you have these 2 bands Landsat 7 ETM+ and this information you can easily find out or you can easily highlight the location of the pixels having gypsum right using this band ratio. So Landsat 7 ETM+ and Landsat 8 and the previous version of Landsat are freely available to you. But there are some senses where you have to pay and you have to get the data sets and this is one of them right.

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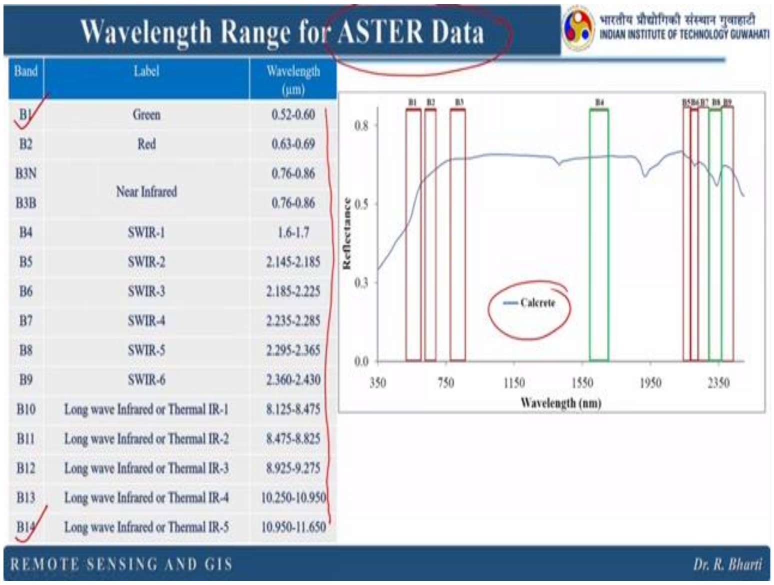


So it started with paid thing and then this is the band designation of ASTER data. So it has 14 bands and all the wavelengths are written here you can see this. And if you have your target like calcrete or the calcium carbonate then can we use this band ratio, yes we can do.

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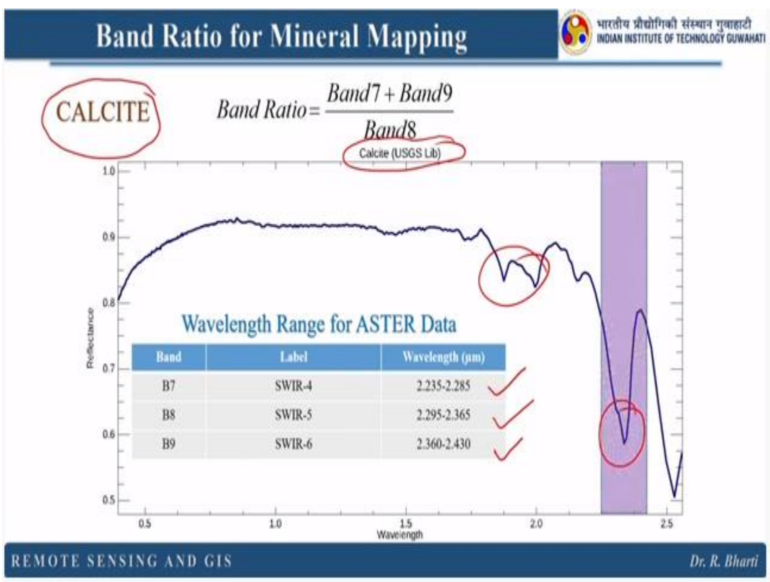


We will see some examples. So in case of calcite, so you can see this is the spectral response of calcite and this is again from USGS library and the band ratio is band 7 + band 9 divided by band 8. So what are these bands? This you can get from the from their website right. So what is the band designation of ASTER data or any given set like data. This band designation is known. So in case if you are going to map calcite.

Then you need to find out which sensor data is available and which is capturing your absorption features right. So accordingly you have to decide what data or remotely sensed images will be used in your application, so here you can see.

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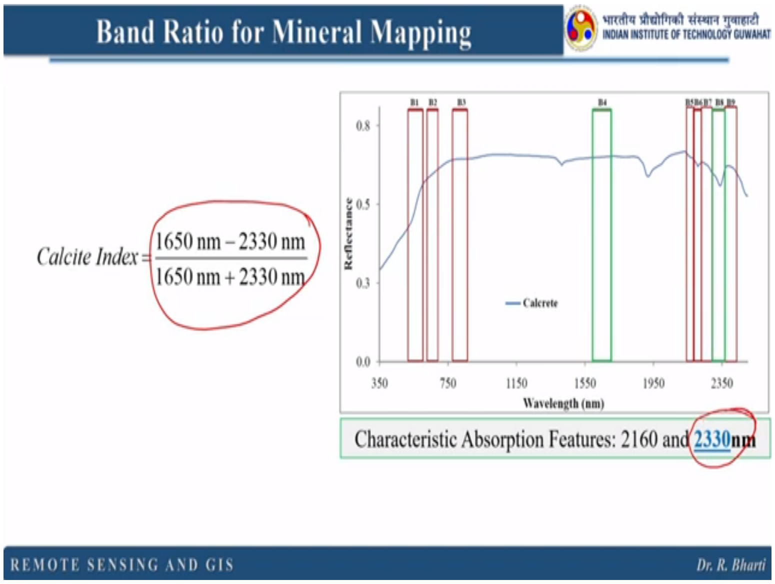


Now next is again calcite and here we are using this combination 1650-2330 nanometre divided by 1650+2330 nanometre right. Because these are basically having the absorption feature. So this is very simple but you have to understand and you have to apply in your application.

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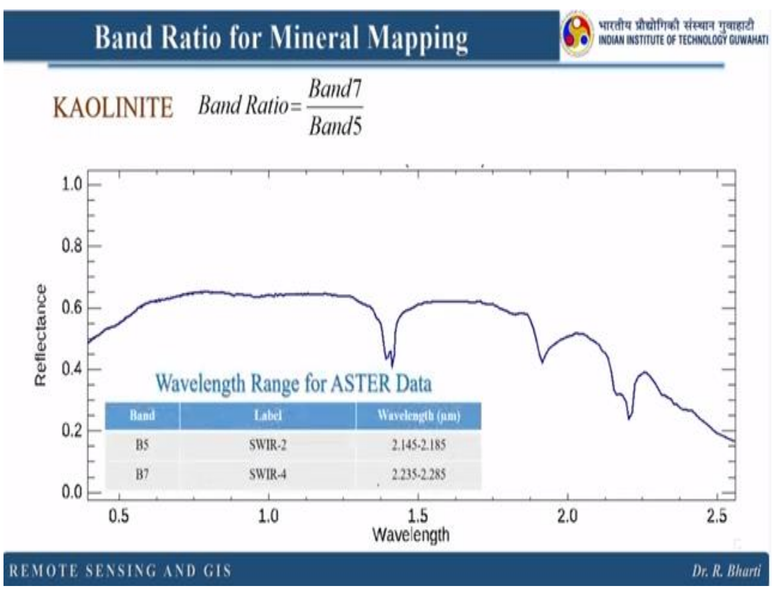


| Band | Label | Wavelength (µm) |
|---|---|---|
| B5 | SWIR-2 | 2.145-2.185 |
| B7 | SWIR-4 | 2.235-2.285 |

Now next is kaolinite this is a clay mineral and for this band 7 divided by band 5 and here you can see for ASTER data band 5 and band 7 are used right.

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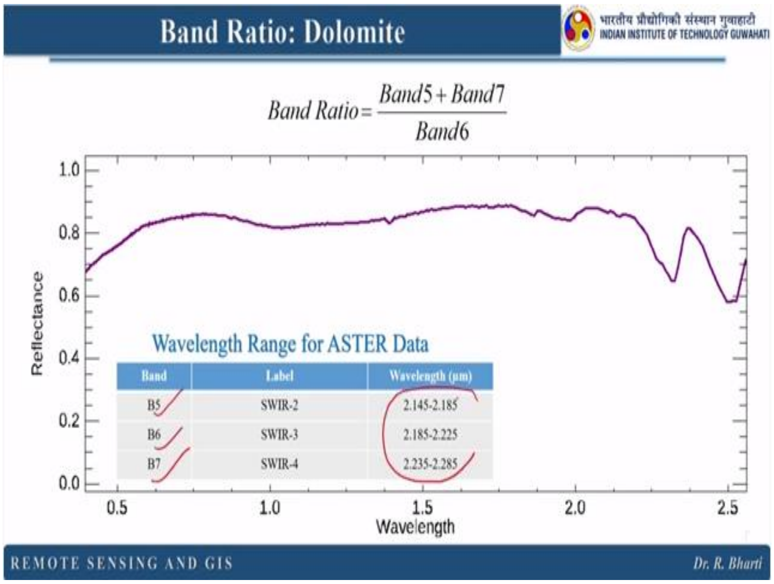


The next is for dolomite, in case of dolomite you can use band 5+band 7 divided by band 6. And here this band 5, band 6 and band 7 are captured by your ASTER data right. So this is very important to identify what wavelength you are looking for and which data is available right. So then accordingly you have to download and you have to process them and you perform the band ratios.

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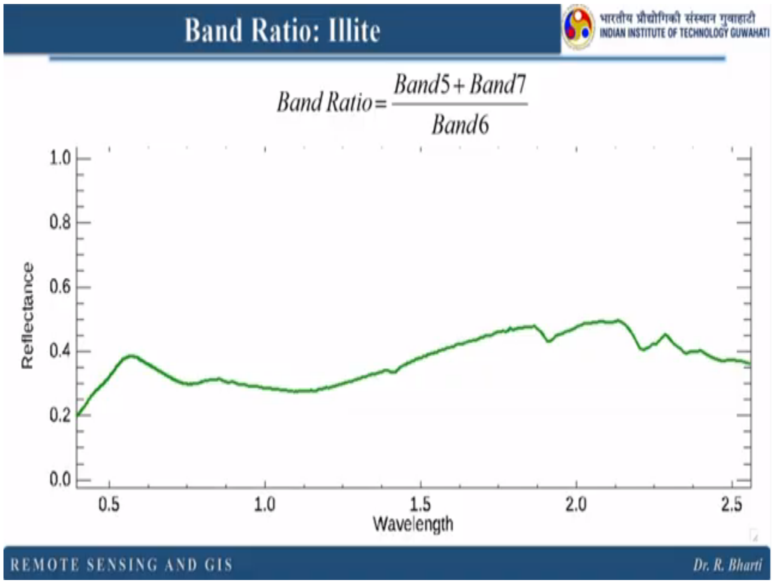


For illite this is another type of clay mineral. This is again band 5 band 7 divided by band 6 and this is again with respect to your ASTER data right.

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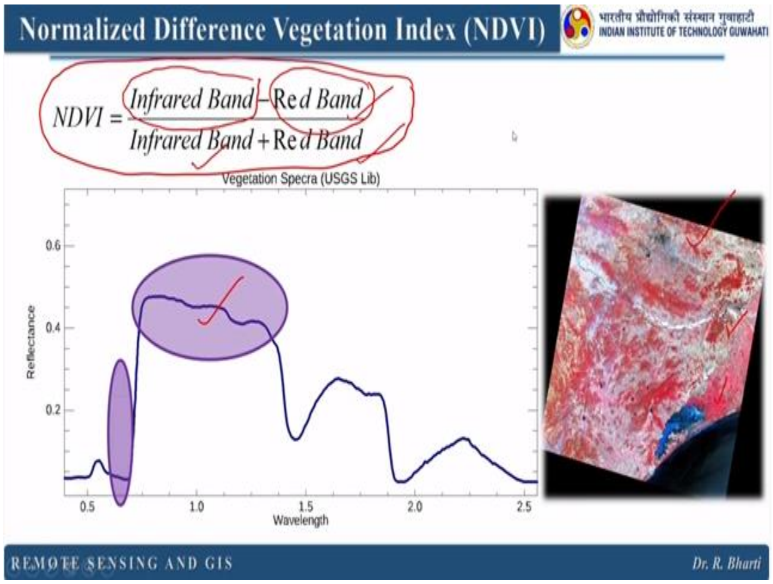


Now I have given you this introduction like I have mentioned this normalized difference vegetation index in the previous slides right. So this is one of the indice which is used to highlight vegetation. So you can see here this is the infrared band minus red band, infrared band plus red band. So how we can identify this infrared band and red band based on their band designation available with the space agency.

So in case of ASTER, Landsat all the things are available. There are many satellite data sets are available nowadays. But this equation or this combination will remain like this. So whenever you are downloading a new type of data. You have to match or you have to identify which band number is basically infrared band which band is basically your red band. Here in this case we are highlighting these 2 particular absorption feature as well as this peak right.

Which is not visible to us because this is in the IR domain. Now in standard FCC all the red colours are basically vegetation or it is having chlorophyll content. It can be because of the crop or it can be because of the vegetation, tree, shrubs, so those things are actually highlighted here. So this is only for the visual interpretation. But in remote sensing we do not rely on the visual interpretation.

Now time has come when we do the quantitative analysis not only qualitative analysis. So depending upon your application you can go to or you can perform the quantitative analysis.

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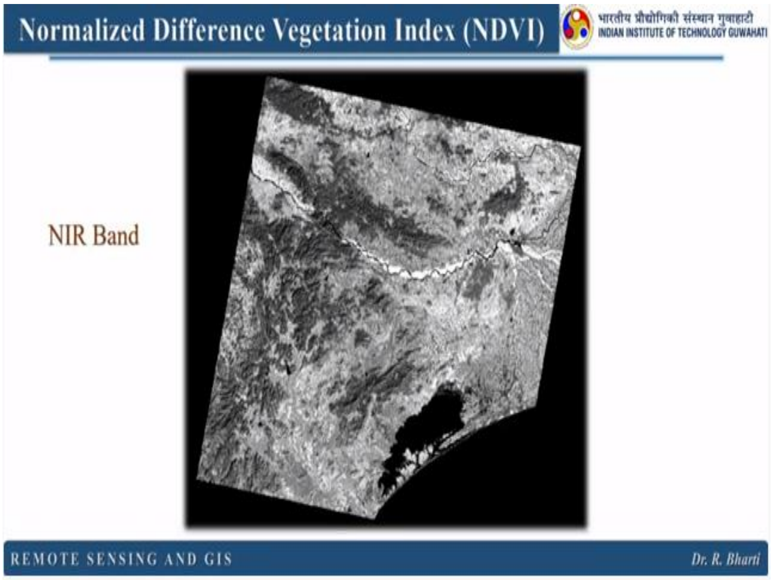


Now this is the example where I have put this NIR band near infrared band.

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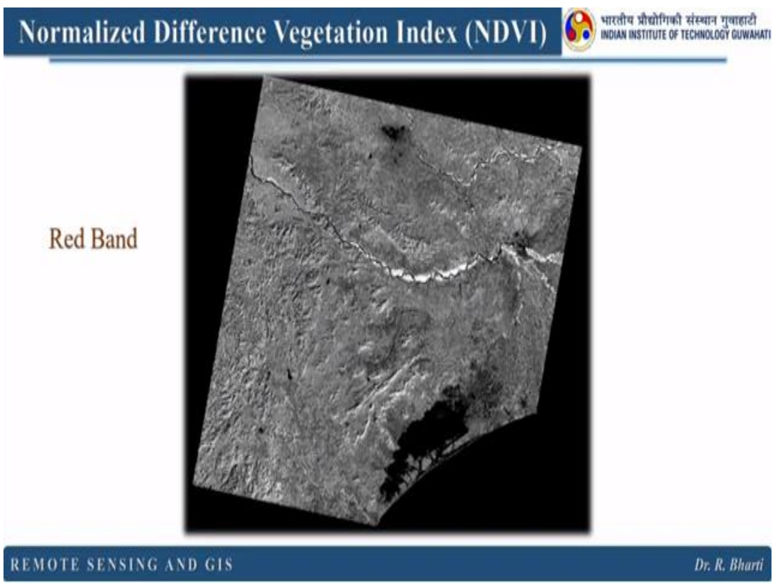


And this is your red band. Remember if you see individual band separately it will look like black and white. Because we are giving same band information in red, green and blue wavelengths or colours available in our display system. So that is why they are black and white.

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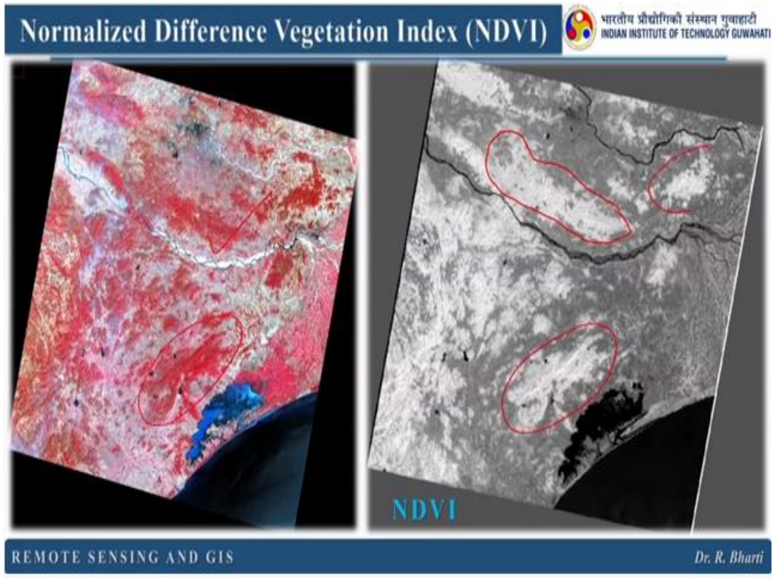


Now this is the calculated NDVI. So you can see here all the higher values are basically your vegetation which was not visible only by looking at red and NIR band right. But here in NDVI it is very clear. Now you can compare with your false color composite image. Now you can see there are few patches which are very prominently highlighted. So you can see right. So these are the patches which are highlighted because of the this indice.

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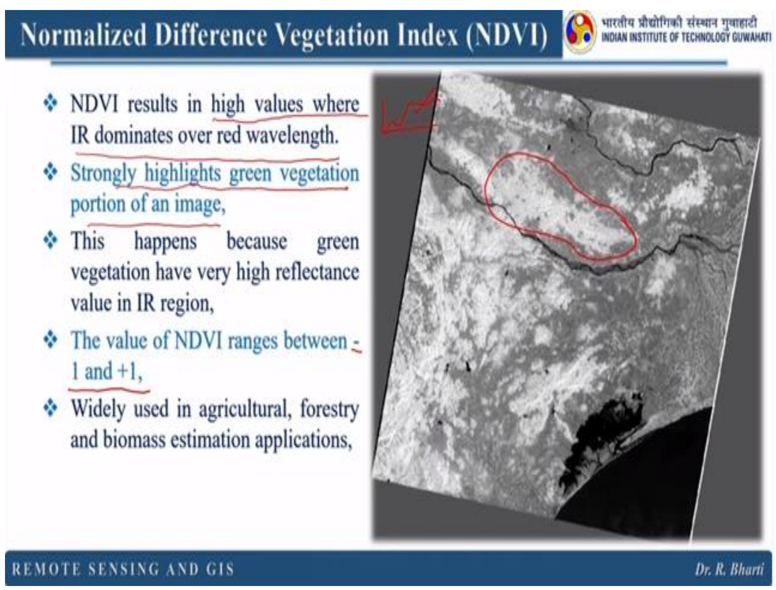


So let us understand more about this NDVI results. So if you see all the brighter pixels are basically your vegetation why? Because we have designed the ratio in that way that it will give the highest value compared to the surrounding. So NDVI result in high values where IR dominates over red wavelength right. And why it is happening because you should remember that curve right it was like this.

So this is the IR wavelength and where we are getting maximum information or the reflectance from the vegetation. And the next point is strongly highlights green vegetation portion of an image. So if your area is having green forest right or the crops which are in the matured phase. So in matured phase that chlorophyll content will be less. So you can easily find out what is the stage of that vegetation or the crop using this NDVI.

This happens because green vegetation have very high reflectance value in IR region. The value of NDVI ranges between -1 to +1. You can see here, minuses come this side -1 to +1. So the higher side of the pixel value will represent vegetation right. And it is widely used in agriculture, forestry and biomass estimation application. So one example I have already given you, if you can easily find out what is the stage of your crop whether it is in this sowing stage whether it is in the young stage or matured stage.

So in young stage you will have more chlorophyll content and crops will be more greener right. So that time you will get maximum NDVI value. This is how we identify the crop stage right. So which I have mentioned here. Now there are other vegetation indices like simple ratio red/NIR.

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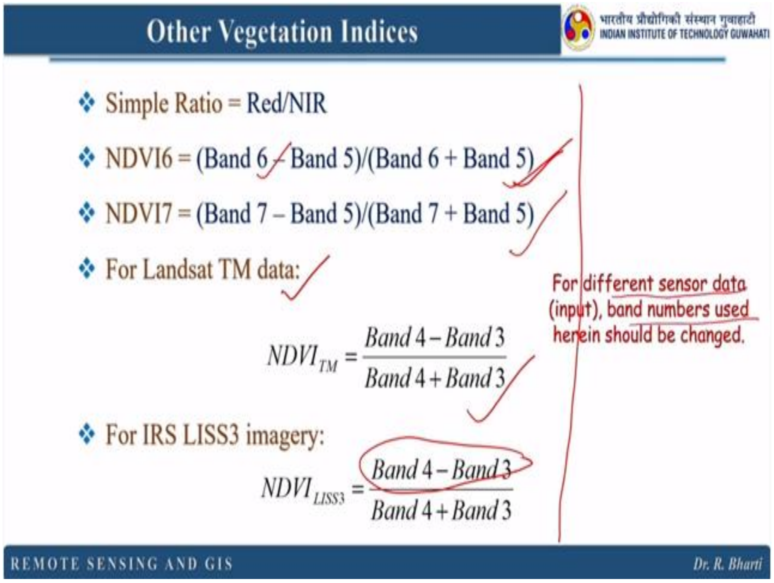

NDVI6 where this is the combination then NDVI7 where this is the combination for Landsat TM data right. So this is the equation. So here you may notice there are numbers written over here. But in NDVI I have written infrared and red band right why? Because if you write infrared and red then you have a duty to identify which band of your sensor belongs to that particular wavelength reason.

So but here it is already written but can be use randomly. Like suppose if you take this Landsat and ASTER data or SPOT data right. So can we compare this band 1 and band 2 of all these sensors, are they equal? No, they are not. So what happens, you have to take care of the band designation. So here for different sensor data band numbers are used herein should be changed. So if you are using X sensor data then this band 5 band 6 should be change accordingly.

So this is only with respect to this Landsat TM for LISS3, this is the band designation for NDVI right. And sometimes what happens they may match like band 4 of Landsat and band 4 of LISS3. They are working in this same wavelength. So you do not have any problem. But you have to cross check and find out are they same or if they are not then accordingly you have to change the band number in your calculation right.

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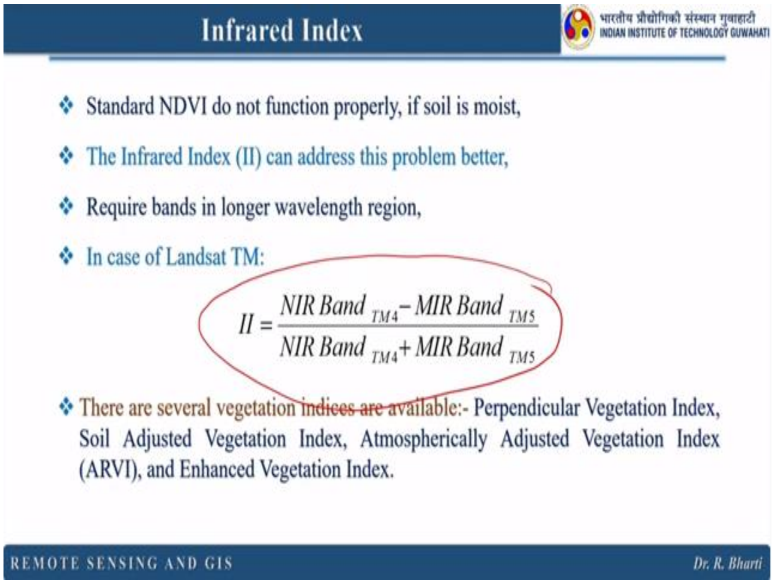


So standard NDVI do not function properly if soil is moist. So that is the real practical problem. Then what happens? You cannot simply use this NDVI. The infrared index can address this problem better why? Let us see and it requires bands in longer wavelength reason. So basically here we need more band in longer wavelength reason. So in the infrared band right. So in case of Landsat TM this infrared index is this one right.

But there are several different vegetation indices are available. So in case if you are going for such studies where you need to highlight vegetation, then you need to check different methods and the latest update on the infrared index or the new available infrared index for vegetation right.

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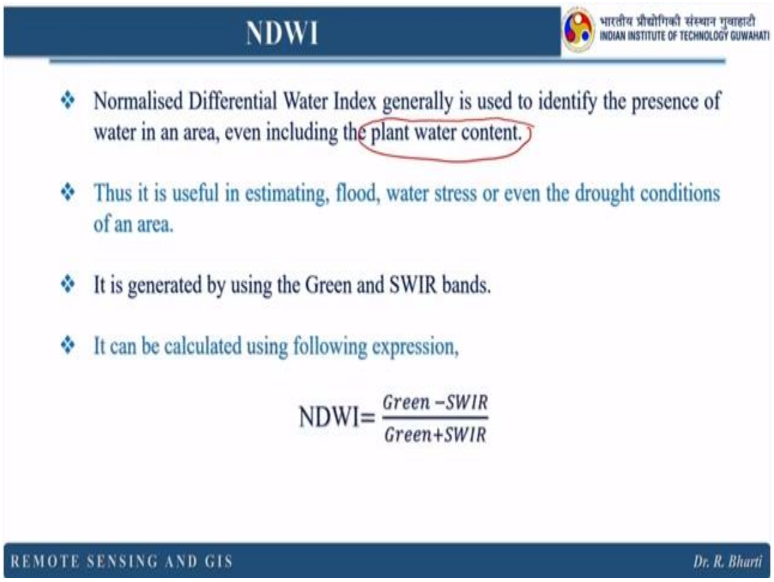


Now there is another index known as normalized differential water index which is used to identify the presence of water in an area even including the plant water content. So this actually can highlight surface water as well as the plant water content. So thus it is very useful in estimating flood, water stress or even the drought condition of an area. It is generated by using the green and SWIR bands. It can be calculated using this equation. So green minus SWIR, green plus SWIR. If you apply this, it is known as NDWI right.

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Let us see the output of this NDWI. This is the green band right. So green band and then SWIR band these 2 bands we are going to use.

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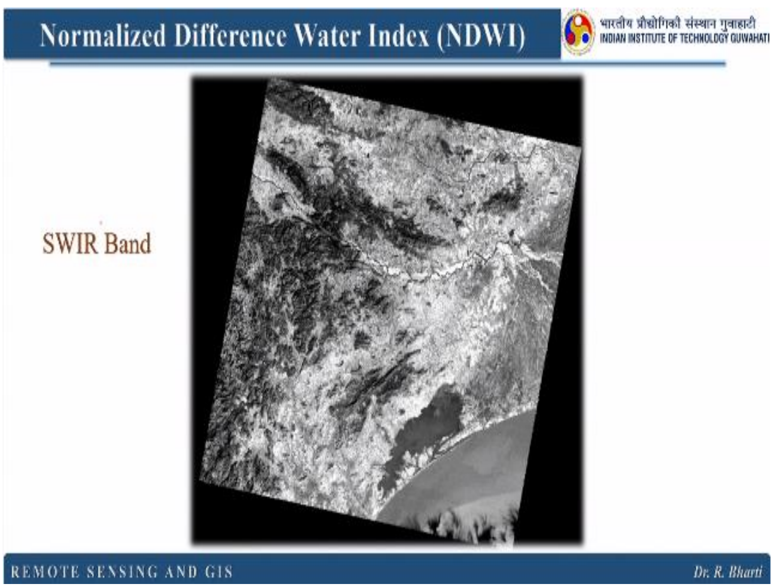


And this is the NDWI. So here you can see the brighter pixel indicate presence of water in this area including the plant water. So this can give you the real scenario of the drought. So this is better than other water indexes. But again time to time there are research going on this field. So you have to check the latest indexes available in this particular problem.

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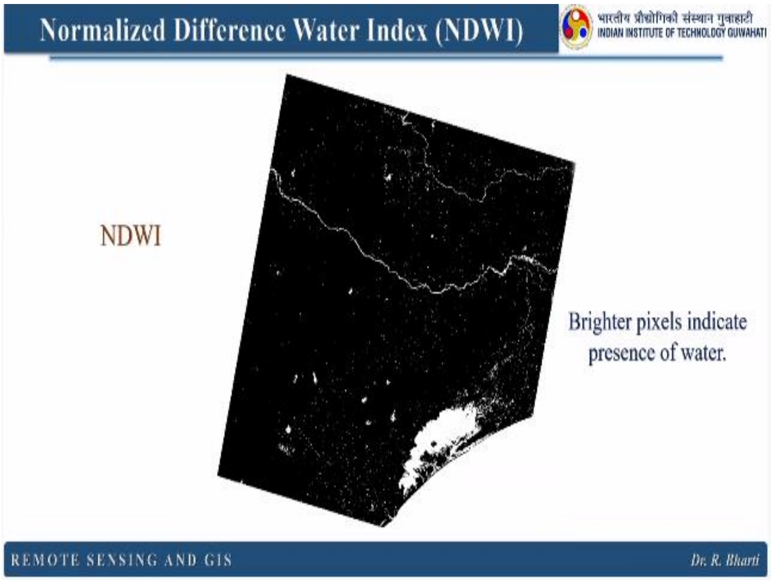


Normalized difference snow index. So this snow cover information plays an important role in various scientific studies and it provides an estimate of amount of water to be expected from snow melt and runoff.

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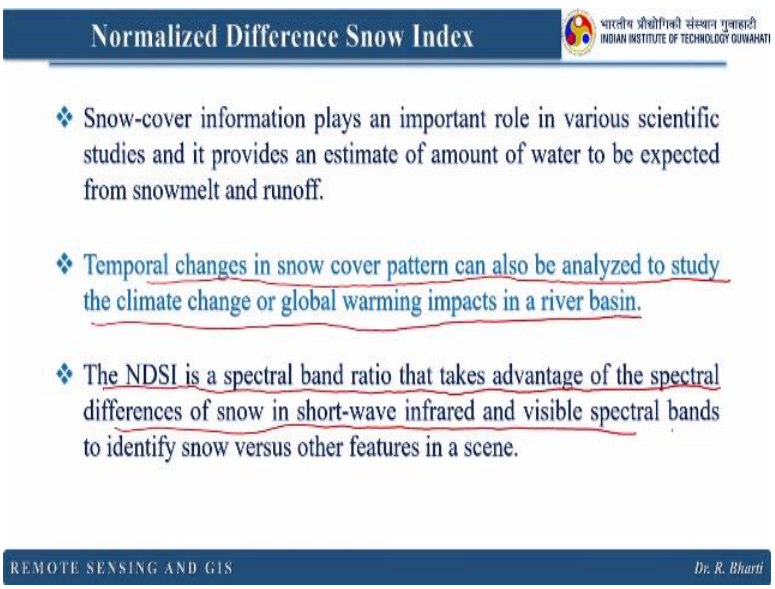


So now you can see some real examples like where we can apply this remotely sensed images and how this digital image processing will help. So here temporal changes in snow cover pattern can also be analyzed to study the climate change or global warming impact in river basin right. NDSI is a spectral band ratio that takes advantage of this spectral differences of snow in short-wave infrared and visible spectral bands to identify snow versus other feature in a scene.

So this NDSI is very important and very effective in case if you are going to study snow cover information right.

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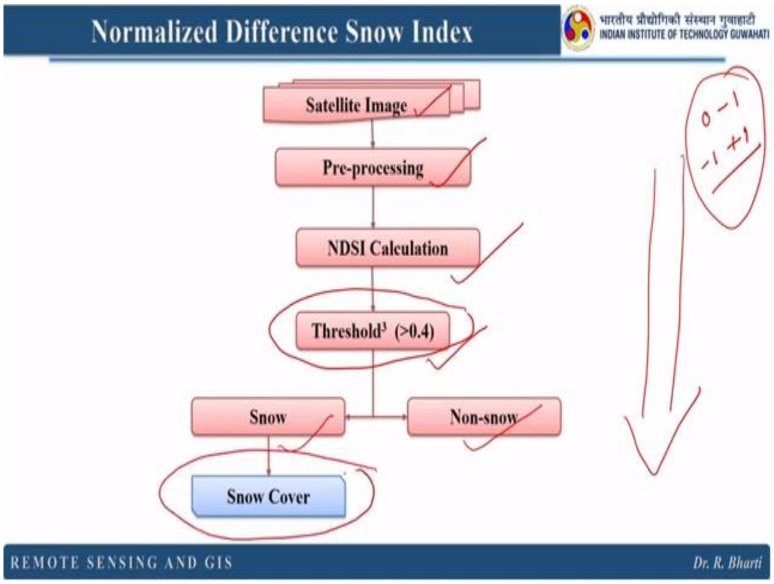


So this is the flow chart generally followed. So here you have a satellite image you pre-process this, pre-processing means correcting these satellite data for the errors and then you apply some digital image processing technique. So here NDSI is calculated and you know all the indices or the band ratios they will give you a value which will range maybe 0 to 1 or -1 to +1 right. So these are the fractions. So you need to find out a threshold.

So after that your objects are highlighted. So here if you use 0.4 in case of NDSI, it will give you snow and non-snow area and once you have that you can easily estimate the snow cover in hill regions.

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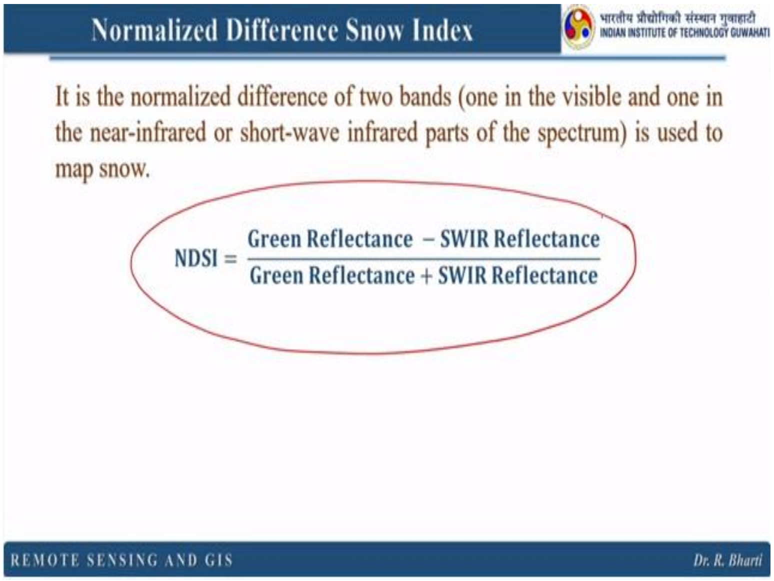


So NDSI it is the normalized difference of 2 bands, one in the visible and one in the near infrared or short-wave infrared parts of the spectrum is used to map this snow. So here this is the NDSI equation. So here it is in the generic form. So if you want to use Landsat or ASTER or SPOT or any other satellite data, you need to find out which band correspond to green, which band correspond to SWIR.

Then you can easily apply this particular band ratio. So once you know how to apply this normalized difference snow index.

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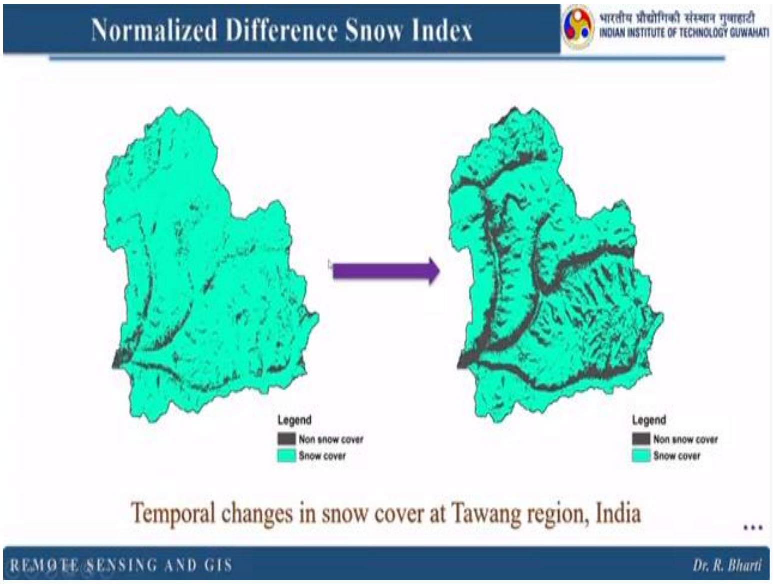

You can easily find out the area covered by snow and the area covered by other materials right. So this is one of the example. I hope you have understood this digital image processing. So from next lecture onwards we will start a new topic right. Thank you.