Geographic Information Systems
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Lecture-50
DEMs derivatives-3

Hello everyone! and welcome to new discussion which is DEM derivatives part 3. After this we will also have one more part that is DEM derivatives part 4. As I have been telling you that DEMs are the store house of information. By now, you must have also realized that so many derivatives can be drive, can be taken out of analysis of a digital elevation model. One more similar kind of derivative or products which can be generated again which is very important is the topographic roughness.

As you go at micro level and start identifying or analyzing micro you know topographic relief or micro topographic roughness, you can get few more new types of analysis outputs and applications. So, basically the topographic roughness is again based on that same concept which we have been discussing that somewhere you are having a best fit line or a smooth surface and then you are having the real surface and you are comparing that one.

So far what we have been discussing is mainly along a line. Now, we can discuss in terms of 3D, rather than in 2D.

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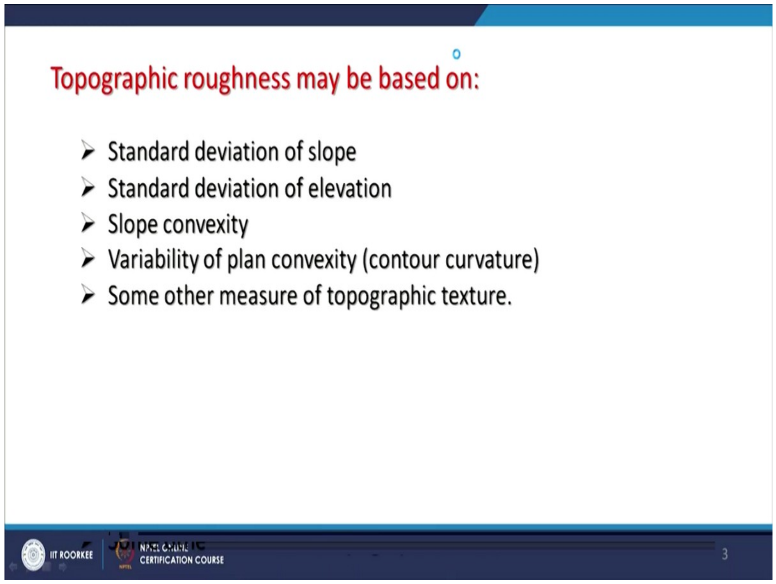

So, this topographic roughness basically if we want to define is the relative topographic position or also in literature, you may find topographic position index is a terrain roughness metric and local elevation index; that means some ratio is there. Now, this topographic roughness or also we can call as ruggedness, basically is defined differently depending on which type of calculation we employ.

Now, these topographic roughness calculations can be based on either standard deviation of slope or standard deviation of elevation. Generally, what we do? We go along this standard deviation of elevation but depending on requirements. Third way is that slope convexity and then variability of plant convexity; that is the contour curvature. And then again, some other measure of topographic texture.

So, what we are basically looking are the topographic texture; the variations in elevations in a very local area, very minute or micro terrain features. So, this scale is here important in such analysis. Not only the scale or spatial resolution of a digital elevation model but at what scale, you are going to do the analysis to characterize the terrain or landscape analysis which at what scale you want? And we will see the example that when we change the scale, the entire output will change. So, this analysis is completely scale dependent analysis.

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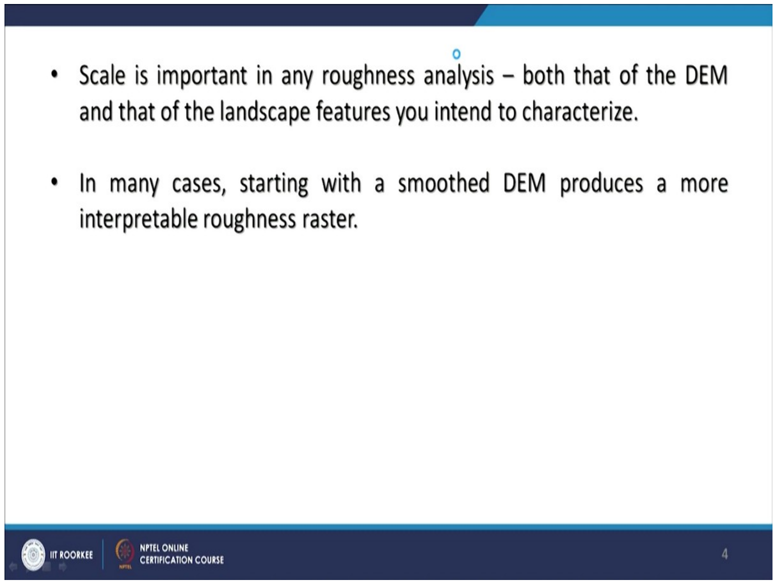

As you know also in the many cases, we start with a smooth DEM like best fit line in linear or in 2D or in case of topographic profile, we have just discussed that is smooth DEM produces a more interpretable roughness raster. That means the understanding can be developed very easily while doing this exercise. Making a smooth DEM and then comparing that DEM with the real one and then finding out where are the roughness which are present at a local level. As we have just discussed that there are several ways to calculate topographic roughness.

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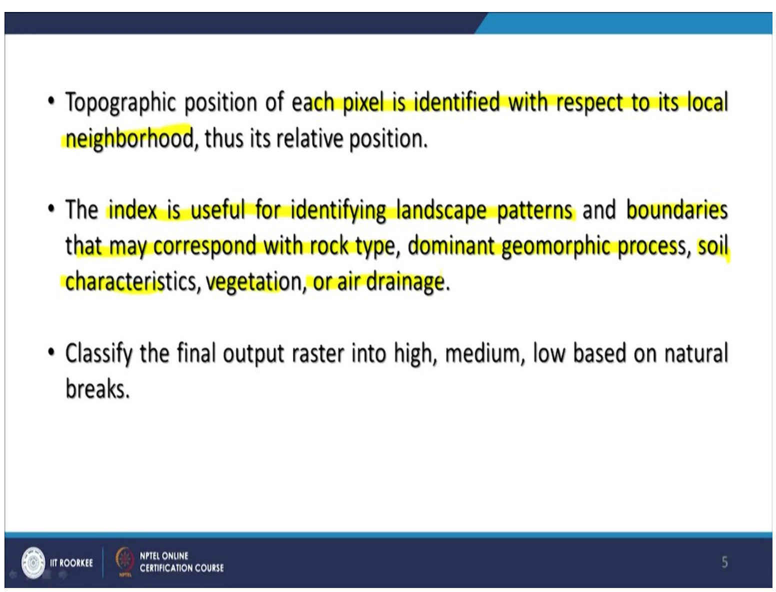

The topographic position that is whether it is a convex area or concave area, for each pixel is identified with respect to its local neighbourhood, also in the previous discussion which we have discussed in terms of using a 3*3 matrix of kernel and finding out relative position in what is in the surrounding or neighbourhood. And if neighbour would be finds that there is a depression, that means the center value is less that means it is a depression.

If center value is less compared to the surrounding or high then it is you know kind of a hill situation or hillock situation. Now, this we can only say as index because this is a smooth versus the real one or smooth versus rough. So, this index is useful for identifying landscape patterns. We will see some examples. Boundaries that may correspond to rock type sometimes because surface characteristics are controlled by the rock's; different types of lithologies which are present, different types of soils which are present.

So, if we find a completely different roughness in two adjacent areas, there must be some reason and one of the possibilities that the rocks might be different in those two areas which are showing 2 Different kind of surface roughness or topographic roughness. Or also useful for dominant geomorphic features processes, soil characteristics. vegetation or air drainage in case of desert areas or other things.

So, classifying this final output raster into high, medium or low based on natural breaks can also be done once this analysis gets completed. And this index; that is topographic position index is also applicable to bathymetric data; that means not only for the land part which is above means sea level but also it can be done for subsurface conditions.

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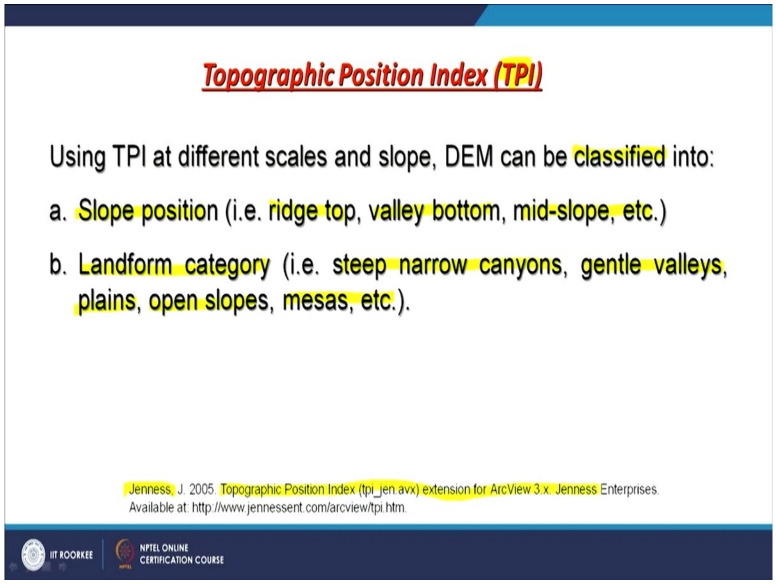

Now in short, we call as a TPI or topographic position index because in many literatures or in software, you may find this term TPI in short. So, using TPI at different scales and slope, DEM can be classified into different categories like a slope position where ridge top, valley bottom and mid slope etcetera. And whereas landform category has been defined then steep narrow canyons, gentle valleys, plains, open slopes and mesas etcetera.

So, these geomorphic features because if we are classifying into using a landform category then these would be the categories. If we classify based on the slope position then we can classify ridge top, valley bottom, mid slope etcetera. Now there is a special extension which has been developed by a person whose name is Janness and this I am showing here that extension is available on ArcView GIS, not on the ArcGIS.

But anyway, that can be used there also. This is very-2 useful tool or extension of software tool which can be used to calculate TPI, I will be showing examples very soon.

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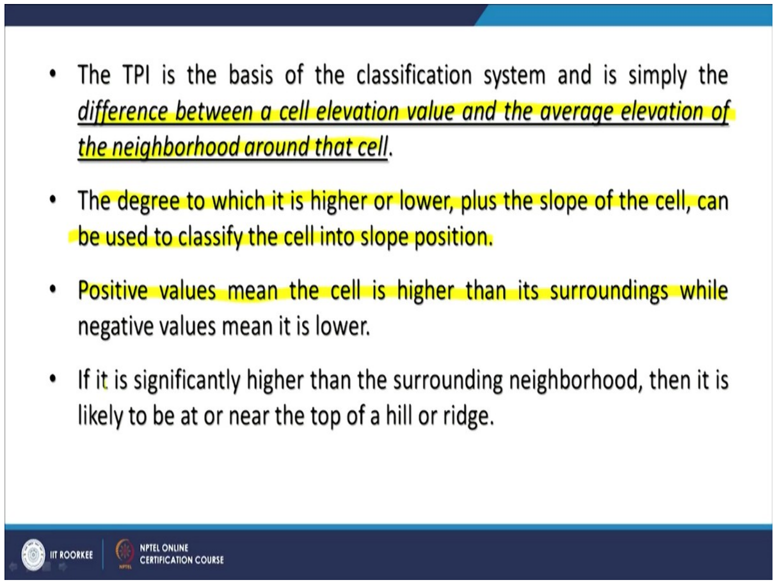

Now, the basis of the classification in case of TPI is this which is simple that is the difference between a cell elevation value and the average elevation of the neighbourhood around that cell, that is why it is called index. Basically, it is calculating a ratio. And the degree to which it is higher or lower plus the slope of the cell can be used to classify cell into slope position. So, when you are doing based on the slope position then this is how the calculation will be done.

And of course, those slow position if I want to classify using landform categories, I can still do it. So, the same output can be classified two ways. Now, the positive value means the cell is higher than the surrounding while the negative means it is lower. And if it is significantly higher than the surrounding neighbourhood then it likely to be near the top of the hill or ridge and this is very common thing in terrain like Himalaya where suddenly you get something which is very-2 high.

So, that might be along near the top of the hill or a range. Now, significantly low values suggest that the cell is at near the bottom of a valley. Now, single cell value will not decide all these different mid slopes or top or valley bottom or different kind of landform. So, few more cells have to be there in the surrounding and once that is there then these categories can be decided.

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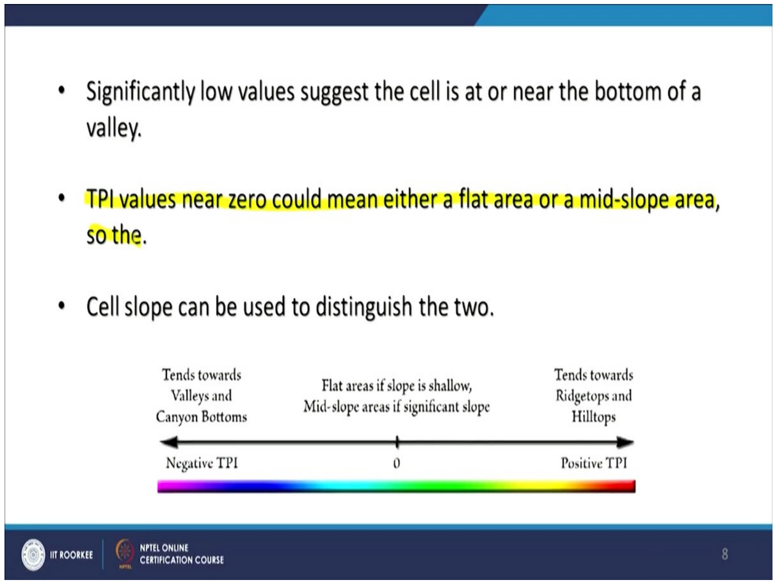

So, the TPI values near 0 would mean either a flat or mid slope area because top of a hill, there can also be a flat. So, the cell slope can be used to distinguish the two whether it is a flat or mid slope area. Now here, if it is the negative TPI then that means that either it is valleys or canyon bottoms. If it is positive TPI that means could be that ridge tops or hilltops. But if TPI value is 0 as we have just mentioned that is the flat areas or mid slope, then that means flat area if slope is shallow, the mid slope area areas if significant slope is there.

So that means using this index, we can assess a terrain from topographic roughness point of view by getting these values.

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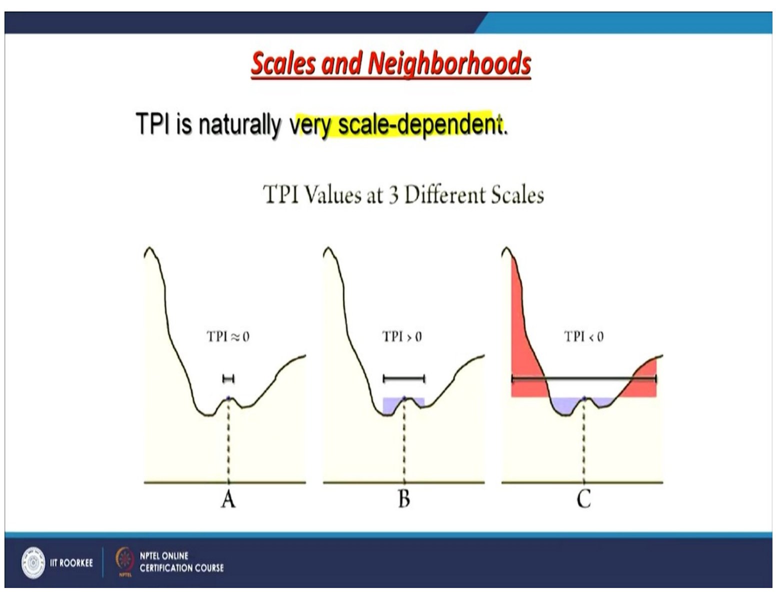

So, TPI is naturally very scale dependent; this point we have already touched before. Now, let us see the example, why it is scale dependent? 3 different scales are here which you can see that it is almost 0 TPI; when TPI is 0 for this area, it is not giving any because in the surroundings, nothing can be checked because scale is different here. Too high resolution. In case of mid resolution like when for the same area or same profile, it is showing the TPI value is more than zero.

So, when TPI value is more than that means the positive then it is ridge top or hilltop. So, whether it is really hilltop or ridge stop, yes, it is hilltop and ridge top. And if scale; that means the scale is very small scale and very large area is being load, means spatial resolution of that input digital elevation model is very coarse in that case. All these changes of the ground or upheavals which are present in the ground or topography roughness will not be considered and a large area is taken, that means here the TPI value will become zero.

So, what basically this example tells us that even for the same area if the scale is different or spatial resolution of input digital elevation model is different, the same area will be defined or will be identified completely differently. This would be identified as a ridge top; this would be identified as also a ridge top or maybe some other category like here which you are seeing the positive or ridge top or hilltop.

But when the resolution is very coarse then this is negative value; that is valley bottom. So, in a in that point of view, it is really a valley bottom. But if we go at micro level then it is definitely a hilltop. So, it varies with the scale. So, scale is important or indirectly we can say spatial resolution of input raster grid is important.

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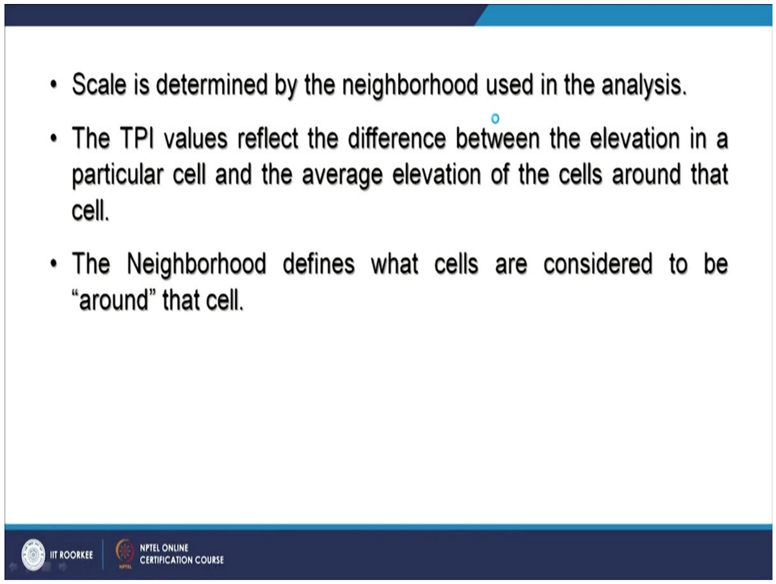

Now, scale is determined by the neighbourhood used in this analysis and TPI values reflect the difference between the elevation in a particular cell and of course in the surrounding, in the neighborhood. So, it basically also falls in the neighborhood analysis category and these around cells are there.

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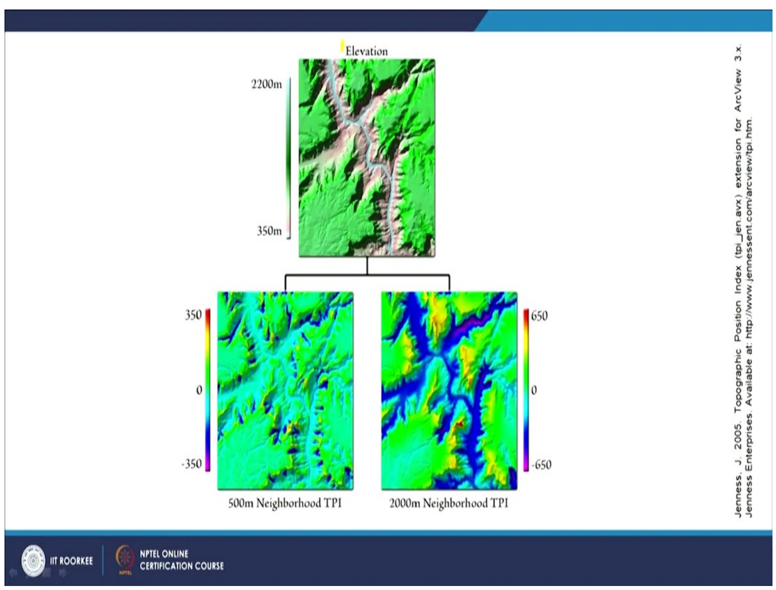

Now instead of schematic if we take an example of the real one. The top one is the elevation; that is the digital elevation model shown with the shaded relief model and as you can see that there are valleys, hilltops and you know flats are there. So, when the scale is 500 or spatial resolution of digital elevation model is 500, this is how this TPI has been decided; the neighbourhood TPI, -350 to + 350.

So, hardly you are seeing few hilltops which have been identified when this is the scenario. But when special resolution is 2000 meter then I seeing many hilltops areas very easily and large valley bottoms are also there and TPI values are also very-2 large that what. So, what we conclude here that coarser the spatial resolution, higher the TPI value can be or large variation between minus and plus values can be.

Like here - 650 to + 650 whereas if resolution is very fine or high resolution like in this example relatively 500 is you know high resolution and in that case, TPI value relatively will have less range - 350 to + 350 and identification will also.

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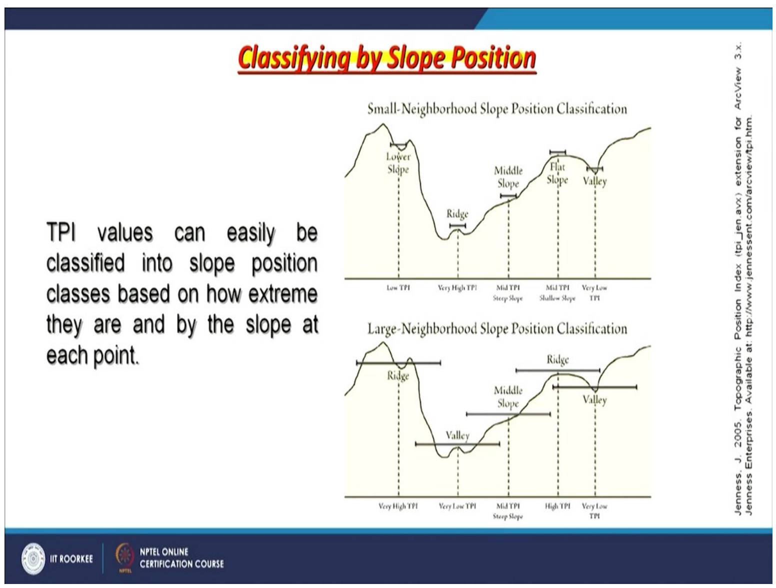

So, that is why it is said that this TPI is completely scale dependent. Now based on this, we can also perform the slope classification based on slow position, that TPI values can easily be classified into slope position classes based on how they are. For example, if small neighbourhood slope; that means the high spatial resolution then like this area is being identified as ridge whereas in case of coarse resolution, this area is being identified as a valley.

Similarly in case here. lower slope and whereas it is being identified as ridge, it is flat cell. So, it is identifying say ridge, say valley, say middle slope. So only the middle slope, valleys are identifying correctly or the same way in both the scales. But otherwise, things are being identified differently. So, depending on your input resolution of your digital elevation model, this analysis can be done.

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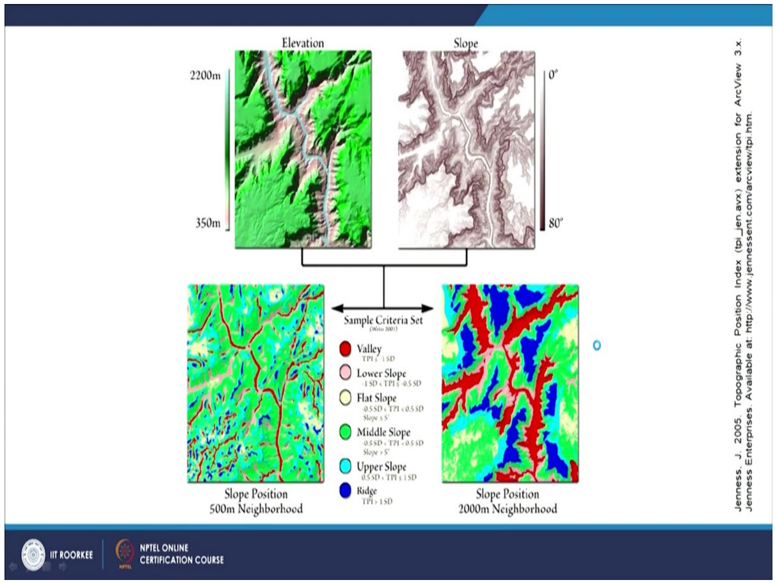

Now here again that same example but based on the slope classifications that here your input digital elevation model. This is the slope map on the top right and then slope position again 500-meter spatial resolution, 2000-meter spatial resolution. And here sees the valley part in the right-hand image; that is 2000 meter is very large and same with the ridge part. Compared to 500-meter spatial resolution, both valleys and ridge areas are relatively very small.

Terrain wises it's same except the resolution has changed and your identification of different features based on slope classification will also changed.

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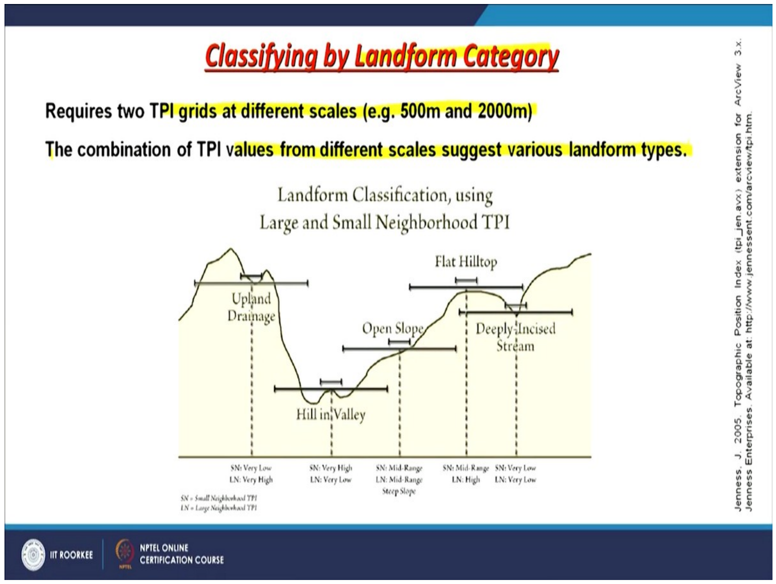

Now, you can classify based on the landform categories. We have also seen examples where you require 2 TPI grids at different scales say for example, 500 and 2000. Combining TPI values from different scales suggest various land form types like here, we can combine and can come up like this one and this one. So, both are SN and LN means a high resolution and low resolution are here and then you get very clear idea about what is happening.

So, by combining these two special resolutions if possible, you can classify based on the land form categories and of course the TPI; that is large and small neighborhood TPI. So, the classification can be done likewise also.

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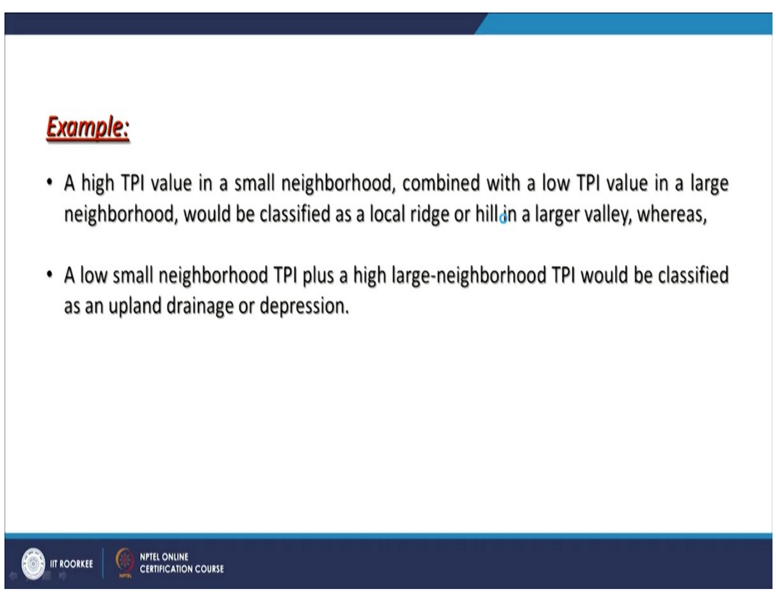

High TPI value in a small neighbourhood combined with low TPI value in a large neighbourhood would classify as a local ridge or hill in a larger valley area whereas a reverse to this, a low small neighbourhood TPI plus a high large neighbourhood TPI would be classified as an upland drainage or depression.

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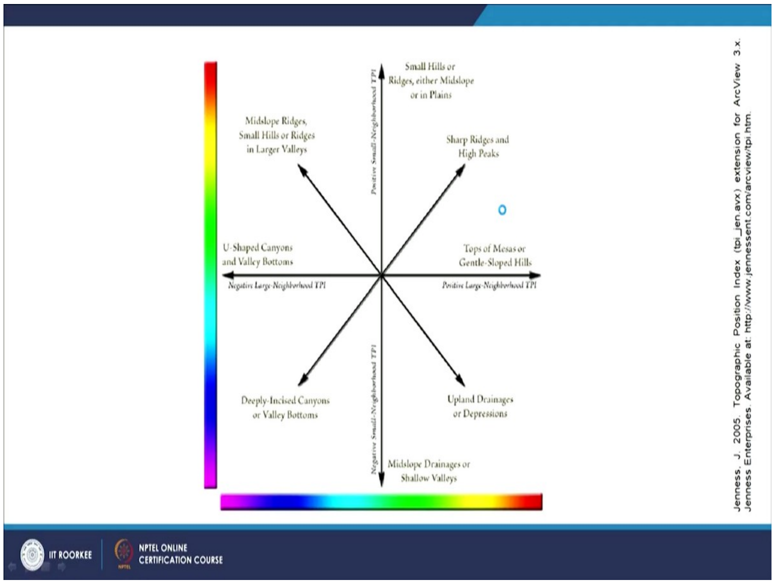

So, all those in summary here that these are the values which are shown the TPI on the both x and y scale and as you move all in these eight directions, you get different classifications. So, like a slope, this sharp ridges and high peaks opposite to this is deeply in size canyons or valleys. Similarly mid slow ridges, here upland drainage or depressions. So likewise based on the TPI, here is a negative small neighbourhood TPI, here is the positive small neighborhood TPI whereas here you are having negative large neighbourhood TPI, here you are having small or positive large neighbourhood TPI. So based on this, the classification can be performed quite easily by combining two also.

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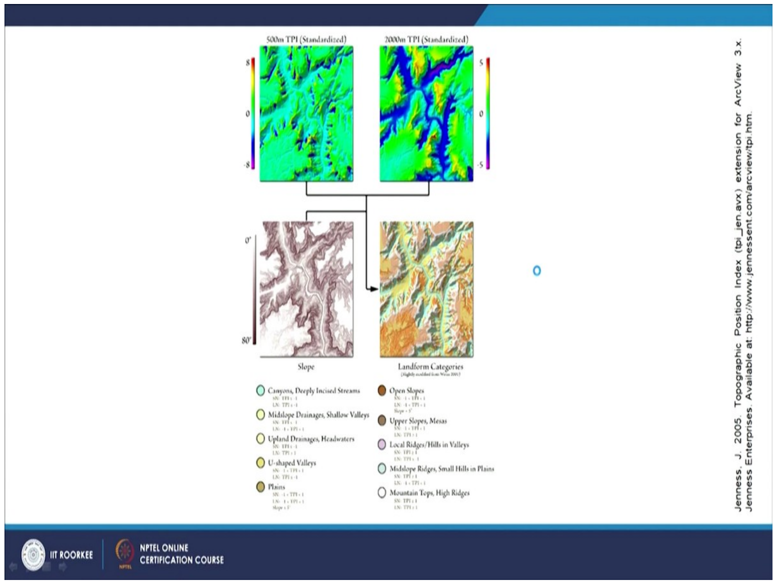

Example here, 500-meter spatial resolution TPI and again 2000-meter spatial resolution TPI; 2 different classification these maps we have already seen. Now when we classify based on slope or landform categories, these are the categories which we can do it. So, a simple digital elevation model when it is subjected to this topographic profile in position index calculations and any of these two basic methods can be employed; either slope classification or landform classification or categories classification, we can create very-2 useful products like here.

So that means employing a digital elevation model and TPI, geomorphic study or automatic detection of landforms can also be done employing these two things along with the digital elevation model on a GIS platform.

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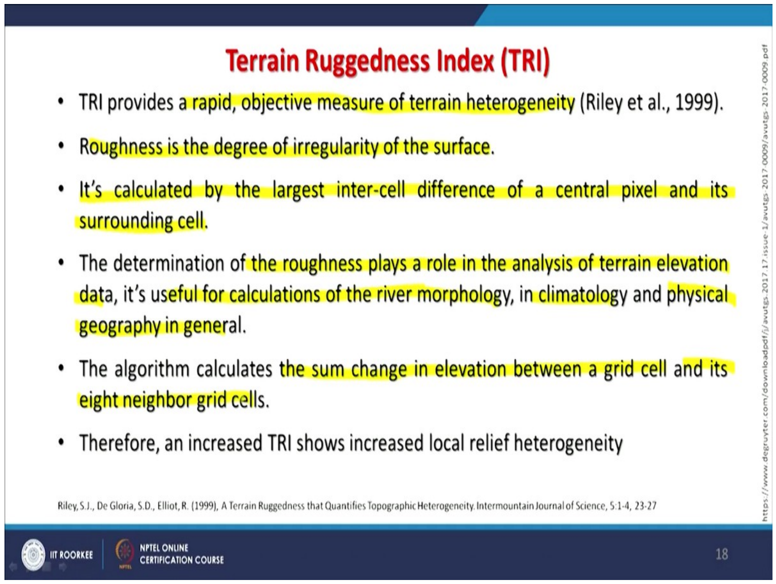

Now, there is some variation to TPI index that is the terrain roughness index. This TRI provides a rapid objective measure of terrain heterogeneity. So, everything is related with roughness and this roughness is the degree of irregularity of the surface. Basically, these are the micro terrain features which are useful in many analyses; from soil erosion point of view or from sediment transfer point of view or from mineral expression point of view.

So, this is calculated by the largest inter cell difference of a center pixel or center cell with the surrounding cells. And this determination of roughness plays a role in the analysis of terrain elevation data, useful for calculation of river morphology, in climatology, physical geography in general and in many civil engineering projects as well. Now algorithm which is employed here to calculate this TRI, is basically the sum change in elevation between a grid cell and its 8 neighboring cells.

So, again this 3*3 kernel will be used and therefore an increased TRI source increase local relief heterogeneity.

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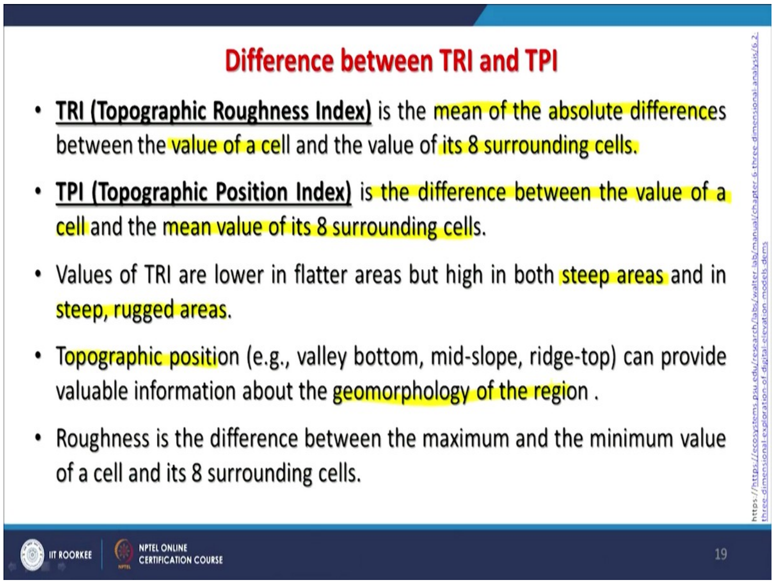

And if we compare TRI and TPI, as you know the topographic roughness index is basically the mean of the absolute differences between the value of the cell and the value of its 8 neighbour and whereas in TPI, the difference between the value of a cell and the mean value of its 8 surrounding cells. So, there is a calculation difference that one is basically with the surrounding 8 cells and here is the mean value of its surrounded cells.

And whereas here, this is the absolute difference between the value of the cell whereas it is the difference between the value of the cell and the mean value. So, this is also mean of the absolute difference. So, one is taking the mean of the center value or other one is taking mean of the difference value. And then these two indices can be derived implying a digital elevation model which can be very-2 useful for identifying steep areas, steep roughness or rugged areas and you can give some quantities, instead of qualitative analysis.

Now this topographic position index can also provide some valuable information about geomorphology of the region which we have just discussed. And this topographic roughness index; TRI is basically the difference between the maximum and minimum value of the cell and its surrounding cells.

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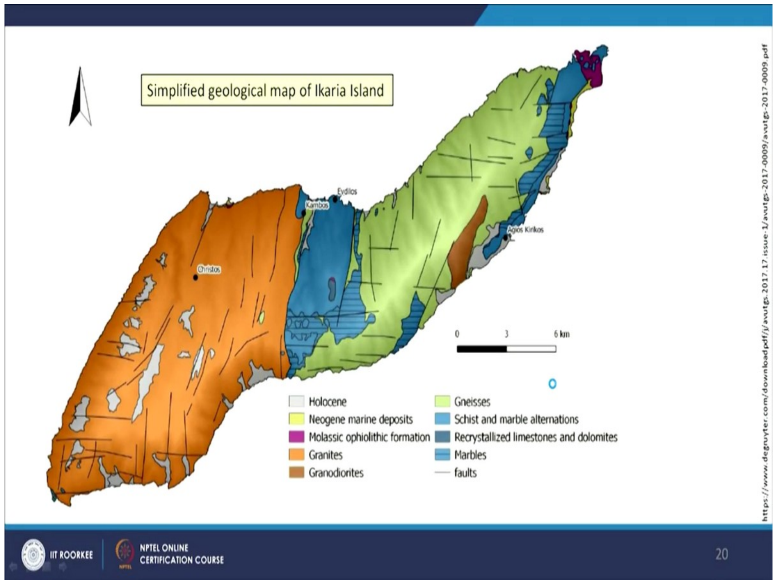

Example here that this is a geological map which is shown here. Different geologies are lithologies are present here like marine deposits, ophiolitic formations, granite, granodiorites etcetera.

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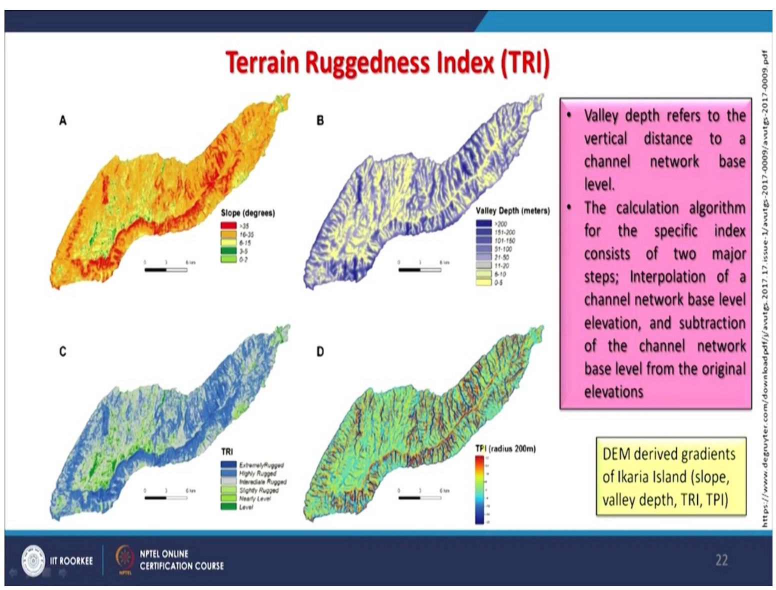

Now, when it is subjected to this calculation that is the TRI, this is what you get. So based on slopes, this is how the terrain is classified. When we see the valley depth in meters, this is there. When we see the TRI, this is the situation and TPI is like this. Of course, TPI will depend on the scale or resolution of your input. So, here is only one. So, DEM has been implied to calculate slope, valley depth, TRI and TPI. All these parameters or derivatives can be derived employing a digital elevation model.

And lot of useful information can be extracted for various applications. Again, that TRI and TPI values are there. The valley depth refers to this output; it's referred to the vertical distance to the channel network base. This calculation can be also useful for various applications.

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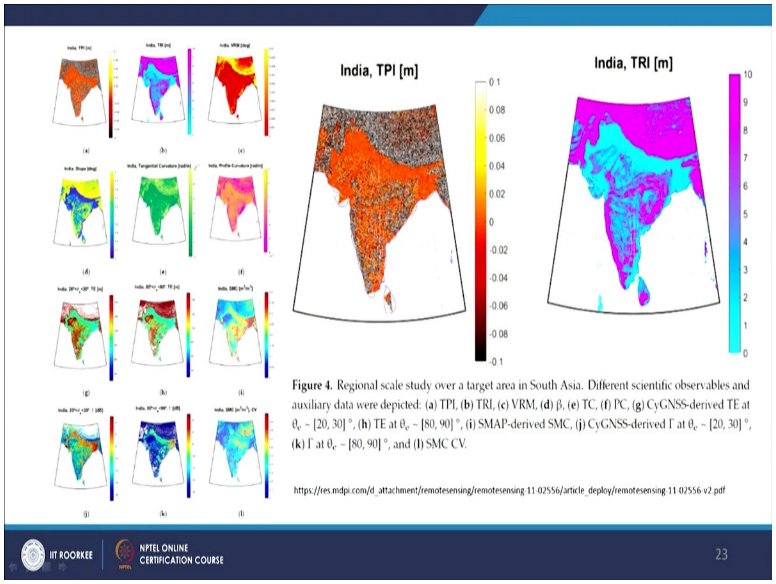

Here I have taken example from this publication is that for overall India, they have derived TPI as well as TRI. And at for different scenarios, these things have also been presented here. So that regional scale over a target area and south Asia, different scientific observations and auxiliary data were depicted; TPI, TRI, BRM and so many other parameters. What is the input? A coarse resolution digital elevation model to cover a regional or continental scale analysis.

So, this brings to end of this discussion about TPI, TRI and their comparison and various other related also indexes. Now the purpose here is to exploit digital elevation model to its maximum. Sometimes we have to imply for the same region, 2 Different spatial resolutions digital elevation models to drive some important information like TPI. So, with this, I end. Thank you very much.