Digital Elevation Models and Applications

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Lecture – 08
Common Derivatives of DEMs- Slop and Aspect

Hello everyone and welcome to the 8th lecture of a digital elevation models and applications course. And in this particular discussion we are going to have now a discussion on series of derivatives; not only in this lecture, but in next two more lectures we will have derivatives of a DEM. So, the entire discussion is now what kind of different outputs can be generated using DEMs.

In the beginning of this course, I have mentioned that DEMs are a store houses of information; lot many information can be derived from digital elevation models. One of a the examples you have seen in the previous lecture that just using a shaded relief model or hills reading, which we will discuss a much in much more detail in subsequent lectures.

We can resolve some issues we can create 3D perspective view, we can also create fly simulations. So, similarly here the DEMs can be used for different derivatives; different derivatives say for example, slope and aspect which we are going to focus in this particular lecture, can be derived very easily with digital elevation models. Few things we have to remember while calculating or deriving these products from using digital elevation models; otherwise a process are quite simple, but before that we have to understand basically what is topography?

So, topography be would like to define here that the surface characteristics, such as the slope, relief and form of an area which we referred as a topography. So, these undulation which are present are making all these other things; important here and visible here. So, slope if undulations are not there. If we suppose say flat terrain then we may not see relief and therefore, we will not see slope neither we will see the aspect.

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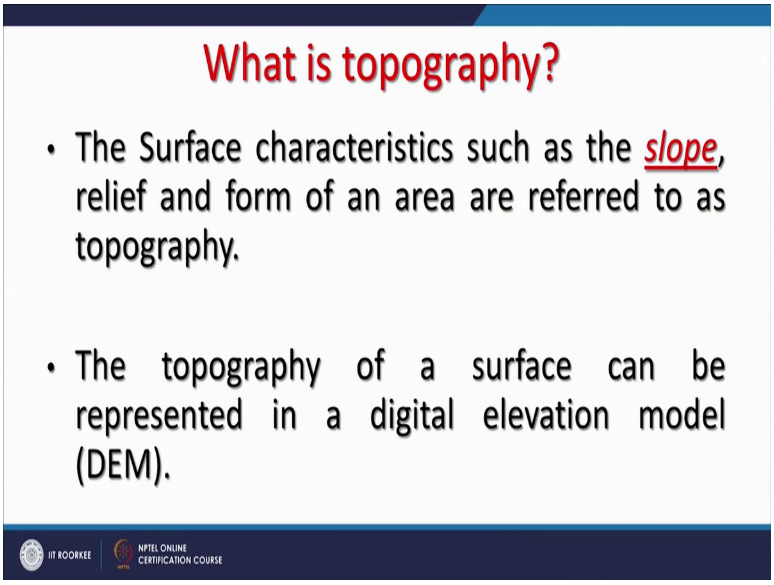

We will see in detail what is basically slope? What is aspect? And how we can calculate using a software like GIS or some digital image processing software and using of course, a digital elevation model. So, topography of a surface you know as we can we represent it through a DEM or terrain models, and DEM represents a topographic surface in terms of a set of elevation values measured at a finite number of points or here the cells and contains terrain features of geomorphological importance such as valleys, ridges, peaks and pits etcetera. And DEMs you know the organized as a regular grid formats because their ease of for direct computer manipulation. So, when the data is in 2-dimensional matrix, this domain has already been developed extensively in mathematical domain.

And therefore, implying those tools here for digital elevation model and we can create lot of derivatives. And another important thing is because the spatial resolution within a DEM file is not changing and therefore, and we can not use them or these cannot adopt for relief changes, whereas a they a terrain or a tin model is adopted to relief changes, but anyway whatever is available is a very good for deriving lot of features or lot of products from digital elevation model.

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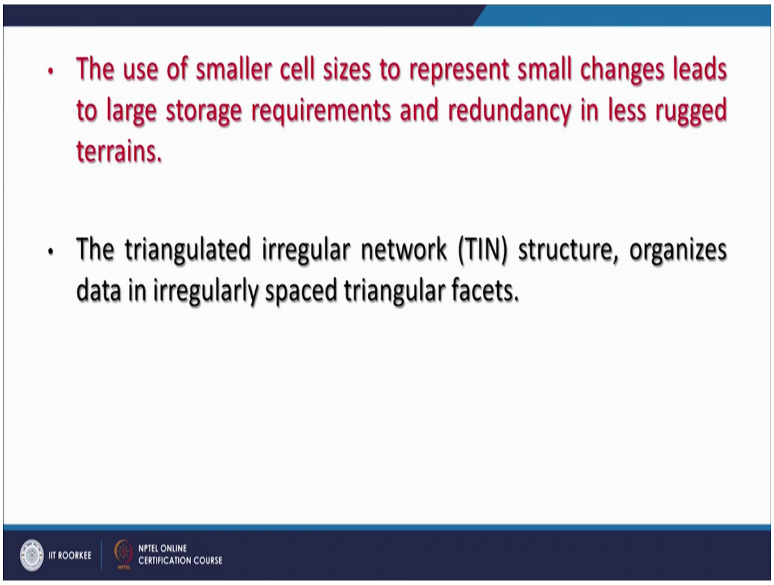

So, the use of a smaller cell size; that means, higher spatial resolution and can be lead us to large storage requirements and redundancy in less rugged terrain; that means, that if a we are employing a very high resolution digital elevation model for any area where we hardly we have got the relief or undulations, then it is going to be a futile exercise or there will be redundancy, but a if a terrain like Himalayan which is highly rugged and relief changes very frequently at a very small distance.

Then always high spatial resolution DEMs can help us to understand the terrain geomorphology and other features very easily. As I have just mentioned that the tin organizes the data in a regular irregularly a spaced triangular facets or using triangles, so it is adoptable to relief changes. And therefore, few products can also be the same products like a slope and aspect can also be derived from digital elevation model.

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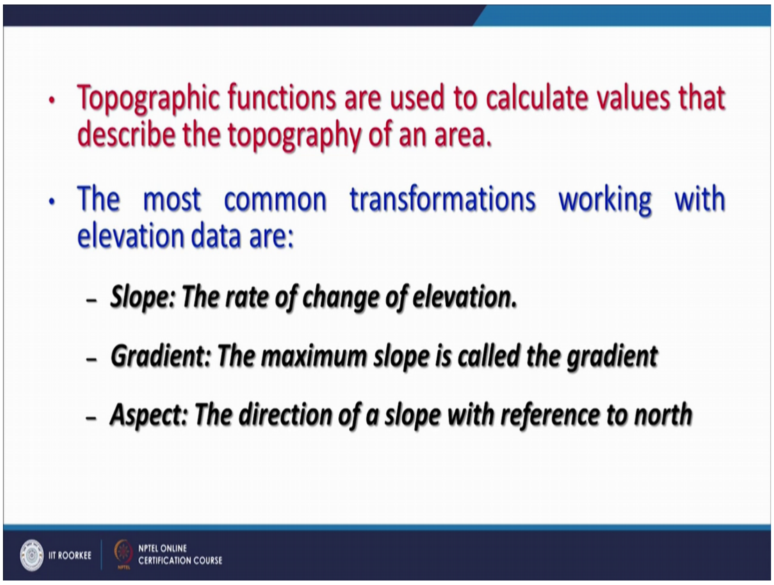

And a topographic functions which are used to calculate values that basically describe the topography and area are the most common such transformations with a digital elevation data are the slope. That is the rate of change of elevation, at a distance how this elevations are changing if we calculate that one or created this transformation function then we can calculate the slope.

Similarly when the maximum slope is called the gradient that 2 can also be calculated. So, there is a slope in surface in which section in which part of that surface or facet we are having the maximum gradient or maximum slope that becomes the gradient and aspect is the orientation of the slope with reference to the north.

So, this is what the direction of slope with reference to the north. So, if we say south facing slopes; that means, they we are having aspect is 180 degree. We will see some examples and how these can be derived in a GIS platform using digital elevation model so this we will see. So, a topographic functions includes a slope aspect and gradient and others to calculate these digit can describe topography at a specific location.

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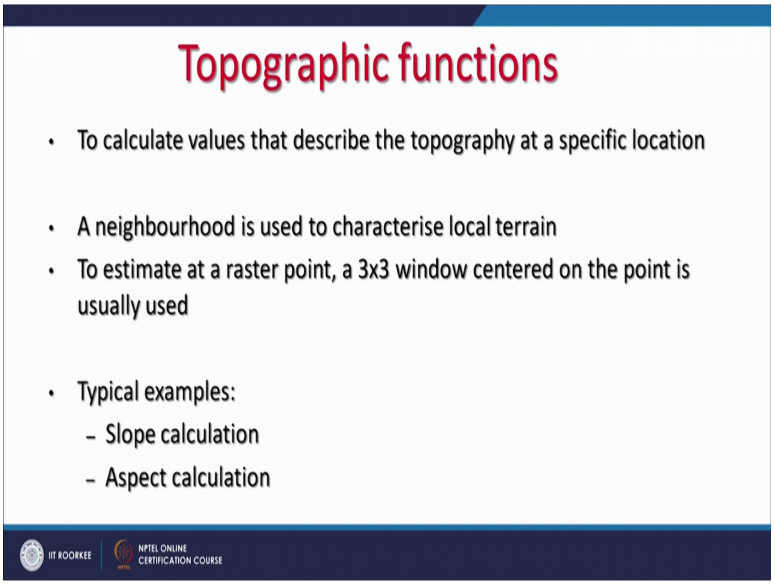

And neighborhood data is used to characterize local terrain. So, near wise sales are used to find out what is slope and aspect and to estimate a raster point generally a 3 by 3 roving window is used for to calculate a value for the center point.

So, this and that is why it is a transformation is there and it is more close to the technique which we have used in digital image processing which is called a spatial filtering. So, the in that concept it fits very well and typical examples in which we use the neighborhood information are while calculating slope and aspect.

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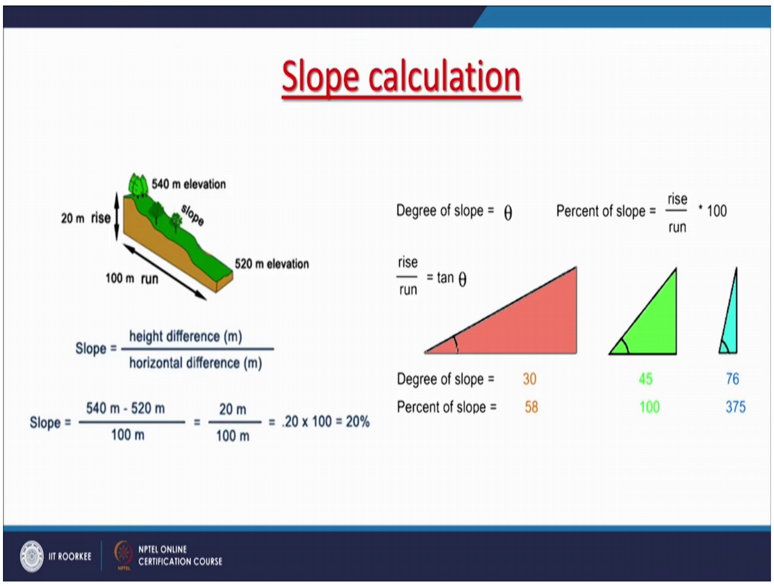

So, if we go for how slope is calculated? Slope can be calculated using digital elevation models in 2 ways, either we can get slope in degree or we can get slope in percentage. And basically it is rise over run and that is the tan theta as you can see here this is the run and this is the rise. So, this angle is a will tell us what is the slope; so we can have slope that is in degree in this particular example it is 30 degree whereas, we can convert instead of 0 to 90 scale, you can convert to 0 to 100 scale and can make a this one as a 58 percentage of the slope.

But generally, in default we go for measure or calculating slope and degree, but in both ways, it can be calculated. Two more examples of different angles are given here, when we go for this thing this is how run rise over run is equal to 10 theta whereas, percentage of slope can be calculated then we multiply by 100. So, here is also that in this particular example is the 20-meter rise and this is the run is 100 meter.

So, if we substitute all these values that 10-theta equal to the height difference that is here is the 20 meter and like here and this is the 100-meter run, then we get the 20 percent slope as we can see here. So, with this distance the slope has changed by 20 percent. So, this is a very simple understanding about slope calculation in a digital elevation model, but a as I mentioned that a 3 by 3 roving window will be moving throughout (Refer Time: 09:17) digital elevation model and for each center cell the value will be calculated.

So, this is how this a if we take the this is the input raster and this is the output raster.

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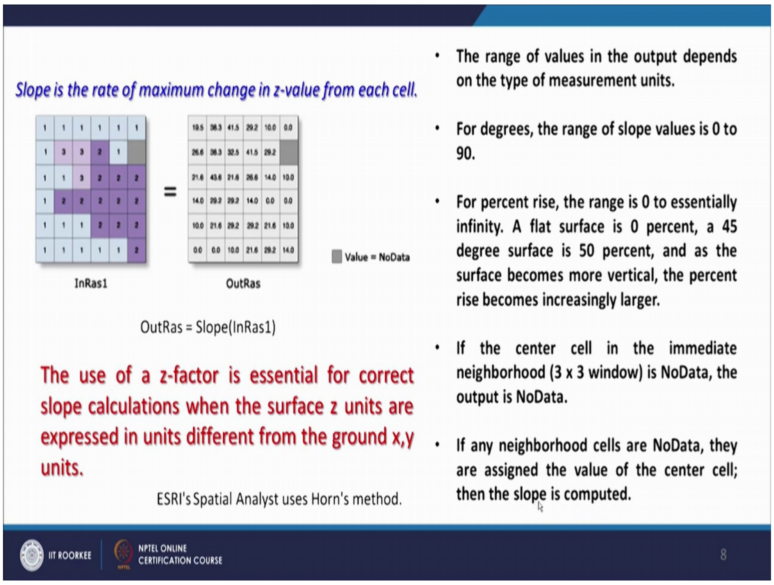

As we can see here that the neighboring cells values have been used and a the data what we are seeing here are the slope which is available here. So, this say another important thing is the z factor is essential for to correct that z factor basically, and the z factor basically means here because as we know that the x the x y or horizontal scale is completely different then vertical scale in digital elevation model and this z factor will allow us to quit horizontal scale with vertical scale.

So, either you can change the vertical scale and bring equal to the horizontal scale which is more easier because you might be using the derivatives of the digital elevation model for some with the other products and therefore, it is always good to use z factor and equate the vertical axis or vertical scale to horizontal scale by implying a z factor.

So, both calculations for a slope and aspect and many other derivative calculations of from a DEM x factor should be the care about the z factor should be taken. So, the range of values in output, basically will depend on the type of measurement units are here and for degrees the range of slope would be between 0 to 90 degree and of course, for percentage it is going to be you know in 0 to 100 and so on, which a 50 percent means just a 45 degree. If the center cell because it is a roving this is a spatial filtering kind of things there will be a roving window.

And that the center cell in the immediate neighborhood that is 3 by 3 window which is a NoData and the output is also NoData. Especially for this because on the edges you do not have the other data set here. So, a input when input rusted and did not have the data and therefore, output ratser is also not having NoData, basically NoData is a concept which came little later in the domain of a GIS is that NoData, basically decades a very you know NoData is a value it is not a 0.

So, NoData is a declaration giving about a value, say for example in a digital elevation model we can give a very absurd value like minus 9 9 9 9 9. So, and be through NoData we declare to the system that while making any calculation please do not consider this value that is the NoData value and a any value can be given to NoData.

But while giving NoData value it has to be a value which may not be at all present in a digital elevation model. So, such values can be given to declare to the system that no calculation for those areas where NoData values are there are required and this is the example here is that a in this says this cell see we didn't have the data and therefore, in output cell there is also NoData and no calculation has been done, and if neighborhood cells are NoData has be we have seen there are signed value of the center cell the slope is computed.

One other thing one has to think about is that when this roving window moves throughout during digital elevation model on the edges and 1 pixel on the edges on all 4 sides there will not be any calculation either. So, it is important that z factor which I was just mentioning that for surface calculations one must know the z factor the that is the horizontal scale and vertical scale.

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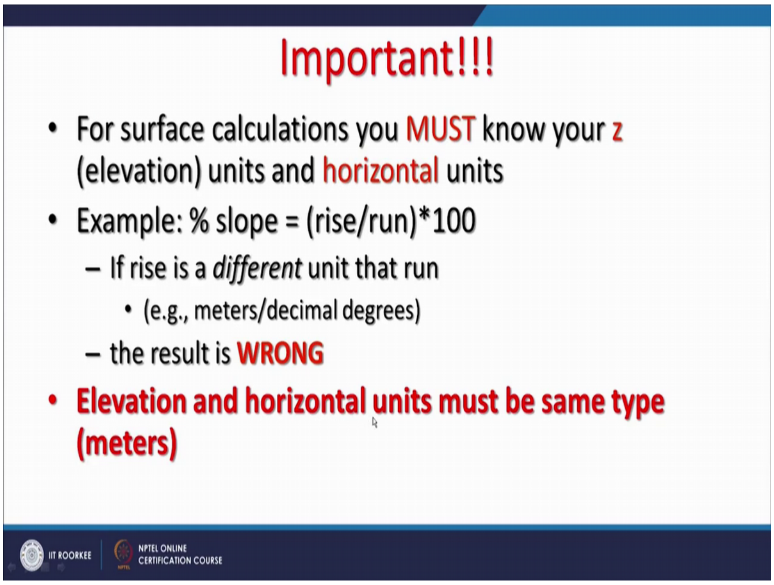

And then horizontal scale has to be converted equivalent to vertical scale and this say this say if it is because in most of the software's by default it is kept one and; that means, that the you are a horizontal scale is equal to vertical scale it is generally not there, unless if you are having your digital elevation model projected in AUTM, in that a in that case the horizontal scale is also in meters vertical scale is also in meters.

And therefore, z factor can be 1, but in other cases suppose you are having values horizontal scale in d d that is degree decimal then the z factor has to be changed. So, that your vertical scale becomes equal to horizontal scale otherwise, the slope say which you will calculate or aspect or any derivative which you will drive from digital elevation model, we will have erroneous results very wrong results if z factor is not taken care.

So, this has to be taken care that the elevation and horizontal unit must be the same type and if they are not there then they it is found to have wrong results. This is the example given by there are different methods also to calculate slope and aspect given by different workers earlier like here this is the horns method is given here and this 3 by 3

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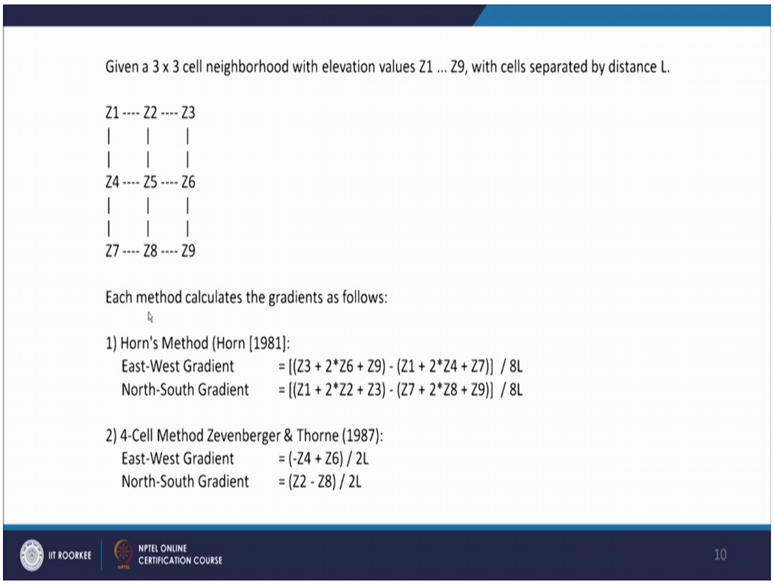

Matrix is also shown which calculates a you know it is slope for the center pixel using the neighborhood deviation values as demonstrated here and that east west drection gradient can be like this north south gradient can be like this and a therefore, there is a another method which is for the 4-cell method, which is given by Zevenbergen and Thorne in 1987 and the calculation is completely different than horns method.

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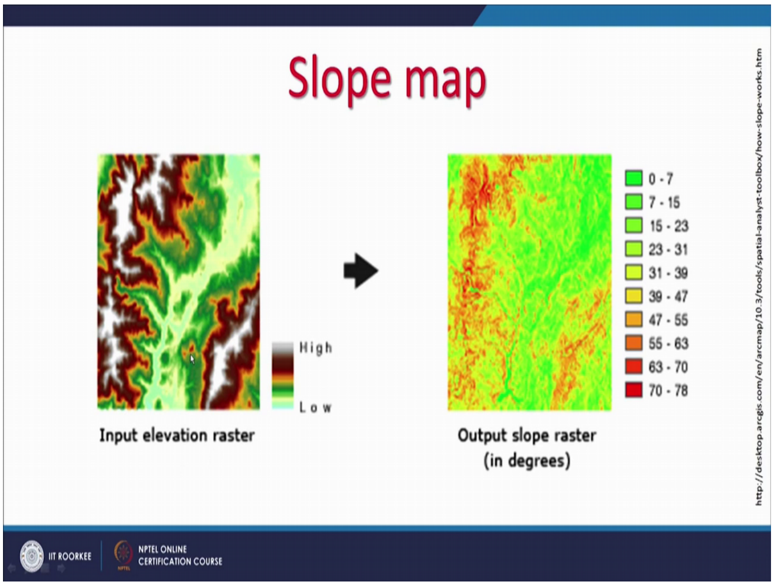

When we see the results using different methods, sometime depending on the input digital elevation model; that means, the terrain conditions sometime may not find a huge difference or differences between slope maps which have been created using these 2 popular methods.

But sometimes a you may get a quite a different results. This is one of example of a calculating a slope map you that 2 in degree using a input elevation model. So, this is input elevation model and this is the slope wherever you see that these color bands are very closely spaced you are seen higher slopes as here and this is in degree.

So, one can classify into number of categories or ranges in this example it is 0 to 77 to 151 can classify 0 to 10 and you know 11 to 20 and on and so forth it can be classified. So, then as per our requirement how many bands of slopes would you like to show or a through a continuous that 2 can be shown, but that is a later step, but first step here is to calculate the slope using different methods.

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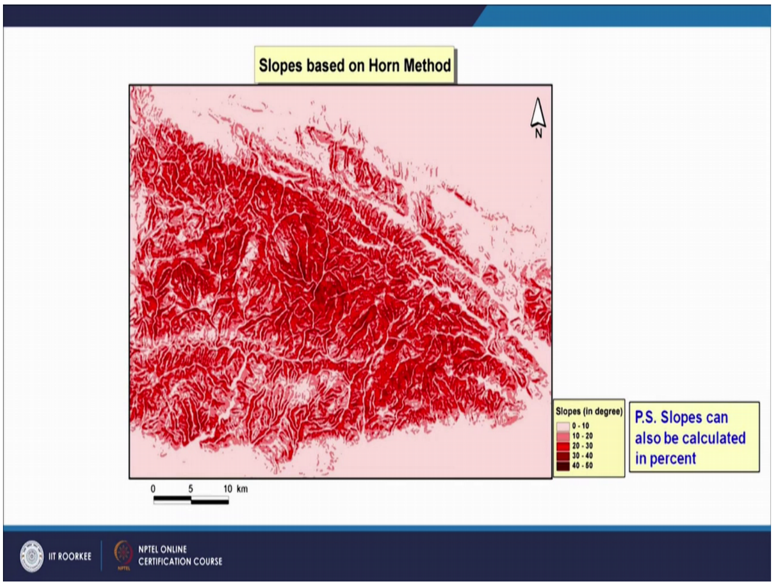

Example here is using slope based on the horn method and a here these classification has been kept a same.

So, that we get a if there are any differences for this in this input a digital elevation model those should be highlighted. So, this is the horn method and a this a that the slopes can also be calculated as you know in percentage and this is the Zevenbergen thorne method. So, if we see both here what we are finding.

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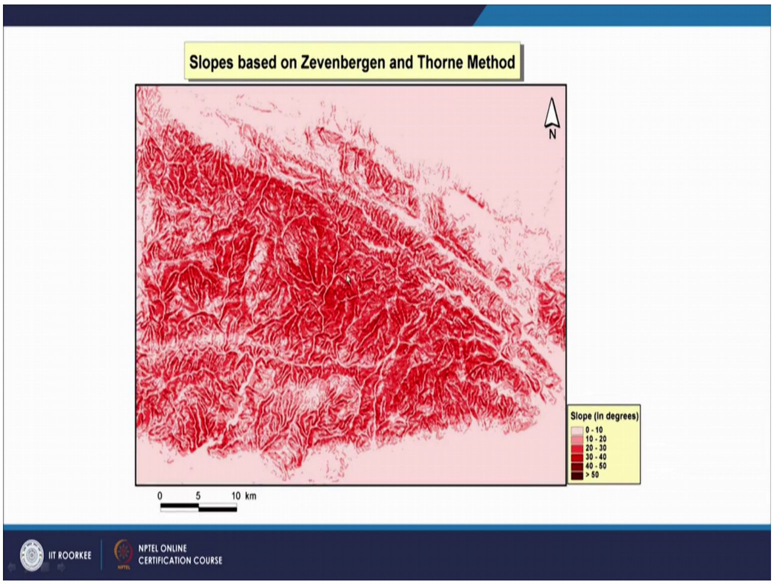

That it is giving a less slopes Zevenbergen and thorne method in this particular for this particular digital elevation model as compare to the simple horn method and we will also see the comparison

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Comparison of slopes derived from two methods

Horn Method	Zevenbergen and Thorne Method
1.2°	3.3°
8.6°	5.0°
28.2°	28.4°
29.5°	25.5°
49.1°	48.9°

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That here this at like when a particular location in horn method that the elevation the slope is coming in 1.2 degree whereas, through this method it is coming 3.3, but here it is a more it is less again it is quite close to, but again it is less it is, again it will less. So, this is what I mentioned here as you can also see that a this one when we are having the same number of classes slope classes between 0 to 10 to maximum slope.

In this area are found around 50 degree. So, that is why only 5 classes we are kept, similarly here also that 6 classes were kept, but what we have just visually we can see that a this Zevenbergen and Thorne method is given more less slope values average less slope values as compare to horn method in this particular example, but there are if we see over all it is not very not much significant differences which we see in these 2 methods and next derivative another very important derivative and very common derivative of digital elevation model is aspect.

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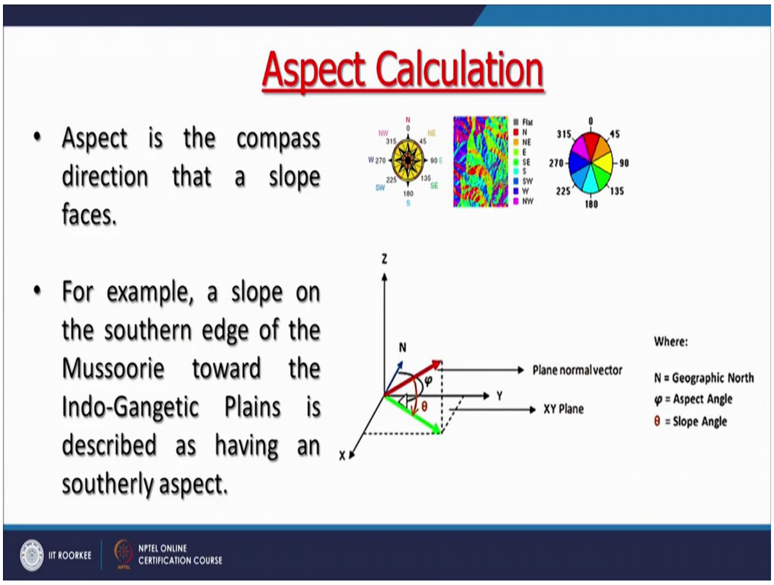

In aspect before that before we go for details about the aspect basically is a compass direction that is slope faces. So, when we say north facing; that means, that the sloping surface is facing north and generally we get in 8 directions 0-degree, 45 degree, 90 and so on likewise and these colors are assigned by different software. If I take the example of like archi is or arcview

And this color is scheme is assigned to different directions slopes if slopes if terrain what the part of the slope is flat or any facet than a grey color is assigned which is not part of this wheel. So, this is a the larger you know examples will we will see here. So, this same the two things one is the slope another one is the aspect. So, slope a measured in the vertical plain and whereas, the aspect directions are measured in a horizontal plain and this is what it is defected here, that a this is planner normal vector here and this is x y plain. So, aspect is measured with this a and they you know this is what the what we are seeing is the aspect angle and this we measured in vertical that is what we see the slope angle.

So, aspect is basically the compass direction with a reference to the magnetic north this slope faces for example, a slope on the southern edge of say Mussoorie towards the Indo Gangetic plains is described as having a southerly slope aspect.

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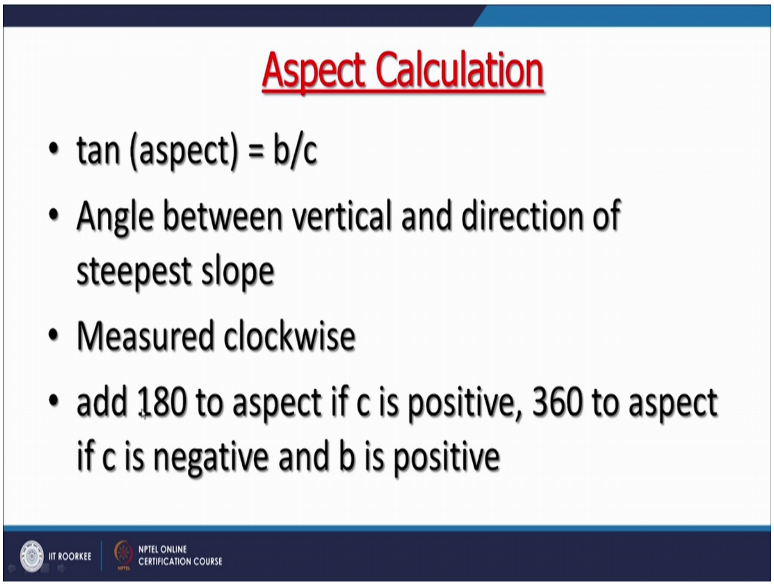

So, this aspect is again tan that is the tan that or that a b upon c and the angle between vertical direction and direction of steepest slope which is what is the aspect and measured clockwise. As we have seen in earlier slide and this a once we when we add 180 degree to aspect if c is positive then 360 degree to aspect and if c is negative then b is positive. So, likewise we calculate this one another example is here, that this is the input DEM and this is the output aspect map we will also see how different methods of aspect calculates a different aspect map. So, aspects basically identifies the down slope direction of the maximum rate of change in value from each cell to it is neighbors.

So, here also this 3 by 3 matrix roving matrix or roving windows used it can be thought as a slope direction, the values of each cell in output raster indicates the compass

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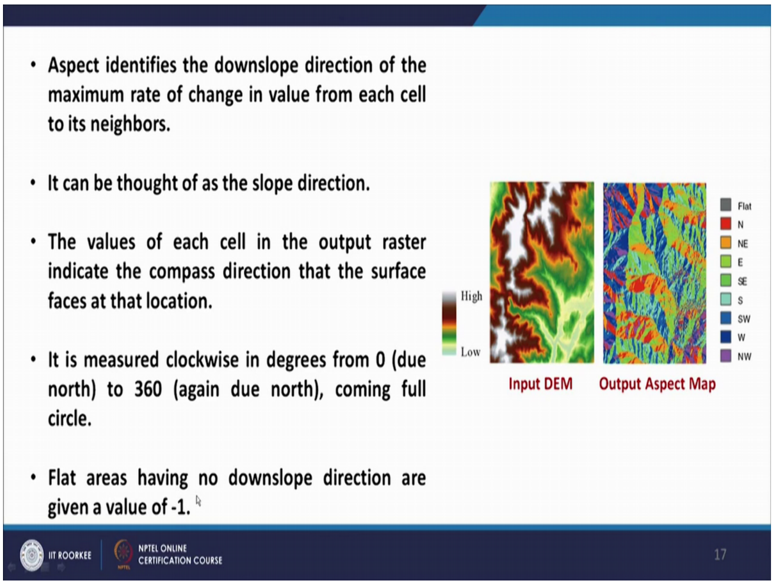

Direction that the surface faces at that location and it is measured as I have mentioned clockwise from 0 that is north to the 360 degree again is compare to the north after going through the entire old directions. And flat areas we will get the grey value that is no slope directions and generally in the color scheme it is given a completely different value may be a digital value may be minus 1 which indicates that the flat areas are there. So, this is the aspect like in case of slope

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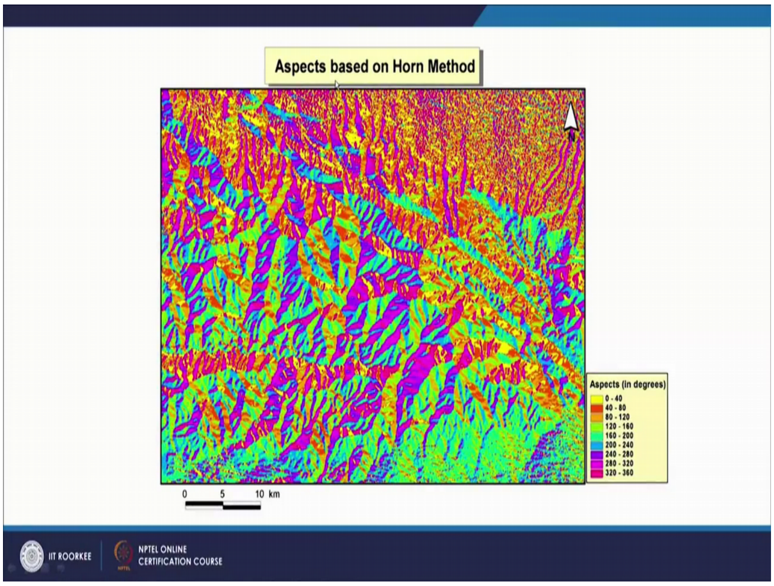

A map the same horn method for aspect is also there. So, this is the aspect calculation using the same digital elevation model using the horn method is here and different classes have been classified here for between different degrees and

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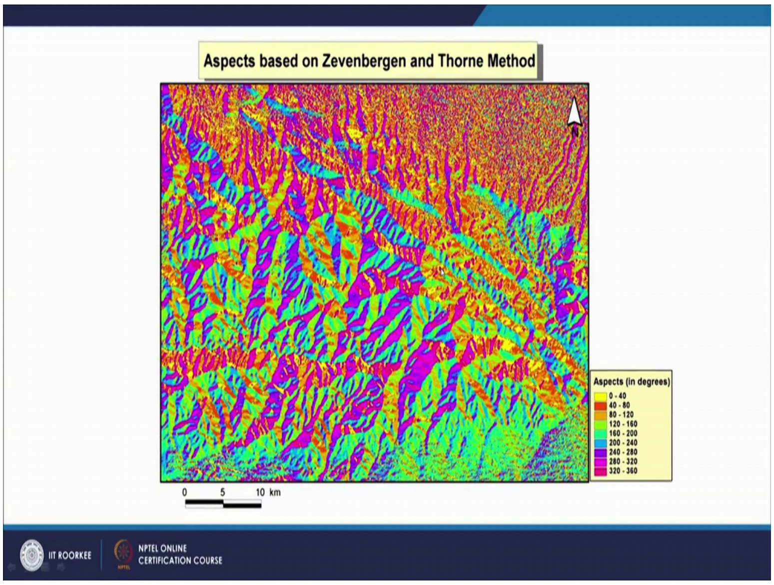

A what this is another one is the Zevenbergen and Thorne method we do not see in this particular example much differences visually.

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Comparison of aspects derived from two methods

Horn Method	Zevenbergen and Thorne Method
9.0°	10.1°
52.0°	49.6°
97.1°	102.7°
134.4°	135.7°
171.8°	168.1°
215.2°	211.7°
256.7°	259.0°
333.8°	331.3°

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But a when we see the table what we find? That there are some variations of 1 or 2 degrees average between these against a different locations. So, individual locations when it we are checked it we have found that they are giving different values. So, both these methods are again giving quite close results.

So, this 4 cell methods have been implemented in many software's including Zevenbergen Thorne and other methods in different GIS software's. This if we add one more thing into the aspect that is a here this is a another product not a simple aspect map which we are seeing here instead of that if we use a you or the colors and create a

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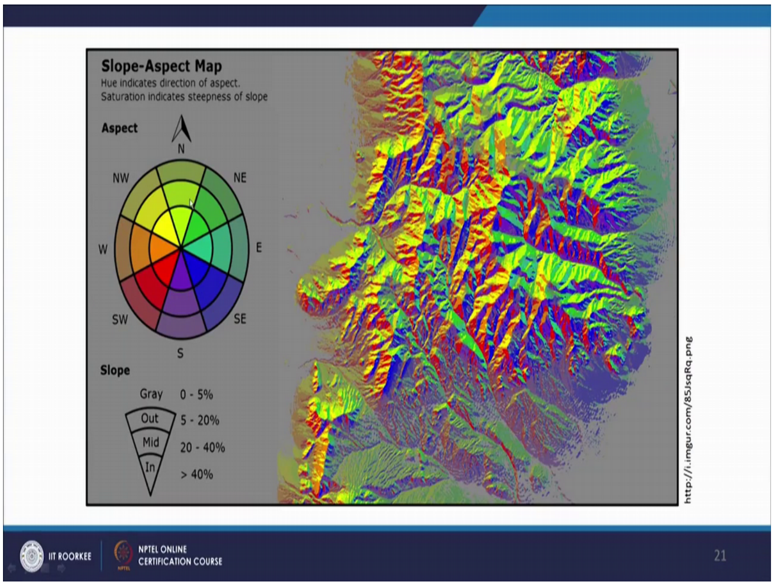

2 3 concentric circles and the intensity changes here or the saturation rather it indicates this steepness of the slope.

That means what we are having now slope and aspect together in different sets of color for each spectrum. So, what suppose if I take a say this red section that is the scheme in which it is coming for south west direction. So, if a if I take if it is there it is having slopes of more than 40 percent, but if it is a little how outer in the middle circle then it is between 20 to 40 percent.

And if it is outermost circle then it is gapping 5 to 20 percent and if it is a away from these 3 concentric circles just outside, then it is almost flat and a new product while implying this saturation of a different colors or you we can involve then a new product can be created which will have both information’s together; that means, they will have slope information as well as aspect information as defected in this particular example.

So, various products while combining different data sets can also be created. So, this brings to the end of a this discussion, but before we close I would like to mention these are the two common derivatives, that is why in the title of this lecture it was mentioned. So, if you are using it tin or this triangulated irregular network these two derivatives are calculated while creating a tin surface whereas, in case of digital elevation model these two derivatives the very common derivatives of a digital elevation model are generally first created and they can give you a feeling about the terrain conditions how undulations are there, what are the general slope directions and so on so forth. So, these are the very common derivatives very useful for various applications in various civil engineering projects, in earth sciences. Or in geological sciences and otherwise for planners for forest tree for a you know animal breeding and other things these a products are very, very helpful.

Because for even for solar energy because we know that for like in case of solar energy when slopes are facing south; that means, they may receive the sunlight from morning to evening, but if slopes are facing north then, the sun light will be only in the noon time. So, that is why the calculating slope just simple product through a digital elevation model can use for various purposes. This solar part we will be seeing in one of the applications of digital elevation models in detail also.

So, thank you very much.