**Digital Elevation Models and Applications**
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**Lecture – 10**
**Shaded Relief Models and their Applications**

Hello everyone and welcome to tenth lecture of digital elevation models and applications course. those who have been going through the first 9 courses may realize that now we have reached to the mid mark of this course. And the topic is also very interesting ah, especially personally to me. I always enjoy studying shaded relief models generating shaded relief models and discussing shaded relief models and their applications, which can we exploit it to large extent.

The advantage with shaded relief model with the using simple your digital elevation model or tin one can create surface which can give a depth perception. So, we do not we do not have to resort to some sophisticated processing a simple processing can enhance our presentations and can create shaded relief models we will see how people are exploiting these shaded relief model's for their uses.

Ah also in a there is another term which is used for shaded relief models as hill shading like in RGI software they use the term instead of SRM that is shaded relief model they use the hill shade. So, do not get confused both are the same thing. What basically hill shade or shaded relief model is that is a grayscale 3Drepresentation of the surface.

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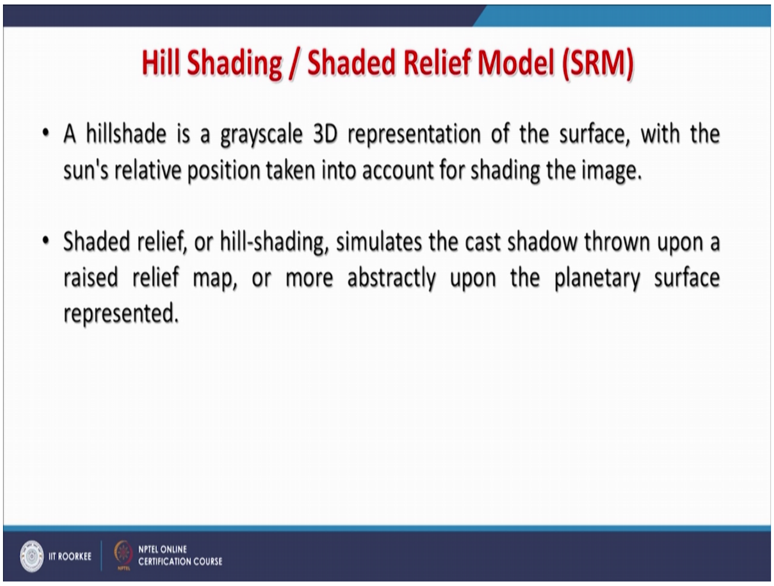


So, within one frame you get a depth perception with the suns relative position because here the sun position or illumination source and it is a elevation and azimuth can be can be chosen by the user itself, but by in default it is always assumed that illumination source is coming from northwest direction. And therefore, in all the software's When you go for hill shading or shaded relief model like in ADAS or in NV or ER RGIS you would find that the values, the azimuth values are always written that they are coming the illumination source is in the northwest direction

So, this, but nonetheless as per our requirement we can change this a suns relative position and; that means, azimuth and elevation and can create shaded relief models as per our requirements. We will see in the last few examples how we can play with these values shaded relief model or hill shade ah, simulates the cast shadow thrown upon a raised relief map and more abstractly upon the planetary surface represented.

That means, that a if the terrain is flat then no matter how much illumination is coming and for whichever direction there will not be any shadow, but if terrain is having undulations raggedness then shadows will be created no matter again from which direction illumination source is coming. So, in the shaded relief models the effects of this hill shading processing can only be seen for a hilly terrain or rugged terrain. And the shadows normally follow the normal convention of top left lighting that is the northwest direction.

In which light source is placed near the upper left corner of the map, this is always assumed in case of picos When we discussed in the previous other earlier lectures that a if we put the this illumination source say for example, in southeast direction; and then what happens that the terrain will look inverted. So, valleys will appear as ridges and vice versa, but if we keep the this illumination source in northwest direction then we see incorrect perception because the concept here is that.

If the viewer and the illumination source are in the same hemisphere when we are illuminating from southeast direction in that scenario the viewer and the illumination source are in the both are in the southern hemisphere. And therefore, you are bound to see a false topographic perception phenomena, but if a illumination sources in opposite hemisphere; like when we are illuminating a surface from northwest direction and the viewer is in the southern hemisphere.

Then when these 2 are in different hemisphere then we will not see false topographic perception phenomenon and that is why in default in most of the most of these software's it is assumed that illumination source is coming from northwest direction if a map because a map be orient always north upward.

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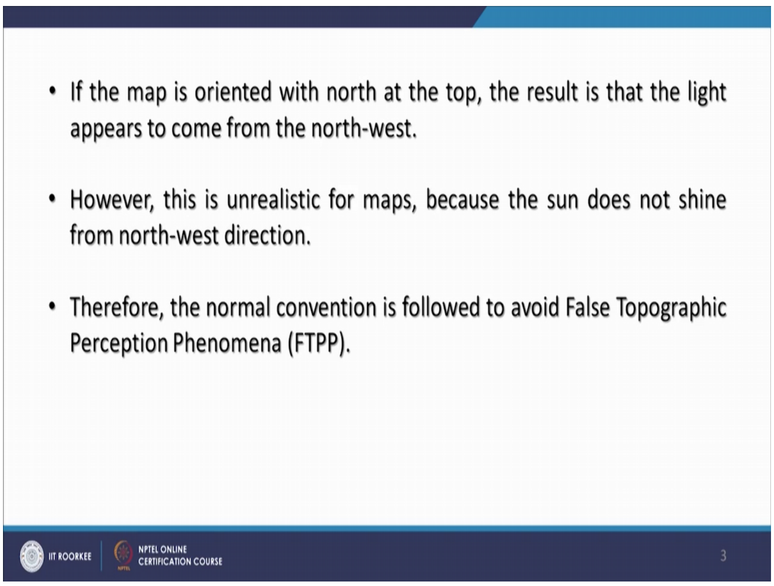

So, if a map is oriented with north at the top the resulted that the light appears to come from the northwest. This is always assumed. And based on that a these default values have been kept in the different software so; however, this unrealistic for maps because the sun does not sign from northwest direction. So, in real real-world scenario this never happens because before it reached to the northwest direction it will set at the west and therefore, the normal convention is followed to avoid this false topographic perception phenomena as I have just discussed. Hill shading is an effective technique to give a 2-d map terrain of terrain a 3D appearance.

So, it is a quick way of creating a 3D perspective; not exactly what 3D perspective be used when we drip satellite images over a digital elevation model as discussed in previous lecture, but here we will see very soon some results of the this shaded relief model or hill shading. So, this is generally achieved in shading using a single point source of illumination. We will also see an examples how we can have varied source of illumination. So, not only illumination from one direction is possible, but nowadays we can illuminate the same terrain same surface using multiple directions or rather 8 directions.

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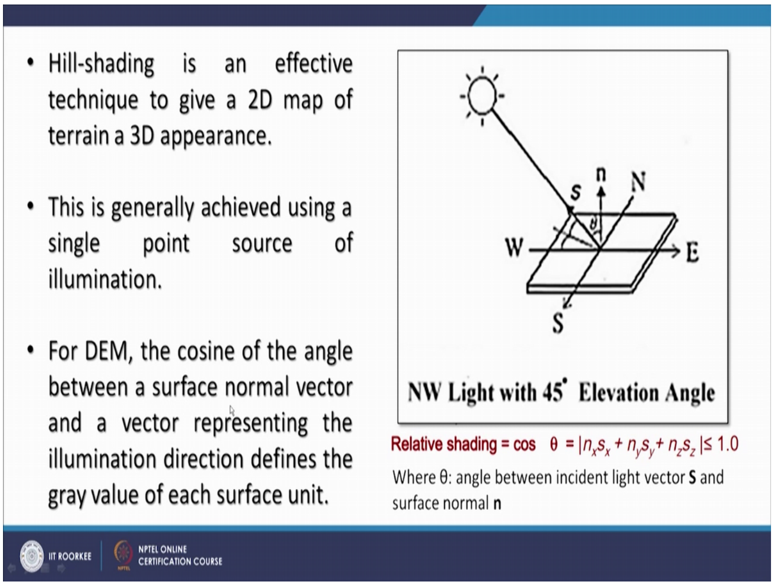


So, here in this my illustrations what we see that the sun is in the northwest direction and it is illuminating the a surface or a terrain and this becomes the azimuth. So, the azimuth angle will be measured in horizontal plane with reference to the north. So, this would be the azimuth angle and this becomes the elevation angle with an the normal here and with the nor[mal] you know this is normal.

So, this becomes the sun elevation angle. So, they say these angles the 2 angles which we have to think while creating a shaded relief model or hill shade for d e ms the cosine of the angle between a surface normal vector; which is the surface normal vector representing the illumination direction defines the gray values for each unit. So, this we have to remember when we interpret, these a shaded relief models.

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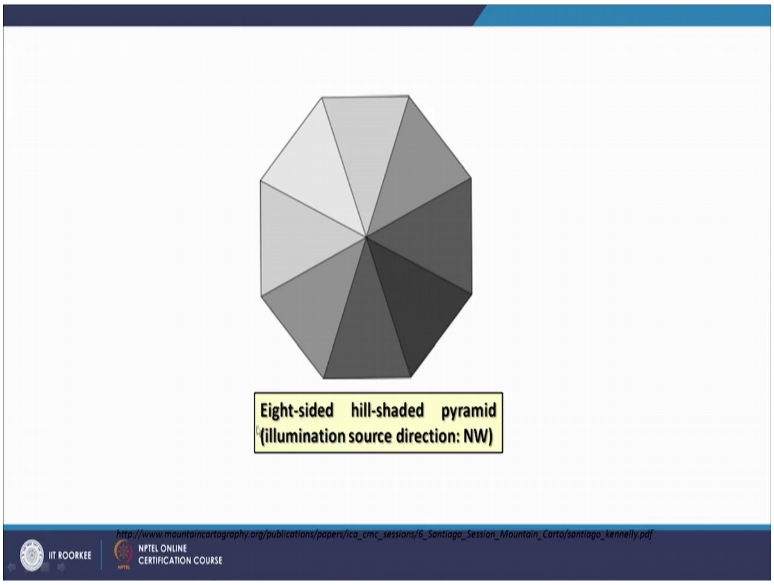


Ah this is one example that a suppose a there are 8 facets are there so 8-sided hill shaded and this pyramid which we see here. So, if we are illuminating from northwest direction then this facet or this triangle will be illuminated most it will have maximum lighting; where is in opposite direction that is the southeast facet or triangle will have the darkness or shadow. So, this is this is what is a done through a this a convolution filtering technique like here.

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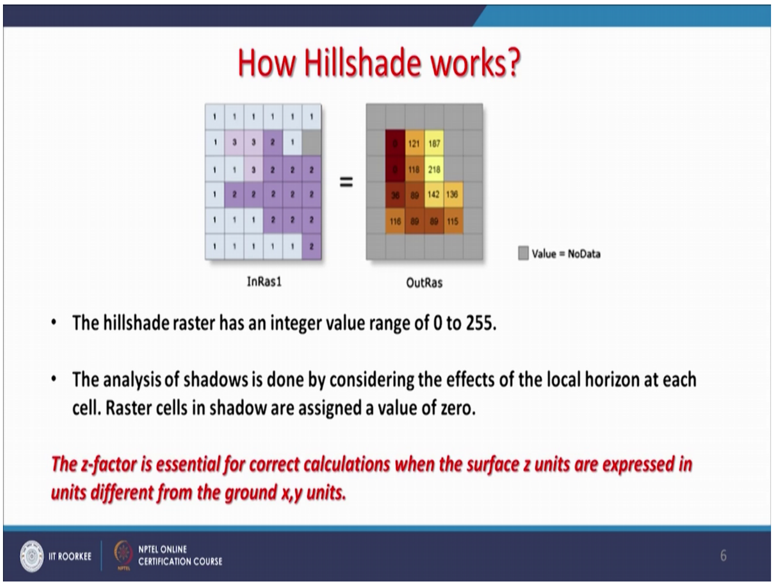


This is the input raster and earlier, in earlier like when slope and aspect we have use the same thing. So, here you know when hill shade is created these are the values which are given for different directions.

So, for different directions different values are assigned and we see that how these undulations because of shadow they are highlighted. One thing again because it is based on convolution filtering what a spatial filtering we say. So, on the edges we are having a still problem because on the edges we do not have the complete data and therefore, one row and one pixel on both top and left and right and bottom will have no output in case of hill shade.

And no data we have already discussed that here is one no data is there so for that also we will not have any output. So, hill shade raster has an integer value range from between 0 to 255 because a 8 bits a can be created very easily, but depending on the requirements and software's ah, one can go for larger range instead of 0 to 255 be one can go for 0 to 5 512 and so on. And the analysis of shadow is done by considering the effect of local horizon at each cell and the raster cell in shadow are assigned a value 0; that means, depicting the shadow..

So, this a this a again the z factor which we have discussed in case of slope and aspect calculations same z factor will play here important role; that means, the x is x y scale and z scale has to be same. So, if it is not in our data is not in UTM projection then we have to get a correct z factor for that latitude areas because a with the varying latitude z factor will also vary. So, these values can only we derived the z factor correct z factor value; in order to convert your z axis equivalent to x y axis or horizontal axis a z factor value has to be found out and that can be and determine using where exactly your study area is there, but if you convert to UTM projection using some GIS software's then z factor which is generally given in software says one can be used because in that case your horizontal scale and vertical scale becomes same. So, z factor is essential for correct calculation, then the surface z units are expressed in unit and different from the x y units.

So, this one has to always remember and just in the default; normally in most of the software it is given 1 if you accept one and whereas, these 2 your x horizontal scale and vertical scale are different you are bound to have wrong results. So, one has to take care about this.

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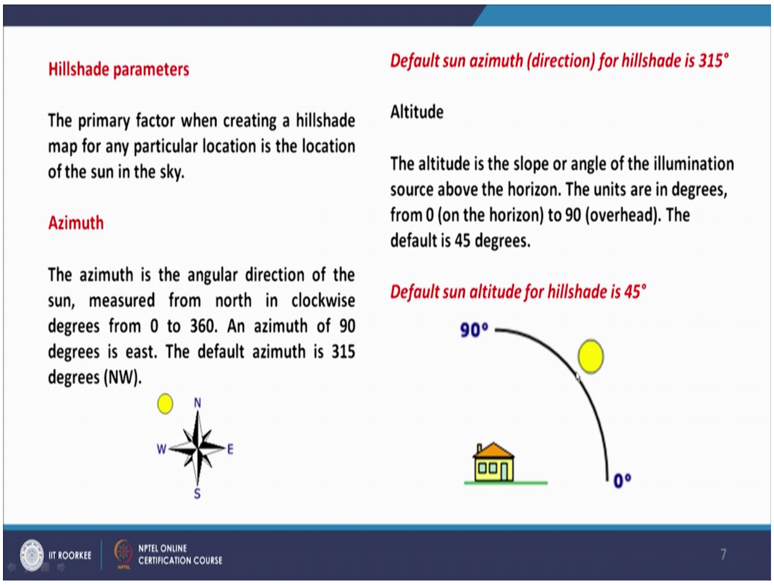


Now hill shade parameters this is the primary factor when creating a hill shade map for any particular location is the location of the sun in the sky from which direction you want the illumination should come, normally we have discussed, conventionally we have discussed that it is from northwest direction. So, this is this direction is we use the term azimuth is the angular direction of the sun measured from north in clockwise direction between 0 to 360. An azimuth of 90 degree that is east and that default is 315 that is northwest direction. And similarly for a default sun azimuth direction for hill shade is 315 degree whereas, altitude or sun elevation also we call use a term sun elevation, this altitude is the slope or angle of illumination above the horizon.

So, this altitude is measured in the vertical plate whereas, azimuth is measured in horizontal plane. And the units say here in degrees from 0 on the horizon and 90 overhead. So, as we know that in the early morning the sun is in at the 0 elevation means it is just parallel to our earth or horizon and we say sun is in horizon, and then by noon it reaches to overhead and that time the elevation angle become 90-degree whereas, the default values in most of the software's you would find it is 45 degree.

So, it midway it is kept whereas, in case of azimuth the default value is 315. and this is this is what we are seeing here that in case of a sun azimuth this is always in the northwest direction whereas, in case of this sun elevation or altitude of the sun it is 45 degree. Now the example here which we will see that the azimuth is the same in each image, but the sun angle altitude has been modified and these 2 examples are depicting..

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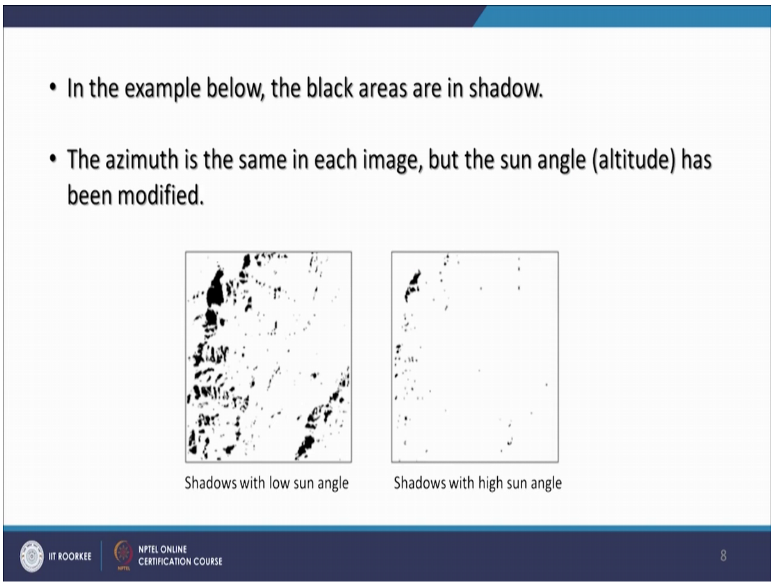


That that here when we have the low sun angle means no low sun elevation, in the morning or evening when sun is near horizon then shadows would be longer and this is what it is depicting here whereas, when sun is having high angle elevation angle or overhead you would not have any shadow at all in a perfect overhead scenario, but normally because you may not have sun depending on the season and where you are located; sometimes you may get even at noon you may get some shadows. So, that is the example here given. So, the it plays very important role and at the end of this lecture we will see 2 simulated animations where these we can simulate and then animate through a film a short film and can see the effects of sun elevation and sun azimuth, what how they play very important role in our perception of the terrain.

Because after all why we are creating a shaded relief model just to bring a depth perception in our digital surface that is our digital elevation model.

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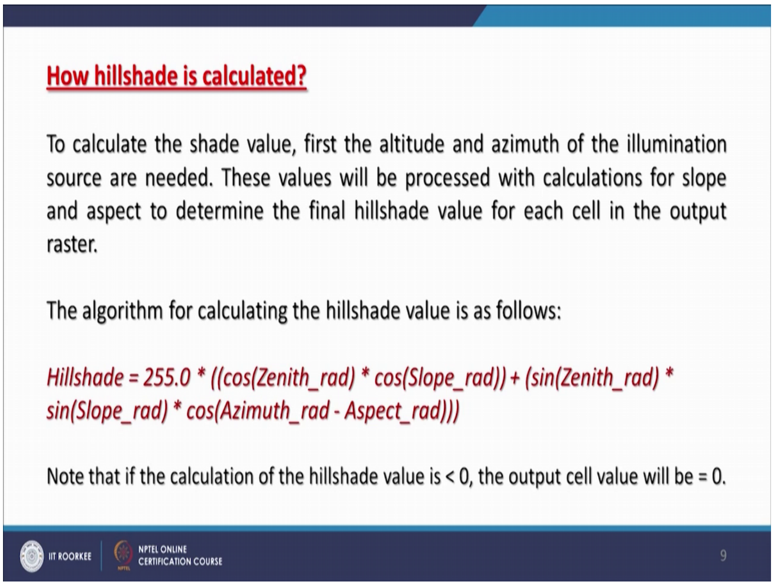


So, how exactly this is calculated? to calculate this shade value for each cell the first the altitude and azimuth of illumination source are needed. So, which are provided by the user; default values we have already discussed these values will be processed with calculation for slope and aspect to determine the final hill shade value for each cell in the output raster.

And the algorithm for calculating the hill shade values is like this that hill shade equal to 255 because as said that if in 8-bit scenario this is what the value can be, but if it is not 8 bit say it is 16 bit or beyond that then these values will change. And this is the algorithm which will be used. And here the angles are in radiation this you are having zenith, and then slope zenith sign and slope and then finally, we get the hill shade.

So, note that the, if the calculation of hill shade value is less than 0; the output will be equated to 0 because you cannot have you know a different illumination for that case. So, options say for example, if I take example of popular GI software which one can use to create hill shades like for example, RGIS then here is the example and these are the details which are mentioned against the z factor.

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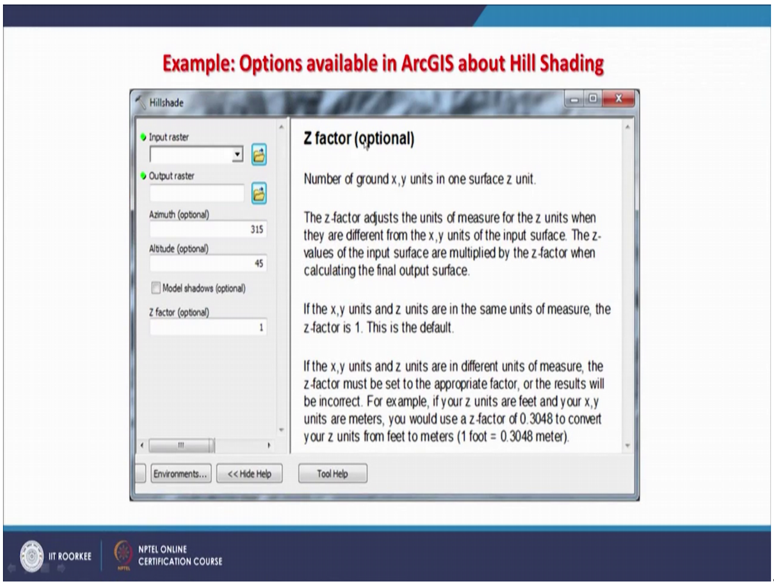


So, when you go for option for hill shade through tool box in a spatial analyst extension of RGIS you have to provide the input raster here. You have to provide where your output or the hill shade will be stored and as you can see the default values are already here ah, for the sun azimuth is 315 and altitude that is sun elevation is 45. You can of course, you can change these values, but generally and do you want to model the shadows that optional that option is also available, z factor though here it is mentioned optional only when you are having x a horizontal scale and vertical scale is are same, then only you can have z factor 1 otherwise not.

We will quickly go through this say help file which in case of RGIS is given the number of ground x y units in one surface z units. So, this is if it is the same both horizontal and vertical scales, then one z factor can be used; otherwise the z factor adjust the units of measure for z units when they are different from x y units of the input surface. The z values of the input surface are multiplied by z factor when calculating the final output surface. So, that has to be taken care about using any software default values will be there, default z factor will be there, but we have to know very carefully that what we are going to do. I have been mentioning again and again because this is the common mistake I have seen with the students while calculating either slope aspect or hill shades.

Whatever is given in default they will just accept it and will create a product which is would which is going to be erroneous if you are having horizontal scale and vertical scale different so this care must be taken. Now as I have said we so far what we have discussed only the single directional hill shading, but nowadays it is also possible to create multi directional hill shade and the we will also see the example and compare with hill single directional and multi directional hill shading.

So, traditionally hill shades are created by illuminating light or the putting the sun illumination source from northwest direction and they sometime this often produces results in which illuminated sites are overexposed and terrain details or none illuminated sites are obscured. So, if you put if you are putting like in northwest direction the slopes which are facing North West direction are having very too much light and whereas, the slopes say for example, opposite to North West; that means, the southeast direction they go complete in shadow.

And you lose details about both these surfaces slopes facing northwest direction and slopes facing southeast direction, but in multi directional hill shading we can avoid these overexposed or underexposed surfaces or slopes.

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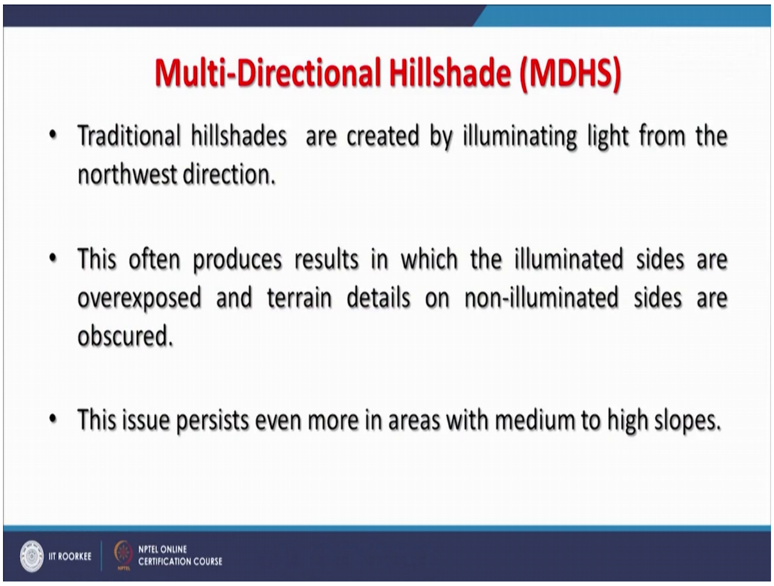


So, this issue of over and under persist even more in areas with medium to high slopes. In highly rugged terrain a single directional hill shading may not be very good; and that is why in this thing has been developed.

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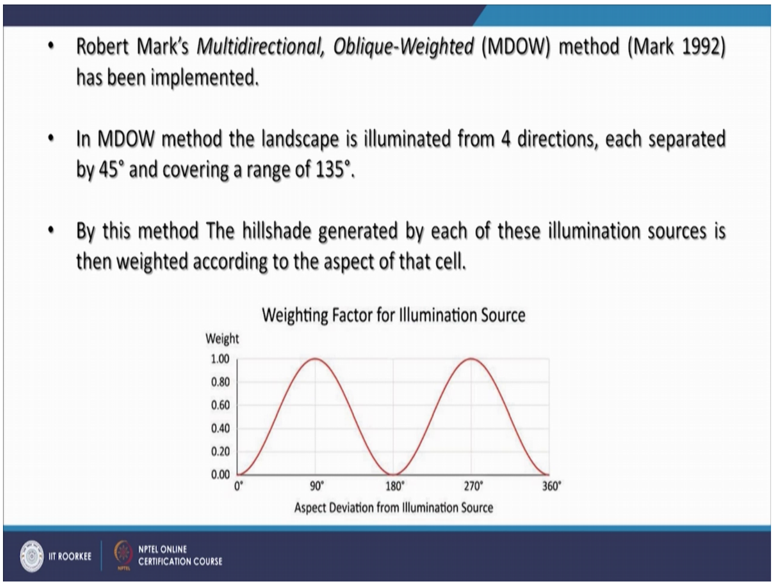


So, this Brussel in 1974 recommended is setting a variable light source direction for each cell that is, the cell of a input digital elevation model based on a primary direction plus minus a directional adjustment computed from the aspect of the cell. And Brussel also recommended that illumination inclination angle, that is the elevation angle how the sun high the sun is for each raster cells should be variable, based on the deviation of the surface normal to primary illumination source.

So, you can have multiple azimuth as well as multiple sun elevation angle. And they by Brussels method every cell could receive a hill shade based on a different illumination angle and; however, so far this has not been implemented. So, exactly what he has proposed have not been implemented, but partly it has been implemented into GIS and digital image processing software, what it has been implemented we will see and also, we will see the algorithm part as well as the results and then compare. So, this is a another contribution by Robert marks multi directional oblique weighted method in 1992 has been implemented into GI software this MDOW method. this the landscape is illuminated for 4 directions each separated by 45 degree covering and range of 135 degree.

And by this method the hill shade generated by each of this illumination source is then weighted according to the aspect of the cell. And here what we can see that a starting on this say x axis we are having 0 to 360 degree and this is the aspect derivation from illumination source. And here we are assigning the weight. So, at a 90 degree we are having maximum weight whereas, 180 degree we are having almost 0 weight and in 270 degree again we are having maximum and so on so forth. So, the cumulative effect will produce a hill shade illuminating generally from average of 4 illumination directions.

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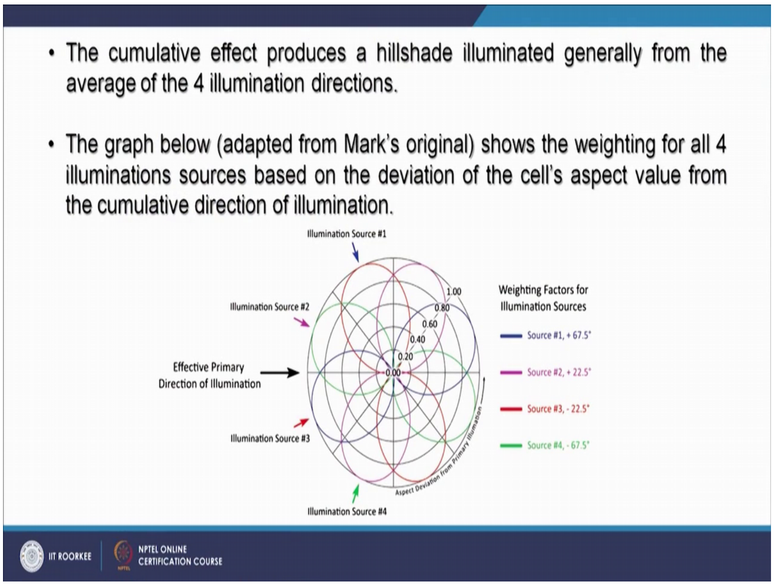


And the, this a what this graph below illustrates that that a shows the weighted of all 4 illumination sources based on the deviation of the cells aspect value from the cumulative direction of illumination. So, as we can see here that this blue the source 1 is a plus 67.5 degree.

So, here one illumination source another illumination source as plus 22 degree. Here we are having third illumination source it is minus 20 degree because first we have decided the in this particular illustrations that effective primary direction of illumination is coming from west direction. And that is why these 2 values are in positive and these next 2 values are in negative.

So, ultimately, we get 4 illumination source directions 1 2 3 and 4. So, 3 is minus 22.5 and then if we make this say 22 in say the 45-degree difference. And third illumination source and 4th again you are having minus 67.5 with reference to the primary direction of illumination. So, these are the weighted factors which are assigned and then illumination is created for a input digital elevation model.

So, why modeling shade one calculates the local illumination and then and whether the cell falls in a shadow or not. And by modeling shadow one identify each cell that will be in the shadow of another cell at a particular time of the day.

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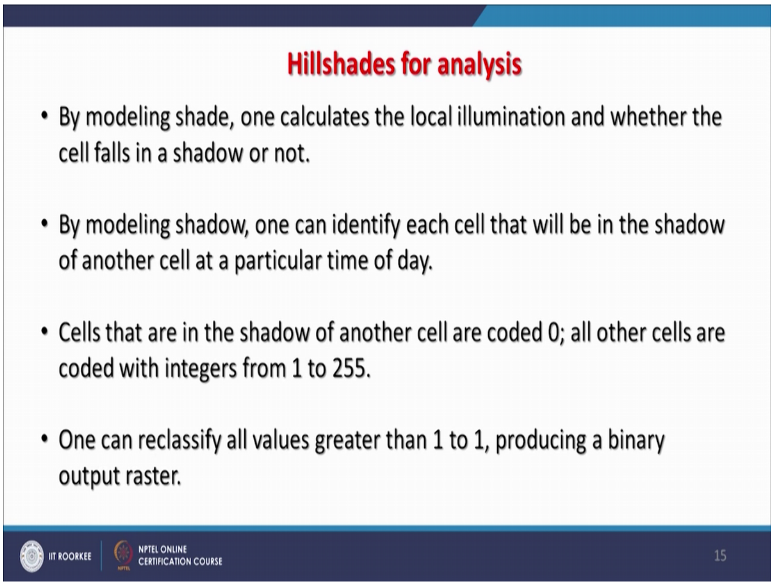


And cells that are in shadow of another cell are coded 0 or all other cells are coded with integer values between 1 to 255 again 8 bit scenario. So, total variations we can have of 256, 0 is also included. And one can reclassify all these values which are greater than 1 to 1 producing a binary output raster..

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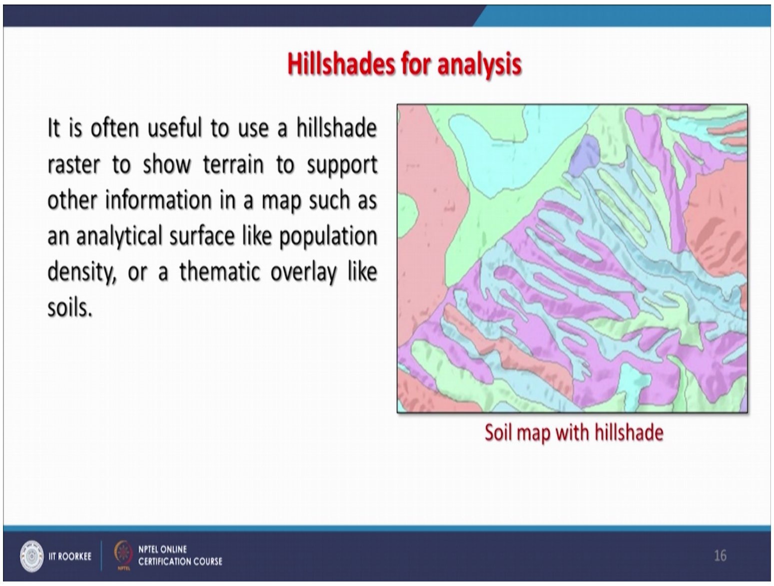


As well example is here that here you are having multi directional hill shade a soil map with the hill shade simple hill shade. So, it is often useful to use a hill shade raster to show terrain to support other information on a map. So, generally nowadays whenever if one has to show a lithological map or even point data for example, locations of epicenters or locations of some observation bells or locations of some blazers and other things.

If in background if we are having a hill shade; a conventional hill shade that will add to the information and this becomes very useful to understand the terrain conditions along with the data as well.

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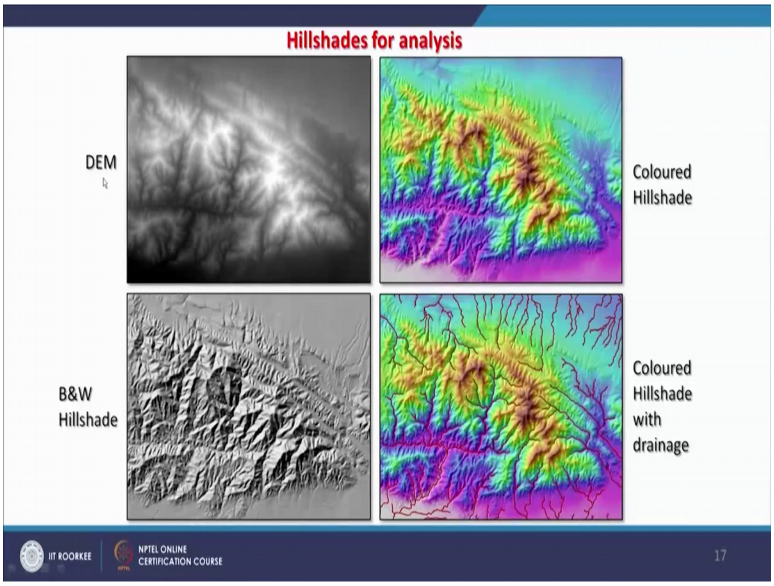


Ah here the examples are given that a simple digital elevation model which goes as one of the inputs; and along with your sun elevation in azimuth angle and z vector and you can create a hill shade, if in you know by default you will create a hill shade with black and white, but they if a if I give a color palette to my original DEM and make this DEM say 50 percent transparent.

Then I can see below the presence of my hill shade and if I if I keep this arrangement that a DEM is having a color palette having a 50 percent transparency and in the background I am having hill shade then I will see a color hill shade something like this. And if I have to so say a drainage network it looks very convincing that how these can be represented very easily and understanding of this becomes much easier.

But without using hill shade or colors if I just overlay these drainage over this simple DEM I may not be able to convince the audience or people very easily. So, that is one of the advantages of a hill shading or shaded relief models, but this say so for the example of a single directional one.

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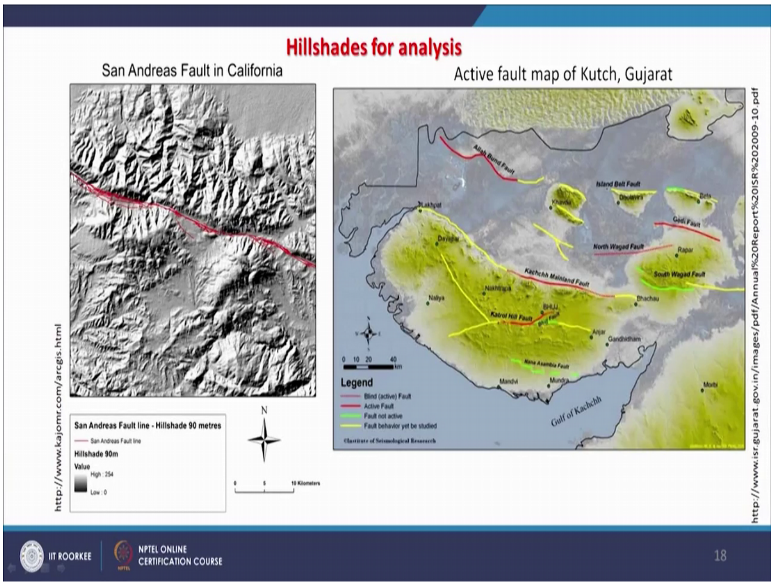


Another example here that a very famous or one can say notorious San Andrea's fault in California; which is a in a very highly seismic active region of the world and also, one of the seismically active region of India is also shown and, in the background, you are seeing the hill shade.

So, when we say plot the fault like here we can depict all details and changes in topography and corresponding and the corresponding changes in the topography very easily. So, that is why hill shade are now being used in the background for you know creating some very interesting maps and very convincing maps also. Another example is in the background you are having hill shade a simple one directional hill shade of Nepal.

And where this earthquakes have occurred this is the location of twelfth may earthquakes of 7.3 magnitude.

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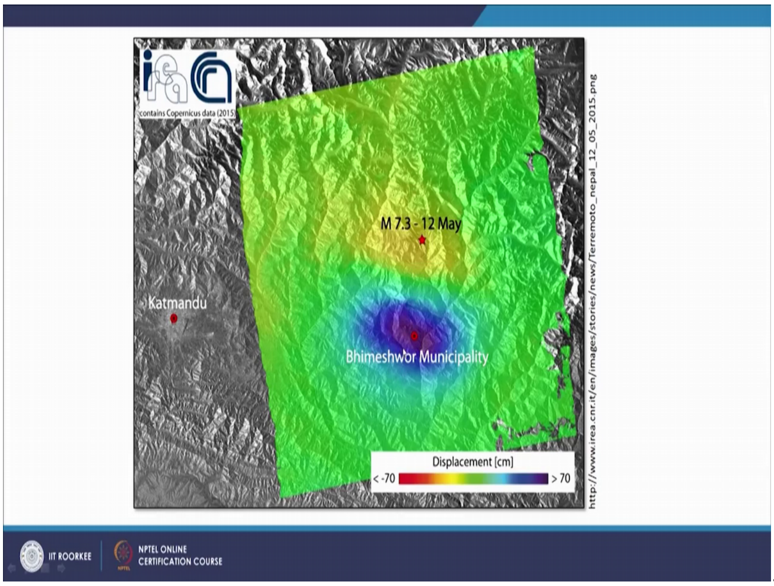


And top of this with a transparent layer maybe 50 percent transparent layer of a deformation map derived from sar interferometry of Alos Palsar data. So, 2 datasets one is in the background another one is 50 percent transparent, but it is a deformation map and this is what, you can depict very easily; that whether there is a relationship with ruggedness of the topography or not that can be seen very easily if such products are generated and these are very easy to generate

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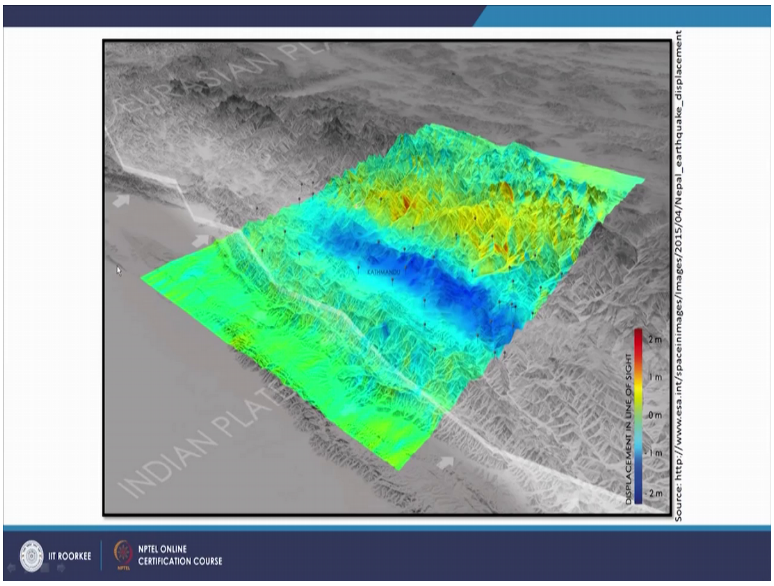

Another example is if 3D perspective you can also be created again a deformation map has been draped over a shaded relief model, which is created using a already available digital elevation model of Kathmandu area the first earthquake of 25 April.

Which occurred in near Kathmandu and all we can see that this is the deformation maximum happened in case of Kathmandu valley whereas, in other places also can be seen.

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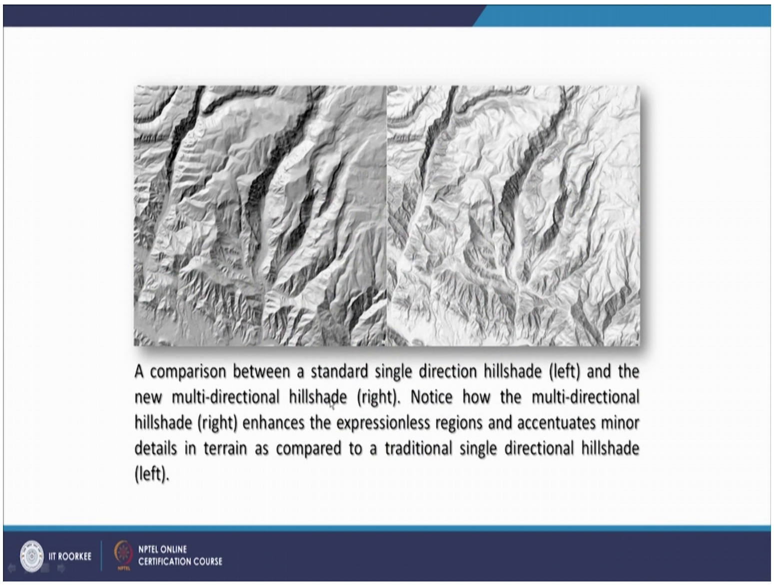


And this is the comparison between a single directional hill shaded and multi directional hill shaded. What is a here? as you can see that a lot a lot many areas or the slopes which are facing southeast direction got completely in shadow; and not much details can be seen here, but when we create a multi directional hill shading keeping a primary direction say from the best direction 2 more directions from you know between north and west.

And 2 more direction between west and south then we still we are able to see more details about the slopes which are facing southeast direction. And overexposing is also not there and that example you can see; that here in the single directional hill shading what we are seeing that these slopes have been overexposed and therefore, the details have disappeared.

But if we go for multi directional hill shading then all these details are still visible here. So, definitely multi directional hills shading is very useful becoming popular and it has been implemented in many standard GI software’s. So, on the right side we are seeing the standard single directional hill shade and whereas, on the right side we see the multidirectional hill shade.

And a as we can see that a multidirectional hill shade enhances the expressionless region, regions which otherwise were completely you know and got overexposed and accentuates minor details in terrain as compared to the traditional single direction hill shade which is on the left side. So, what are the advantages of multi directional hill shading over a single directional hill shading

We can realize that multi directional hill shade presents an unparalleled view of the worlds mountains plateaus valleys canyons and hilly terrain. And a by varying the direction of the light we can choose it is not that primary direction has to be always from the best direction

But we can choose a primary direction, but generally in default this is kept there.

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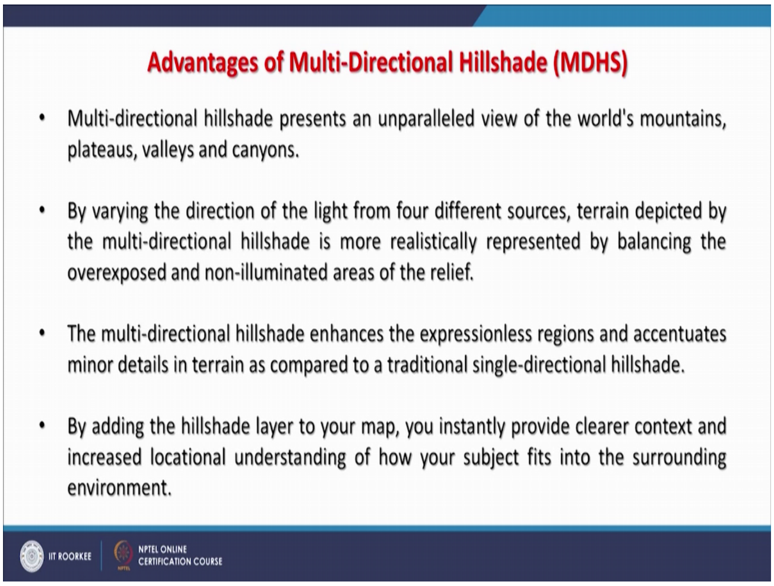


So, by varying the direction of the light from 4 and different sources of 4 different directions; terrain depicted by the multi directional hill shade is more realistically represented by balancing the overexposed and underexposed or none illuminated areas of the terrain or relief. And multi directional hill shade enhances the expressionless regions and accentuates minor details in terrain as compared to traditional single directional hill shade and by adding the hill shade layer to your map, no matter whatever the map is maybe a soil map, may be a lithological map, maybe a fault map, maybe earthquake epicenters or maybe a deformation map examples we have seen. if we bring this a hill shade or maybe a multi directional hill shade in the background and bring the our map in a transparent manner .

Then it becomes a provide a very clear context and increase locational understanding terrain, conditions about a whatever the phenomena which we want to depict through such integrated maps

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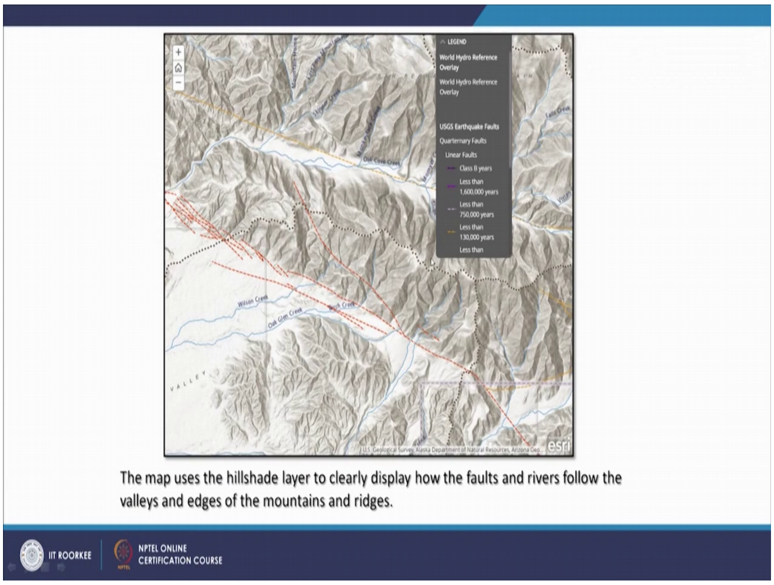


One example here is that a in the background we are using a multi directional hill shade and these drainage network is shown geological faults have been shown; because they are they sometimes they are having a direct correlation with the ruggedness or alignments with the mountains and valleys. So, if we plot both together and create such products we can see things very easily and convincingly. So, as we know that mountains or hilly areas where the relief undulations are there may look eternal, but in fact, they have been saved over millions of years by the interplay between tectonic forces and water erosion. And therefore, we try to plot all these things over a hill shade. So, that we can convince the audience very easily and this relationship becomes clear when the hill shade is juxtaposed with rivers and faults

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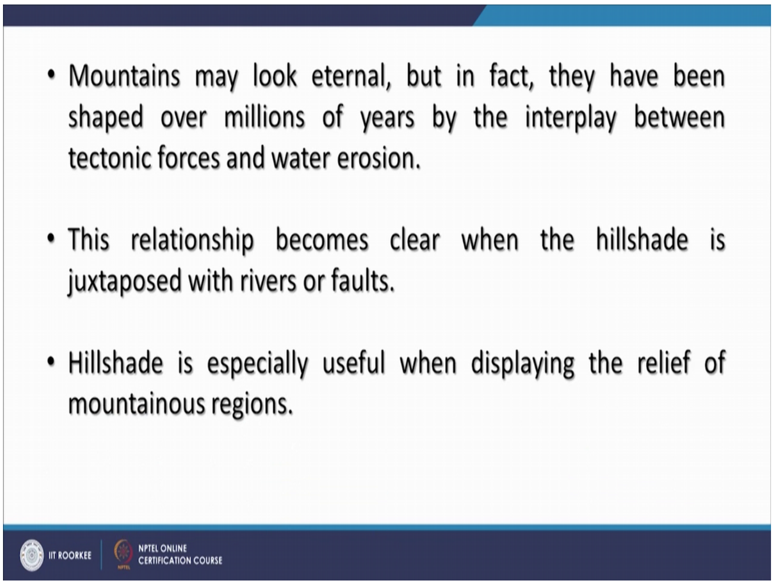


We have just seen the example and the hill shade is especially useful when displaying a relief of mountainous regions of course, for flat areas hill shade may not be any use of us.

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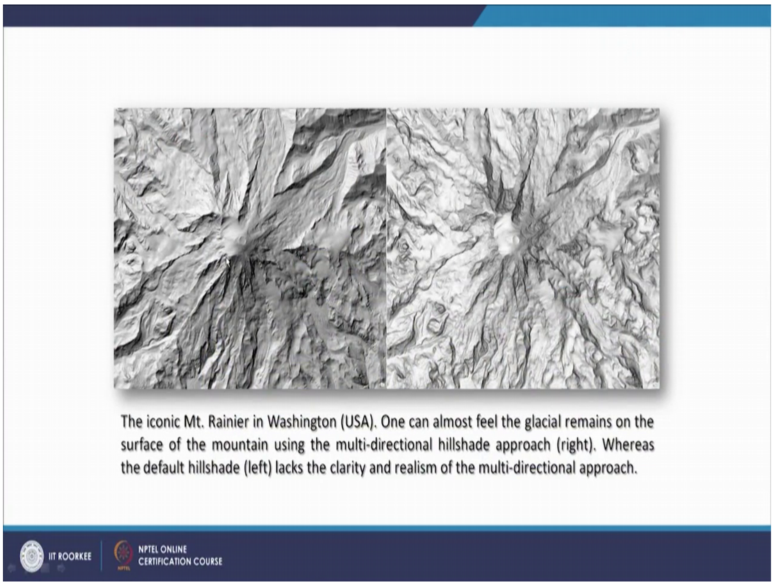

And another example of this multi directional in single directional hill shade can be seen of a mount rainier in Washington and this is what we see here. That a lot many details about the terrain now can be seen in multi directional hill shade as compared to a single directional unidirectional hill shading is there.

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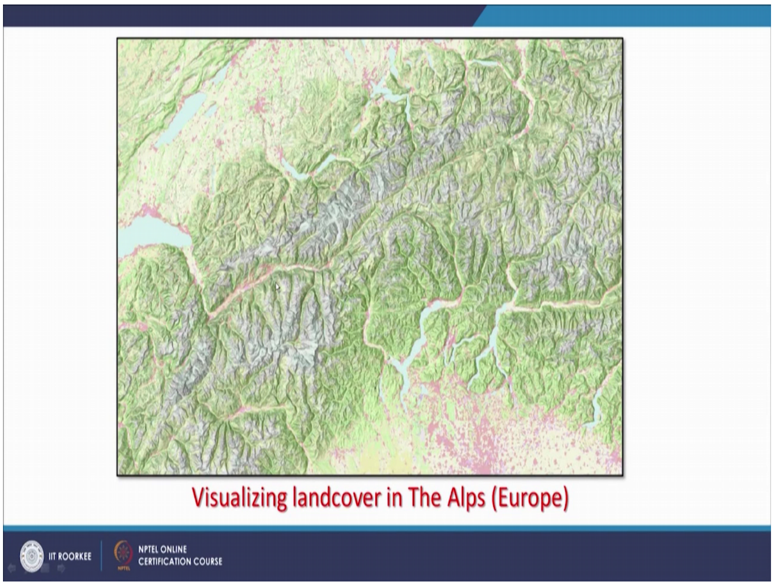


Another you know application of this that a land cover or a land use map land cover land use map has been overlaid, over over a multi directional hill shade and the top map which is a land cover map has been made transparent maybe 50 percent or forty percent depending upon of the terrain conditions and then both things you are seeing in such products integrated products not only you are seeing land covers, but you are seeing the relief and topography as well. So, one can even you know you know checks say the quality of the output of land cover when we integrate such maps. .

And also, in glacier studies one example or in avalanche studies, and these can be used one example is here with multi directional hill shade, and over which these glaciers have been plotted, that layer has been juxtaposed over this. Multi directional hill shade is another example from India. And what you see here in the background is a this a aster g d e m of 30-meter resolution.

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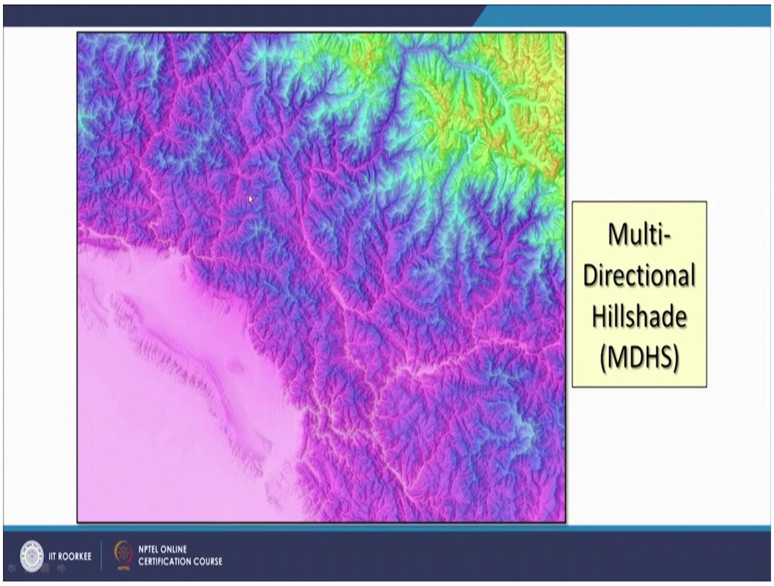


And then you see this a Shavlik ranges then Doone valley and then you are seeing lower Himalaya and higher Himalaya as well. one of the examples, or one of the uses of hill shading also discussed in earlier lectures when we elaborated on false topographic perception phenomena; that a if we want to remove the false topographic perception phenomena or in short FTPP from satellite images then when we can create a opposite direction.

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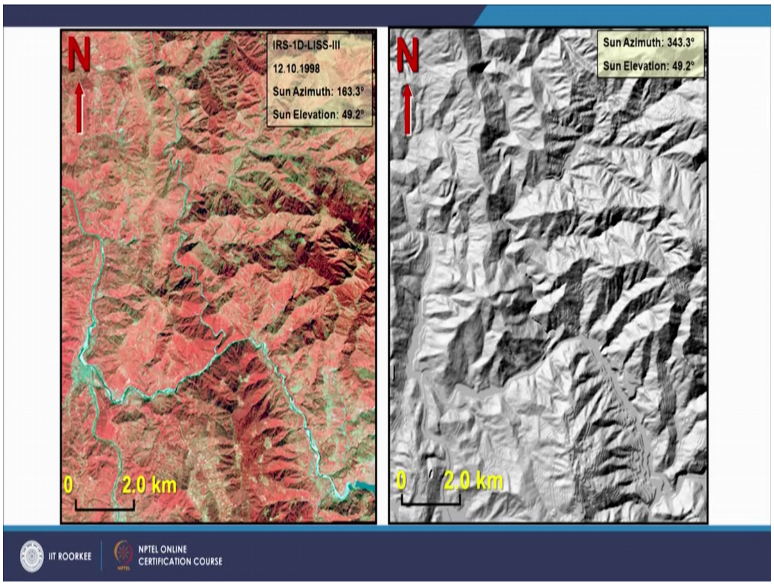

And directional hill shade which is opposite to the satellite image illumination source, and especially the azimuth. Because in generally in sun synchronous or polar orbiting satellites when the data is acquired, the sun is generally in the southeast quadrant. As we can see it is 163 Degree the sun azimuth angle. So, if we want to remove the FTPP, because here in this example the river is flowing on the ridge; that means, it is suffering the image is suffering from false topographic perception phenomena.

And if we want to keep north upward, and would like to get rid of FTPP, then we can create first a opposite directional hill shade like here. So, 163 plus 183 we get a 343, degree for sun azimuth which is just opposite and in which we can see that the river is flowing in the valley; that means, in this simulated image the FTPP has gone. Now this image can be used through color transformations to get an image which will still will have north upward, and FTPP is gone. color transformations in color transformations what we do? We use the hue and saturation of the original image like; in this one is this a left image, and a intensity part we use from this simulated image.

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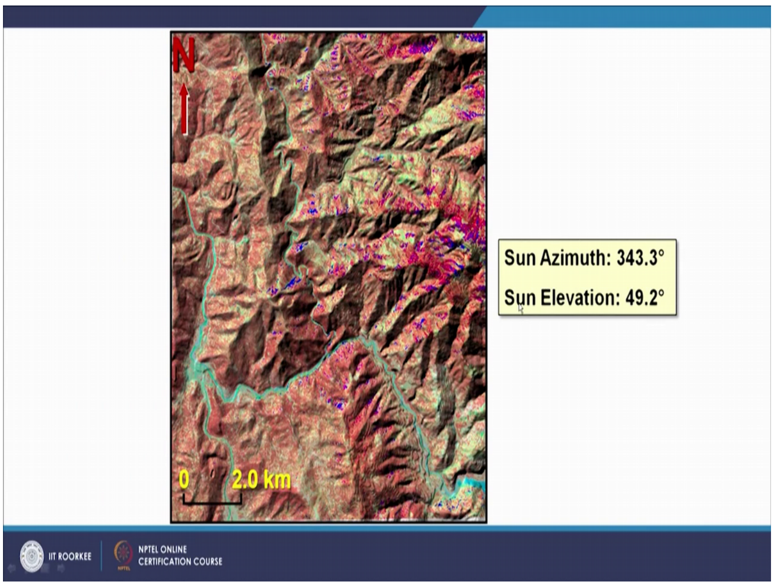


And then we can create a product in which north is upward and a FTPP is gone. So, just using a simple concept of hill shading, we can get rid of a very complex phenomena, which is FTPP. one more example is here, this is simple a digital elevation model this is a hill shading.

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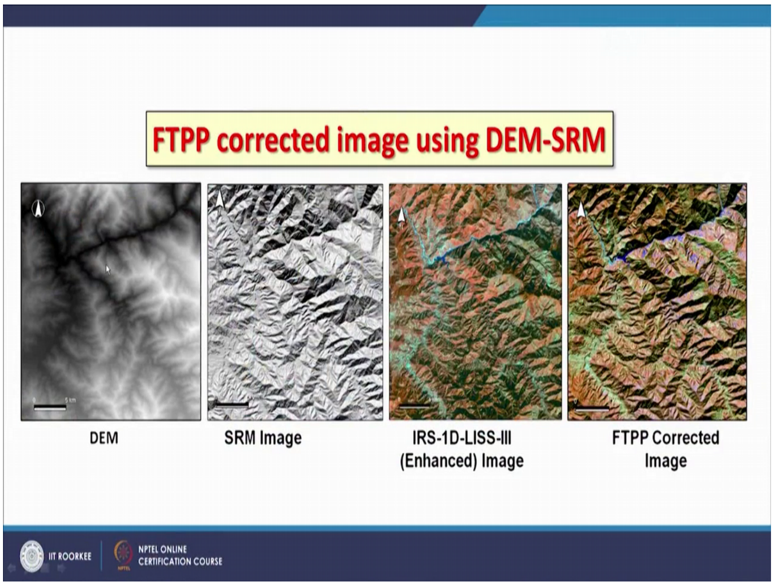


So, we can consider as intensity image, and when we do color transformation using the colors and saturations of this input image, then when we can create a product in which the FTPP is gone. 2 examples of animations which has simulated animations I will show..

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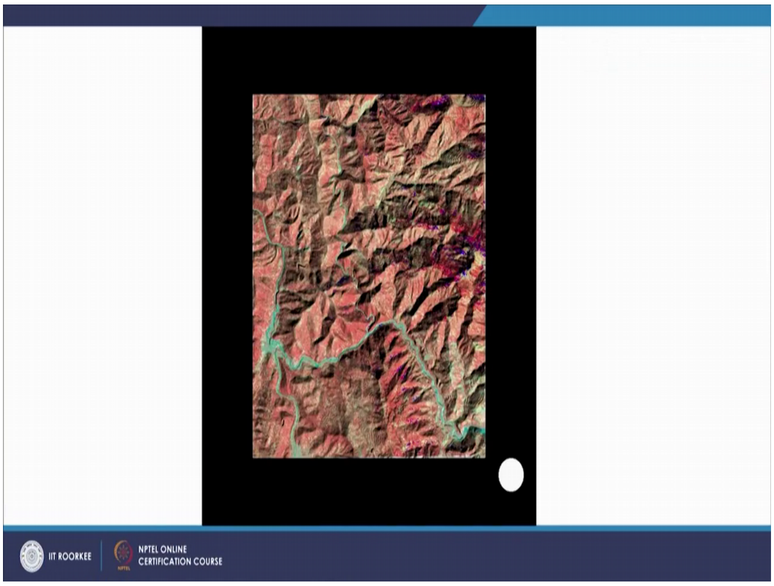


We have been I have also shown in previous lectures as well. previous to previous lecture that here a height hill shadings of different directions have been used to illustrate, or to explain how FTPP effects.

So, when sun illumination or azimuth is in the southern hemisphere, then FTPP is seen in a satellite image, in this like in this particular example. And when sun azimuth is in the northern hemisphere, viewer is always assumed to be in southern hemisphere that is in both are in opposite direction then FTPP is gone. So, when you will see that this is the sun when it moves in the northern hemisphere, and then we do not see FTPP and river appears to be in the valley. But when it comes in the southern hemisphere; that means, the viewer and illumination source in the same hemisphere you be are bound to see FTPP. So, this in simulated animation illustrate that. Another example is not playing now with a sun azimuth.

But instead playing with the sun elevation angle and in this example we see that when the sun is near horizon the darkest image which you see at 5 degree. So, when the sun is at near horizon, and then you are having the maximum you know darkness in the image, because the shadows are much larger. For the same slopes, but when sun is overhead. Then you see the terrain is very bright, and your shadows are very small. Also, it varies this say you know sun elevation angle can also change our depth perception as well.

So, when you are having large shadows, we feel a higher depth with the or a higher ruggedness in the terrain, but when the sun is overhead or 90 degree then we see the less. So, this also illustrate this one. So, these 2 angles sun azimuth and sun elevation are very, very important angle, angles 2 your simulate or create a terrain surface using digital elevation model as hill shade or shaded relief model. So, this brings to the end of this discussion.

Thank you very much.