Digital Elevation Models and Applications

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Lecture - 11

DEMs Derivatives- 1

Hello everyone. And welcome to 11th lecture of Digital Elevation Models and Applications. And in this model, in this lecture and after this, we will be discussing various derivatives of digital elevation models. As also mentioned earlier that digital elevation model is a storehouse of information, we can retrieve many, many types of informations from it. And some people also put as a terrain analysis, when we derive the terrain parameters, especially it is meant only for that. So, it is also called terrain analysis that is the derivations of terrain parameters, starting from slope aspect and drainage network, watershed boundary and a topographic position index, and many, many other things. So, we will be seeing one by one all these things, and how these can be applied, how these can be used for various engineering and other applications that to we will be saying this.

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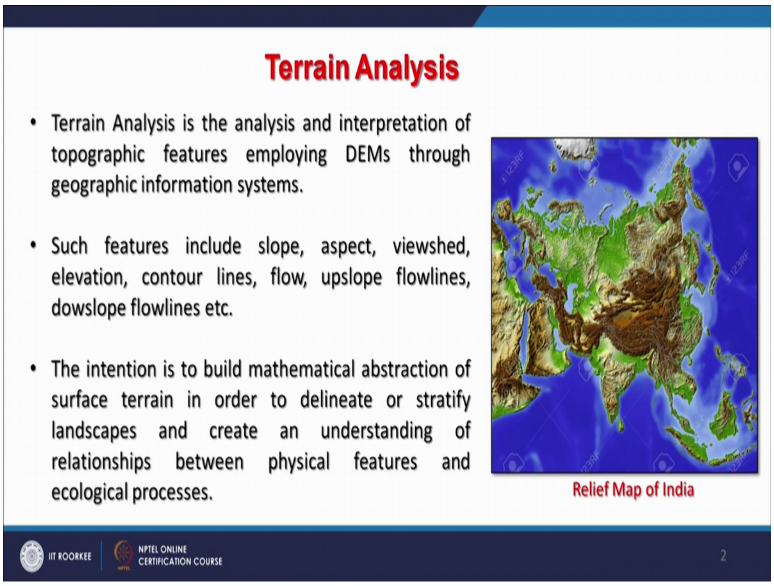

So, terrain analysis is basically the analysis and interpretation of topographic features employing DEMs through GIS. So, we have to have a GIS platform on which we can derive lot of a terrain parameters using various digital elevation models as per our requirements. Second thing is that such features say as mentioned that slope, aspect, viewshed, elevations, contour lines, flow, upslope flowlines, downslope flowline and various other parameters can be derived from digital elevation models. As the availability of digital elevation models or global digital elevation models from various sources are becoming possible or available, more applications and more derivatives people are developing through on GIS platform using these DEMs.

And the basically here what we try or what we intend to build mathematical abstractions of surface terrain in order to delineate or stratify landscape. And the purpose here is that because that for every derivative of digital elevation model of course there is a mathematics behind it. And as a more requirements of processing is there, so more development in the mathematical domain is also taking place how to exploit a digital elevation models to this maximum. So, people are employing not only for terrain parameters, but for other parameters, even for landform identification depending on the spatial resolution and requirement.

So, basically if we think start from say slope point of view, then the area of a slope in pixel is not the same size as one that lies flat, and sloped pixels occupies more area then a flat one as we will see very soon a diagram through which we can understand. So, that basically here what we are trying to discuss here that if it is a flat terrain, then the area is going to be less for a one cell. Whereas, if it is a sloping a cell or undulating terrain, and there is a sloping cell, then the area of that sloping cell is going to be more. So, it is planimetric area versus a sloping area that we are going to discuss in details.

So, the planimetric to surface area ratio, we can exploit and that becomes an index of topographic roughness and which can be used for various purposes especially for habitat assessments, erosional studies, land used studies and even to geomorphology. And this say index is largely independent of is scale. So, it does not matter that what is the resolution or what is the scale of a digital elevation model.

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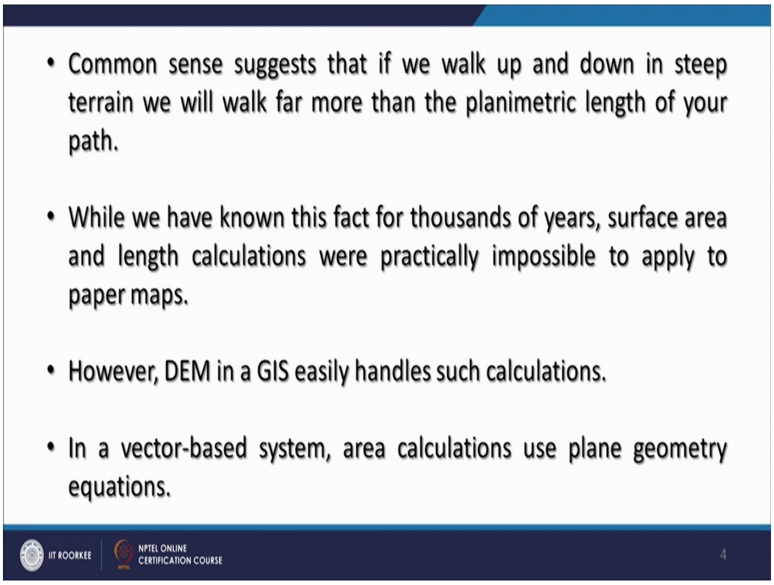

And common sense say as we know that suggest that if we walk up and down in a steep terrain we will walk more than in planimetric length of your path. So, if we have to because the length also increases in case of a sloping terrain. Whereas, if we have to walk on a flat terrain then the length is a not that much as compared to the sloping length. And while we know that this fact of thousands of years surface area and length calculation were practically impossible to apply to the topographic maps of paper maps which we were using. But now implying the digital elevation models which is a two-dimensional matrix, we can calculate this planimetric area, we can calculate the surface area, and a sloping areas, and also indices for surface roughness. So, DEM with GIS can handled all the such calculations. In a vector system that when we are having contour lines another thing, these calculations to some extent are also possible.

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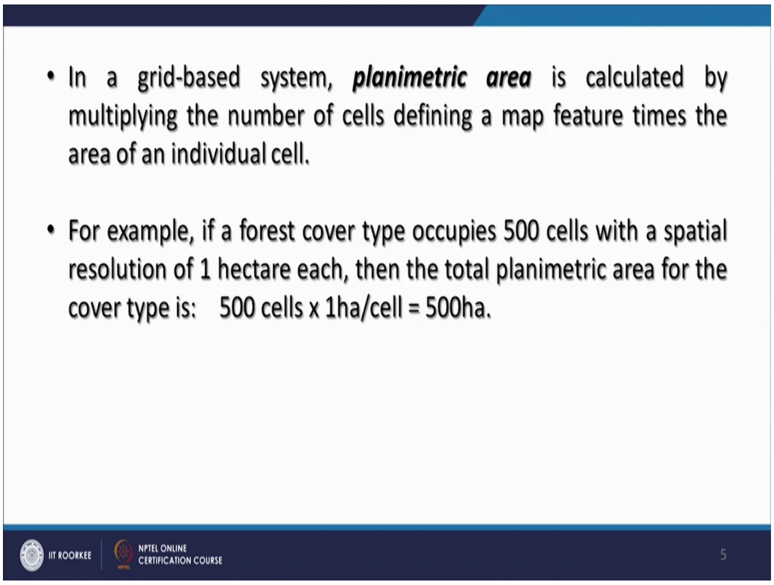

But in a grid-based system the planimetric area is calculated by multiplying the number of cells defining a map feature times the area of individual cell. And for example, if a forest cover type occupies say for 500 cells with a spatial resolution of 1 hectare each, the total planimetric area for cover type would be 500 hectares 500 multiplied by 1 hectare per cell.

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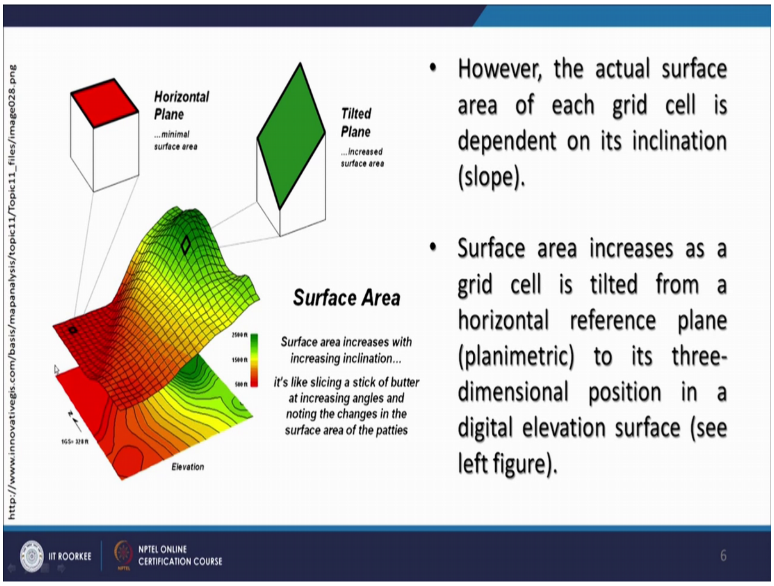

And this is what I wanted to show to you that if a flat terrain like for example, indo-magnetic plane of Northern India, then this is the scenario you might be facing that your cell is completely flat here and this will become our horizontal plane or a planimetric area. Whereas, if say cell is representing a sloping terrain like in part of Himalaya then it will have more area. So, the planimetry area is always less than the tilted plane or tilted area. So, with this surface area increases with increasing inclination this we can conclude very easily, but in case of a topographic maps as shown below, where we use the just simple contours such calculations to a high accuracy is not possible.

So, this say actual surface area of each grid cell is dependent on its inclination that is the basically the slope. And the surface area increases as grid cell tilted from a horizontal reference plane, as in this case, we can see this is the oriental reference plane in the bottom and reference plane to its three-dimensional and this is the three-dimensional representation of the same terrain through a digital elevation model. So, this is the major discussion in this topic that how we can calculate planimetric area and sloping area and indices. And what are the intricacies while doing all this thing.

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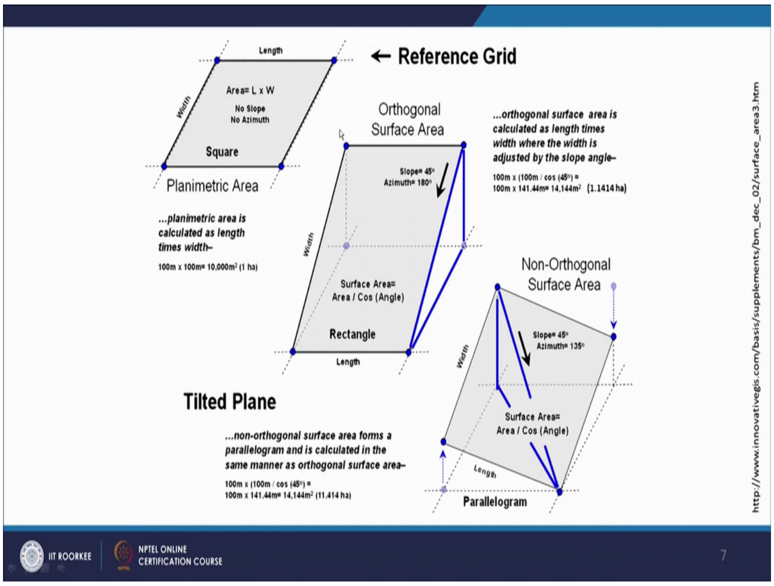

So, if we take the top left figure here this is the planimetry area when the your cell of a digital elevation model is representing a flat terrain. But when it is a representing a tilted terrain then this becomes sat sort of rectangular in that sense. Though on if we project on a horizontal plane as shown in the bottom then it will remain of course a square because square is the unit of a digital elevation model. But in case of a tilted one, it becomes a sort of rectangular and then it will have more area than a square. And this is orthogonal surface area and this is non-orthogonal surface area where it is not having a 45 degree with this length.

So, when you are having a parallelogram here, parallelogram here, and this becomes a non-orthogonal area. So, in non-orthogonal surface area forms a parallelogram and it is calculated in the same manner as orthogonal surface. So, it is not necessary that digital in digital elevation models, the slopes will be only calculated for north south sloping, they may be in any direction. So, all kinds of in all direction slopes can be calculated or the area of the sloping surfaces can also be calculated.

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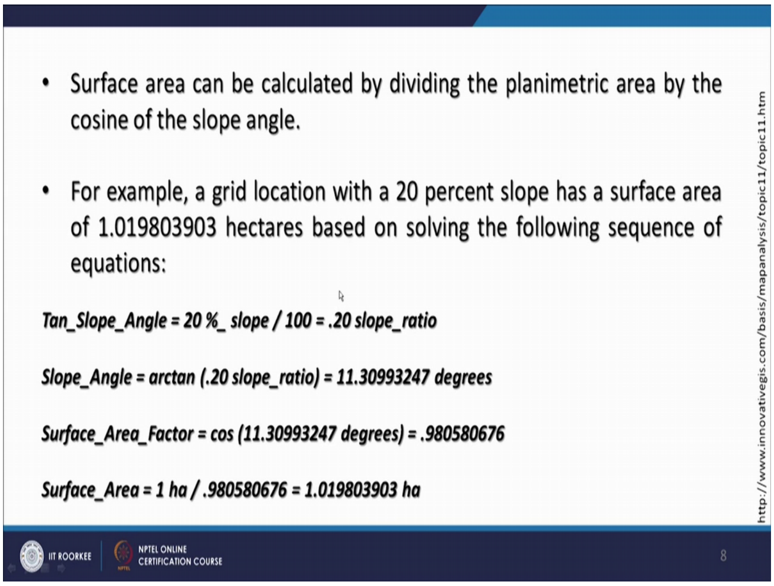

So, surface area can be calculated by dividing the planimetric area by the cosine of the slope angle. And for example, a grid location with a 20 percent slope has a surface area of 1.019803903 hectares based on solving the following sequence of equations. And that tan sloped angle equal to 20 percent slope divided by 100 equal to 0.20 slope ratio. And similarly slope angle can also be calculated as mentioned in this equation. So, surface area over the factor surface area factor is also can be calculated in a similar way using these equations. And surface area first one the first surface area factor now surface area the two can be calculated. So, that is why when we say this that when grid location with a 20 percent slope has a surface area of this, this is how we reach here with this 1.019803903 hectares. So, this is how the area of a sloping surface can be calculated.

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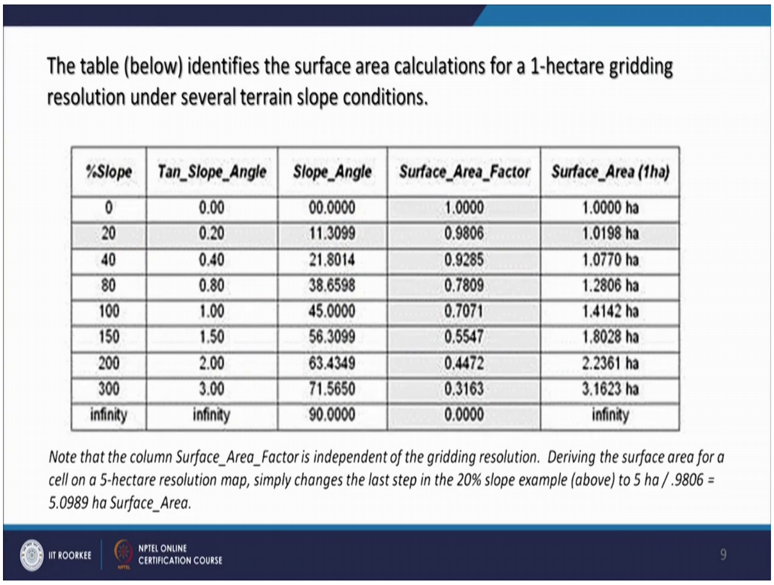

And this table below basically what is identifies the surface area calculated for one hectare gridding resolution under several terrain slope conditions. So, here when as slope increases, how the area also increases. As you can see when you are having a flat terrain, the surface area is going to be perfect 1 hectare, but say if it is a slope percentage a 80 percent then it is going to be 1.28. And then we go for 200 percent, it increases and likewise, so that the column here what the surface area factor and this one is independent of gridding resolution that it is independent from spatial resolution of digital elevation model. And the driving surface area for a cell on a five hectare resolution map simply changes the last step in the 20 percent slope example here. And in this one only it will change as per the resolution, but the result would remain same.

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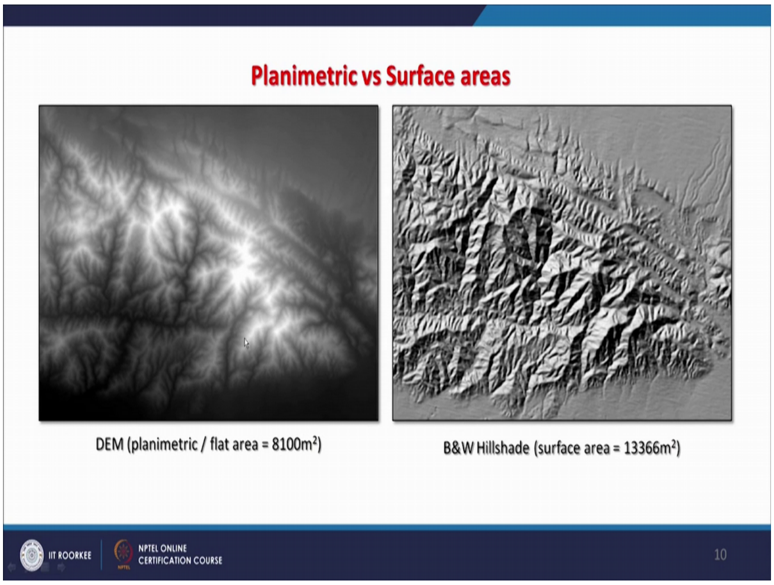

And this is we can see these this a planimetric area versus surface area or area of a sloping surface through these two figures. Left one is simple digital elevation model, and hear the z-axis has not be given except grey value, it has not been given any height scale. And therefore, what you are seeing only in the sets of grey. The lighter color toned cells are representing the higher grounds, whereas the darker one are representing the lower grounds.

So, here the like for example, for this total digital elevation area coverage, this planimetric area is going to be this much, because multiplied by the number of a cells multiply by the spatial resolution. Whereas, since it is the surface area, and this is the same terrain, same digital elevation model has been represented through a pseudo relief model. And where the z-axis has been given the basically it has been used as a z-axis and therefore, you are having now sloping areas as well. And when we when we are having something like this then the slow the surface area for all these slopes which are being seen here, it is going to be more area than a simple planimetric area, and this is what it is depicted here that here it is 8100 square meter, and here is 13366 square meter. So, this is definitely will have the more surface area.

If someone calculates for the even for a heli-terrain if someone calculates the area or surface area has planimetry for the flat terrain, then he is going to make lot of wrong interpretations or wrong calculations for the area which is available in a hilly terrain. So, this has to be kept always in mind, because all terrain or rather most of the terrain are not flat, there are some undulations even on in indo magnetic planes. So, therefore, the square has to be taken while calculating the surface area of a terrain or through a digital elevation model.

Another thing which also place very important role is the surface curvature how these a sloping surfaces are having curved whether up slope, down slope, over across slope or along slope all these or in combination. So, all these will also influence the area and therefore, other processes for example, erosional processes, depositional processes and maybe in case of landslide it is they are going to behave completely differently. So, we have to also see these parameters.

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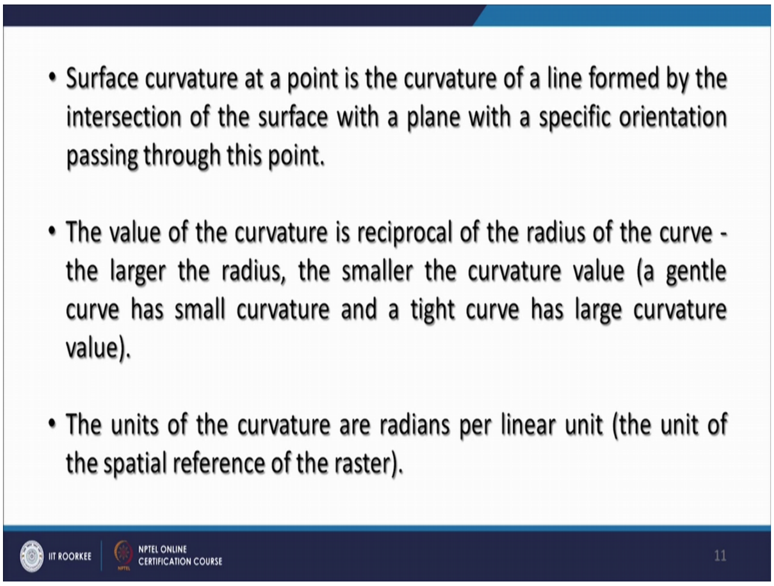

So, surface curvature at a point is the curvature of a line formed by intersection of surface with plane and a specific orientation passing through this point. And this the value of curvature is reciprocal of radius of curve - the larger the radius, the smaller the curvature value - a gentle curve has a small curvature and a tight curve has a large curvature value. And this we will see also through diagrams. And this say units of curvature are in radians and per linear unit that is the unit here is the spatial reference of the raster or our digital elevation model. We may be having digital elevation models that is the horizontal scale and reference system in meters in case of UTM or maybe having in latitude longitude. So, depending on that unit we will have the total curvature units.

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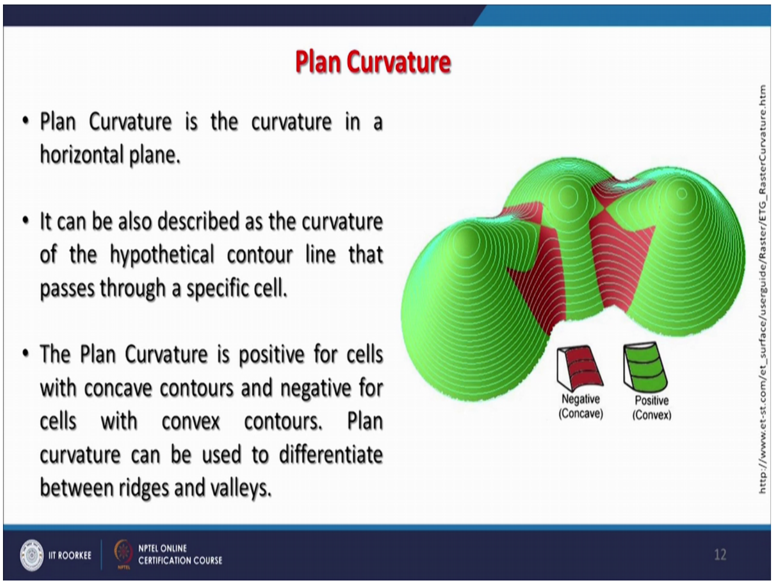

And now these curvatures can also be there are various types of curvatures. So, we will take one by one the first and the simple one is the plan curvature that means the curvature which we see from that. So, the plan curvature is measured in a horizontal plane and that is the curvature in a horizontal plane. As we can see there can be two types of plan curvature, negative that is concave, and positive that is the convex.

Now, the curvature of the slope and concave and convex that it means positive and negative and positive will behave differently in different natural processes, erosional processes, or and other cases. So, it can also this plan curvature can also be described as the curvature by the hypothetical contour line that passes through a specific cell. And this plan curvature is positive for cells with concave contours and negative for cells with convex contours.

Here instead of discrete lines like contours in a digital elevation models, we are going to has cells or a continuous grid, but does not matter the concept might will remain same. So, plan curvature can be used to differentiate between rigids and valleys as we are seeing here also. And when you are having positive curvature positive plan curvature, then this is a representation of a ridge kind of situation in this particular schematic. And when you are having negative that is concave, then these are the indications of valleys as you can see here.

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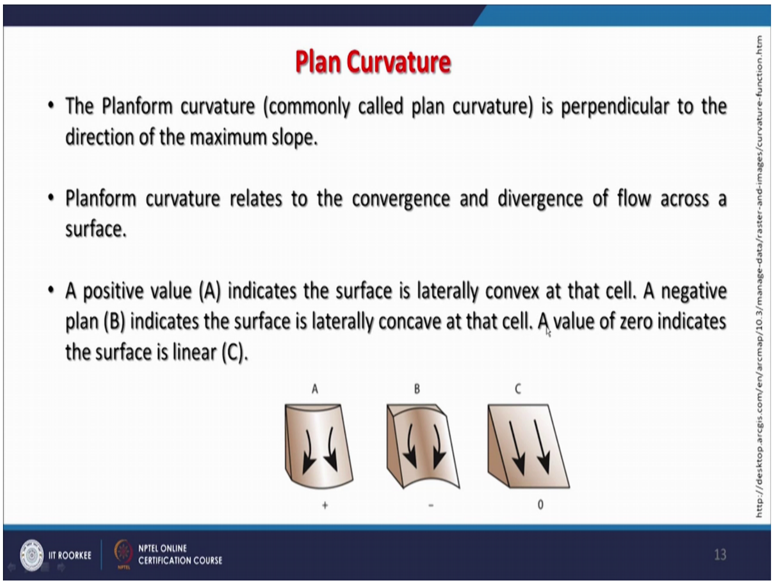

Now, this planform of plan curvature commonly called plan curvature is perpendicular to the direction of maximum slope. As we have seen here that this is perpendicular to the direction of slope always we measure in that way. And then the plan curvature relates to the convergence and divergence of flow across a surface because these curvature values we can use to estimate erosion erosional processes in a hilly terrain, and therefore, the convergence and divergence of flow becomes very important also.

So, this is like example here that in example A, we are having positive plan curvature that is indicating a surfaces laterally convex at that particular cell here. And whereas negative plan B indicates here that the surface is laterally concave at the cell. So, laterally it is concave here and a value of zero indicates the surface is linear that is the surfaces flat. A natural surfaces are generally not like that; there may be some curvatures and that has to be for better estimations of erosional processes or flow processes or any other engineering applications, we need to calculate all these parameters. Now, one was the plan curvature.

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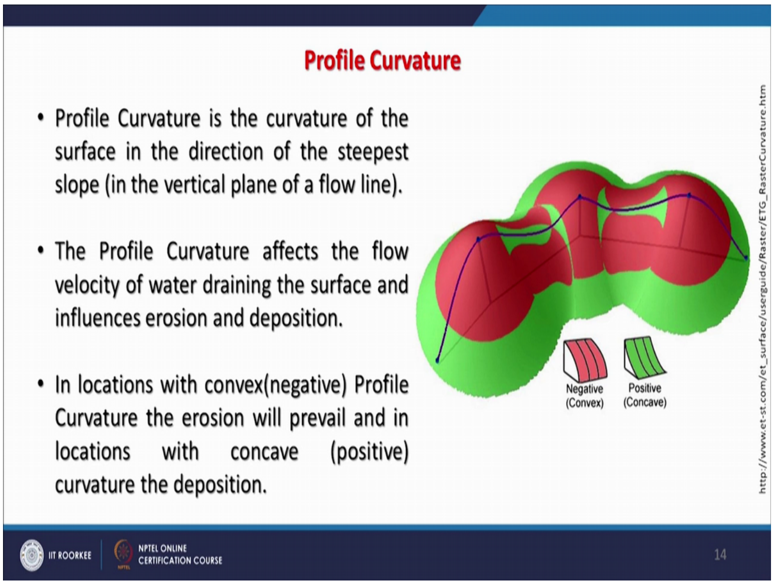

Now, another one is the profile curvature. What is profile curvature is that curvature of the surface in the direction of a steepest slope is the vertical plan of the flow line. So, here like here we can see these are the direction of a steepest slopes which are shown here. So, this red one are showing the negative or convex profile curvatures as we can see here. And whereas, the positive or these concave here green are showing positive profile curvature. So, this is profile curvature is the curvature of the surface in the direction of a steep steepest slope that is in vertical plane.

So, plan curvature is measured in a horizontal plane; whereas, profile curvature as name implies measured in a vertical plane. And profile curvature affects the flow velocity of water draining in the surface an influences erosional and depositional processes. And in location with a convex that is negative profile curvature, the erosion will prevail in case of like this. When you are having a negative or convex profile curvature, you expect more erosion; and in case of positive that is concave, there might be possibility of deposition or less erosion, so that is why the calculation of these curvatures are important.

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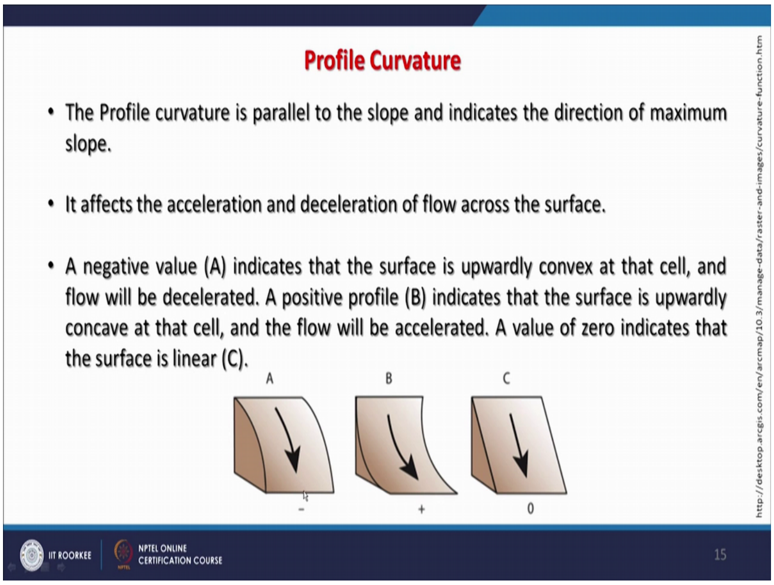

Further that the profile curvature is parallel to slope and indicates the direction of maximum slope and because we are seeing or measuring in a vertical plane. And it affects the acceleration or deceleration of flow across the surface. In case of plan curvature, we were thinking of flow divergent and convergent flow. Here what we are seeing the acceleration or deceleration because we are measuring in vertical plane, and it affects the velocity of your flow.

So, a negative value in case of a profile curvature indicates the surface is upward convex as in case of scenario A at the cell and flow will be decelerated, because it has to pass through a curved surface up the slope upwardly convex a slope. There is in case of profile curvature like in B, when you are having upwardly concave at the cell the flow will be accelerated. Here we will have more flow, here we are going to be a decelerated slope. And in case of flat, it is the when the value of 0 indicates the surfaces linear. So, in case of our plan curvature the same scenario was there that a value of zero indicates surfaces linear. So, when you do not have any curvature then in both the cases in case of plan curvature as well as in profile curvature, we will have this value curvature value zero.

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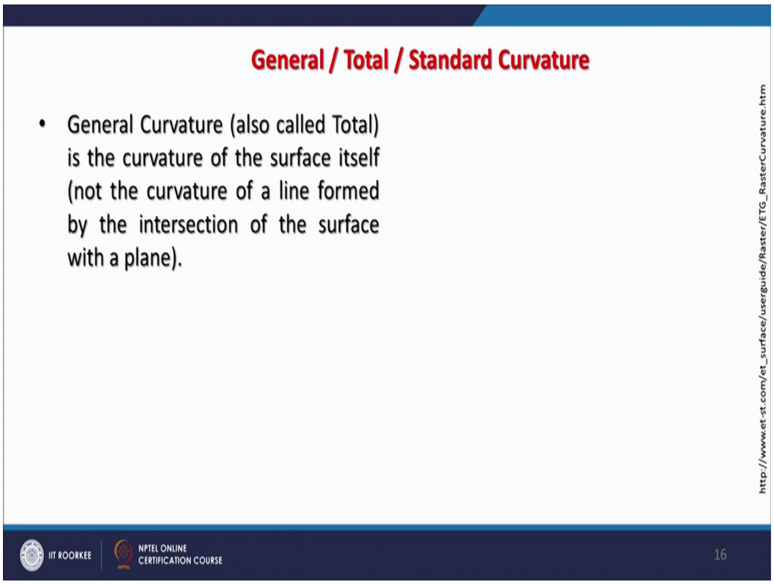

Now, there is another curvature which is called in different literatures in different software, different words have been used like for example, general curvature may be total curvature or a standard curvature that is basically combining both. So, general curvature that is also called the total curvature is the curvature of the surface itself not the curvature of a line formed by the entire section of the surface with a plane. So, like in a plan curvature, we thought the line is going or passing through a horizontal plane or cutting through a horizontal plane. Whereas, in case of profile curvature we because we measure in vertical plane. So, we have been thinking about the line. Here, now it is the total one, so instead of line the complete one.

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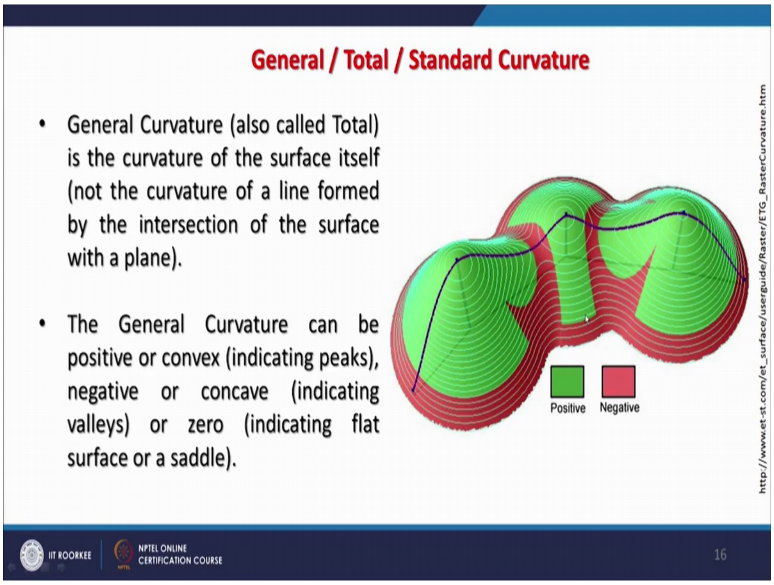

It is here like the example given here that in case of positive the green one is shown here and these are the all ridges part, which you are seeing the total curvature. And in case of negative which is convex, and what we are concave sorry and what we are seeing is all if these are the ridges then these are the valleys part. So, general curvature can be positive or convex indicating peaks like here and the green colored one and negative or concave indicating valleys, and of course, zero indicating flat surface or a saddle. So, this is how we see these curvatures.

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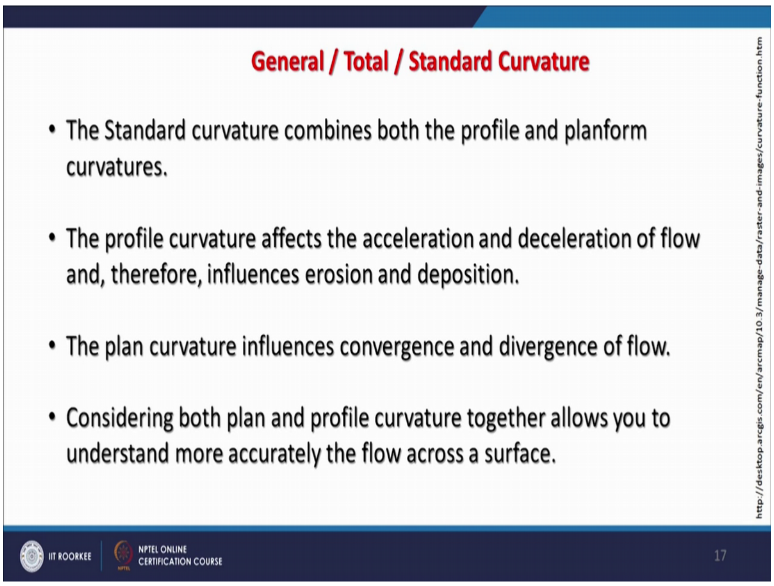

Further, this standard curvature combines both the profile curvature as well as the plan curvature. And profile curvature affects the acceleration and deceleration of flow and, therefore, influences erosion and deposition. Whereas, plan curvature influences convergent and divergent of flow and accordingly it will affect ultimately the erosional processes and depositional process as well. So, considering both in plan and profile curvatures together allows us to understand more accurately the flow across a slope. Because normally the slopes are not in a plane form, they are either you are having concave or convex, and they behave completely differently for different natural processes like erosion or deposition.

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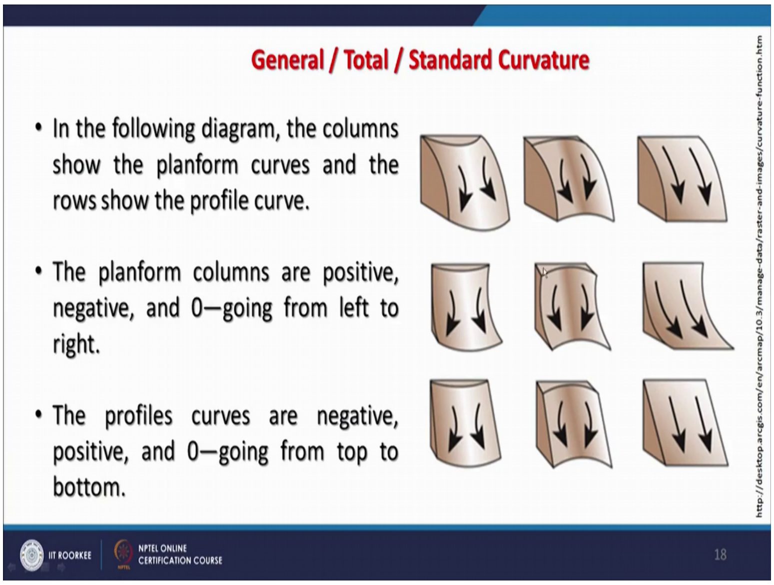

So, in this the diagram which we are going to have on the right side that there are different these things are shown that the columns shown here the planforms curvature and the rows show the profile curvature. So, in this way what we are seeing the planform curvature and in row direction we are seeing the profile curve. So, this planform are positive here like here they are you are seeing in positive and negative and also zero are in the last, so that is in the here also. So, profile curves are negative, positive or zero going to the top to the bottom. So, all kinds of scenarios have been incorporated in this particular diagram.

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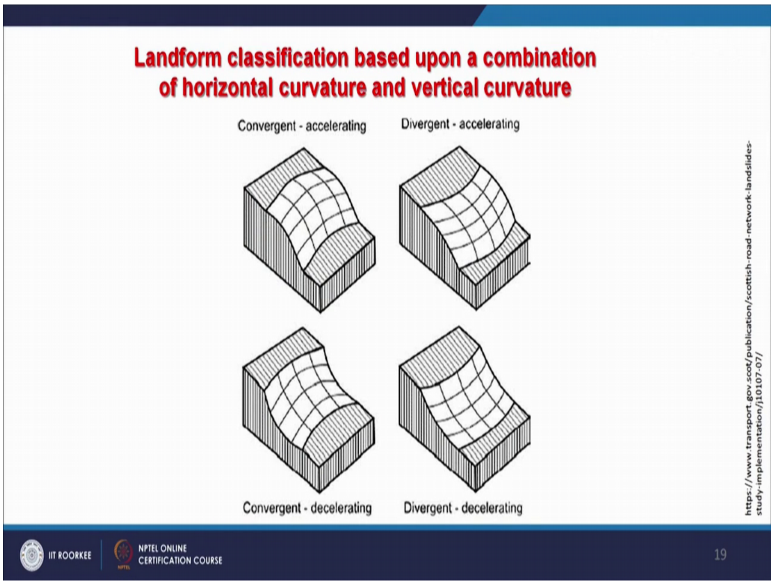

Now, land classification or terrain classification is also possible based upon a combination of both these curvature horizontal or vertical curvature or plan curvature or profile curvature as shown here that when convergent things are there then it is associated with accelerating of a flow. When you are having divergent, these lines indicates whether they are converting or diverging, and they are basically showing the shapes of our cells which will which will be representing the sloping surfaces.

So, when you are having accelerating such scenario, you will in this here in the bottom left we are having the convergent decelerating scenario, this is also this is just opposite divergent also here, but decelerating. So, in the top two cases, we are having accelerating scenario, but convergent and divergent flow is possible, here convergent divergent both are representing the deceleration scenario. So, likewise these can be exploited to understand a terrain in a much better manner for erosional in depositional process.

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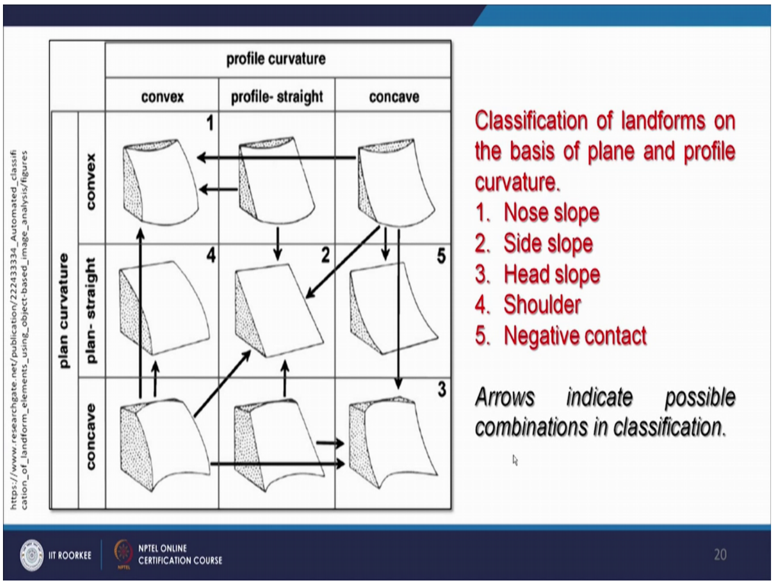

In geomorphology, classification of landforms on the basis of plan and profile curvature is also possible as shown here that on the rows we are having profile curvature, here we are having plan curvature and then we are having the convex scenario. So, in both the cases, this is convex and this is one then you are having in the both the cases, it is concave. These are the two extreme members. And then you can have in between the other. So, the slopes can be classified like in case of one scenario one we are both plan and profile are showing the convexity of the slope, then we say no slope. When we are having in case of like this a scenario two, where profile is the straight and plan is also a straight then this is side slope.

Then we are having scenario three, when profile is concave plan is concave then we say head slope. And there are other mixed scenario like in profile curvature, you are having convex and in plan you are having straight then we get shoulder. And then negative in case of fifth one whereas, a profile concave and ah plan straight then we get negative scenario. So, theses basically are indicating that how we can classified different types of slopes based on the curvature values.

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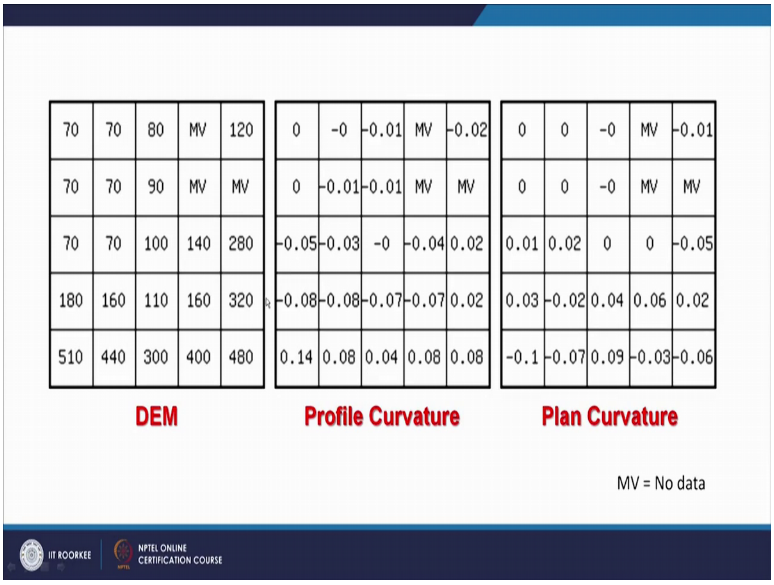

70	70	80	MV	120
70	70	90	MV	MV
70	70	100	140	280
180	160	110	160	320
510	440	300	400	480

DEM

0	-0	-0.01	MV	-0.02
0	-0.01	-0.01	MV	MV
-0.05	-0.03	-0	-0.04	0.02
-0.08	-0.08	-0.07	-0.07	0.02
0.14	0.08	0.04	0.08	0.08

Profile Curvature

0	0	-0	MV	-0.01
0	0	-0	MV	MV
0.01	0.02	0	0	-0.05
0.03	-0.02	0.04	0.06	0.02
-0.1	-0.07	0.09	-0.03	-0.06

Plan Curvature

How exactly it is calculated in GIS using a digital elevation model and this is what it is depicted here that on the left side we are having a digital elevation model and the values are shown. MV stands for no data; basically no value are available here. This scenario is always kept, so that we would like to learn how ah it will behave when no data values are there. And then you are having a profile curvature, this is how it will be calculated, this is how the values exactly would be in and this is a plan curvature scenario. So, likewise using a digital elevation model on a GIS platform, we can calculate these plan curvature, profile curvature as well as total curvature.

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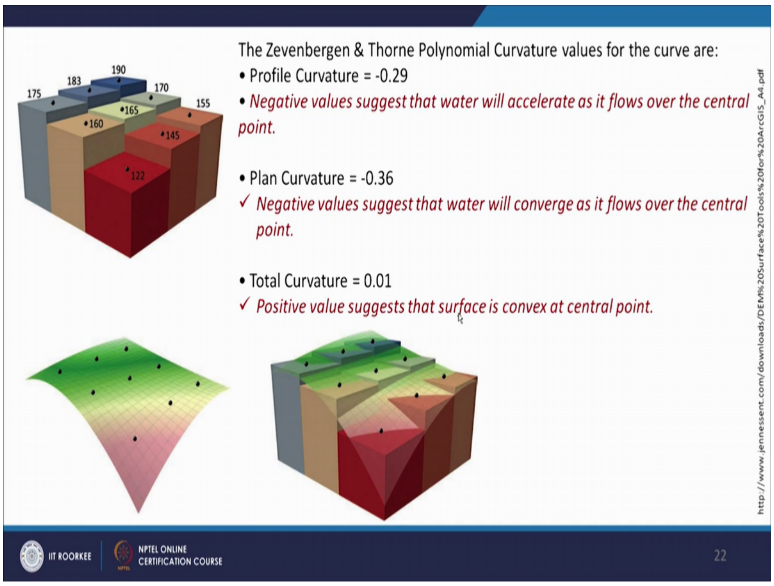

Now, there are different methods are there given by first one by the Zevenbergen and Thorne like in case of slope aspect we have discussed their methods. So, in different methods, we will might bring some different values because they approach in different methods are different. So, in this case, the profile curvature is minus 0.29; whereas, the negative values suggest that the water will accelerate as it flows over the central point in this one. And plan curvature here is going to be minus 0.36, and that negative value suggest that the water will convert at it flows over the central point. And likewise the total curvature is positive value, but is a very small value 0.01. So, using the Zevenbergen-Thorne method, with this input elevation values of a 3 by 3 rows, rows and columns this is what we get in calculations. And this again here positive in case of a total curvature positive value suggest the surface is convex at the central point.

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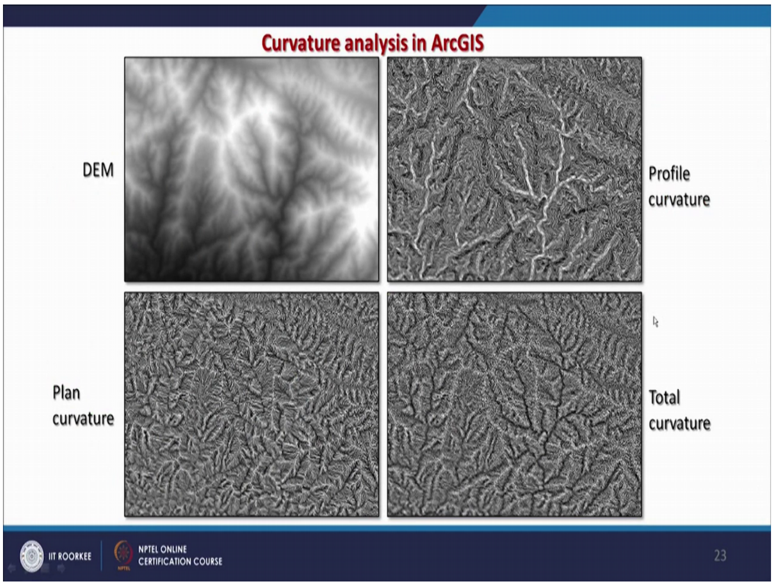

This is how in this example all three types of a curvature have been shown. For the digital elevation model which has been we have taken since beginning as an example, example digital elevation model. And on that model these three things have been performed using a GIS software which is called ArcGIS, Arcmap. And this is the input digital elevation model profile curvature is like this, plan curvature is like this, and total curvature this is what we are seeing. For individual cells, we see there.

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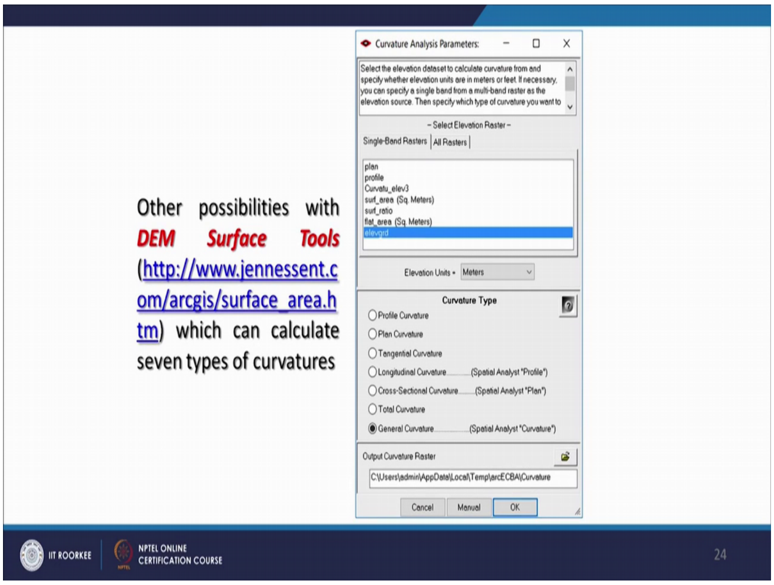

And when we go for this like ArcGIS there is an spatial extension which can be downloaded from net from this site. And this will give us the all possible scenarios to calculate and different type of curvature like here. We can choose profile curvature, plan curvature, tangential curvature, longitudinal curvature; and based on the methods which Zevenbergen and Thorne method which we can employee there.

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And here also we can see how these would look in a shade relief model. So, is the here is the d e m with fifty percent transparency over a hillshade. So, hillshade and DEM together this we have seen in earlier lectures that how these two the same data set, but one is just flat DEM having colours, and another one is shade relief model which is in black and white. But having said was when be overlay this two with 50 percent transparency then this is what the left figured depicts. So, this is 50 percent transparent DEM over a hillshade and this is the same DEM over a plan curvature 20 percent transparency.

So, now we are having a shade relief model, plan curvature as well as DEM 3, all together one is 50 percent transparent, another one is 20 percent. And by this method we can see that where are the pronounced valleys, and ridges. So, we can very well depict there are the ridges like here this white criteria are depicting the ridges and here these darker areas are depicting the valleys. So, likewise these things can be calculated. So, what are the applications, applications of curvature map curvature map has been indicating for erosional studies and depositional studies and other purposes slope stability analysis we can.

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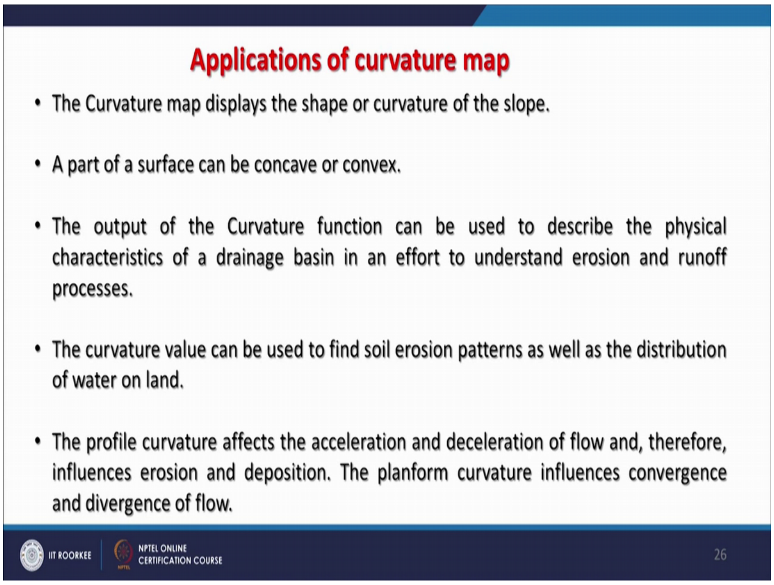

So, this is what quickly we will go through that the curvature map displays the shape or curvature of the slope. And the part of the surface can be concave convex. And the output of curvature function can be used to describe the physical characteristics of a drainage basin in an effort to understand erosion and runoff processes. And the curvature value can we used to find soil erosion parameters as well as the distribution of water on land, because when we go for soil erosion modelling another, there also the slope curvature can play very important role in soil erosional modelling studies. And this is how we can calculate and provide these inputs into the modelling. And the profile curvature affects the acceleration and deceleration of flow and, therefore, influences erosional and depositional process. The plan curvature influence it convergent and divergent of flow.

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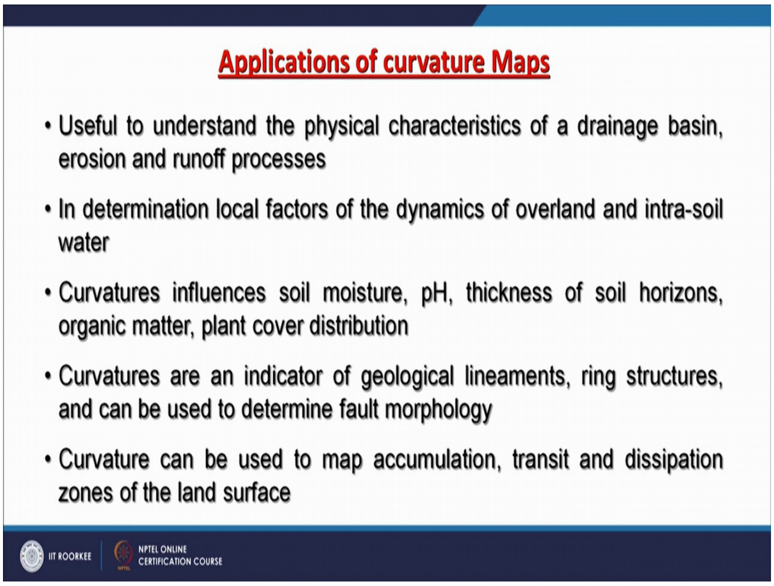

And application of these curvature maps will be useful for to understand physical characteristics of a drainage basin, erosion runoff process. And in determination of local factors of dynamics of over land and intra-soil water flow. Curvatures influences soil moisture, pH, thickness of the soil horizons, organic matter, plant cover distribution. Curvatures are an indicator of a geological lineaments, ring structures, and can be used to determine fault morphology also in geomorphology we can employ in a geological applications. And curvature can also be used to map accumulation, transit dissipation zones of the land surface. So, this brings to the end of this discussion.

Thank you very much.