Digital Elevation Models and Applications
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Lecture – 01
Concept of Digital Elevation Model (DEM) and it is Represented

Hello everyone and welcome to a new course which is Digital Image, Digital Elevation Models and Applications; if you recall that earlier I have done two three courses on the first on the GIS, then digital image processing and remote sensing also. So, those who are having background of these subjects will definitely enjoy learning more details about the digital elevation model. Though digital elevation model has been briefly introduced during the introduction to our principles to GIS course, but now as you will realize that it has it is really a store house of a information, which we can drive for own and digital elevation model.

So, in this particular course we will be discussing about what is the basic concept of digital elevation model, and how it is represented, how we can utilize it with which are the processes which we can perform on it, what are the products we can generate and also various applications especially in the field of a civil engineering, earth sciences and in other domain as well. So, we start with this concept that a digital elevation model is a basically a if you recall raster data. So, you see raster data is a two dimensional matrix, and each cell of that matrix is representing an elevation value. This is a typical digital elevation model, but there different terms are also used like a digital surface model digital terrain model there are some differences which we will also see in this particular lecture.

So, if we see the a typical definition of digital elevation model is a 3 D representation or terrain surface, and which is commonly for the planet the planet can be earth or mars or a moon which is a satellite of the earth or any asteroid as well. So, for any natural surface we can create a terrain model. There are various techniques by which we can create these elevation models, which we will discuss in a subsequent lectures also it can defined that a DEM is an order, ordered array of number that represents the spatial distribution of terrain attributes. Here terrain attributes means here that not only the elevation value, but some other values like slope values, aspect values, and other values can also be represented.

This in a two dimensional matrix the cell value can also be some other value instead of digital elevation value. So, for example, it can be a pH value of soil or a sub surface value say ground water surface and so on so forth. So, it is to in a in a typical DEM or digital elevation model, we assume that the value cell value is elevation, but otherwise for a digital surface model DSM or terrain model we can have some other values as well. So, this is the advantage of having such a data structure.

So, DEM represents the spatial distribution of elevation about some arbitrary datum in a landscape, generally as we know that we use the data about mean sea label. So, that can be represent, but a even below mean sea level, the terrain surface can also be represented, but it is not that easy to create a below mean sea level terrain surface.

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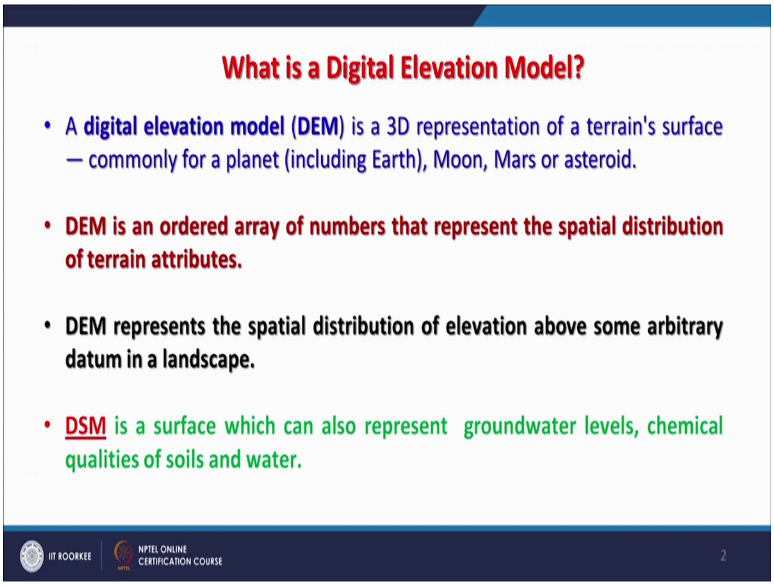

DSM as I have been mentioning, the DSM or digital surface model is a surface, which can also represent ground water levels which are the sub surface information, chemical quantities of soils and water can also be represented through DSM.

So, DSM, but he most popular term as we will see very soon is the digital elevation model, which encompasses all most very kind of surfaces, which we deal in our due course or in our day to day practices. So, the most common digital data of the shape of the earth surface is basically cell based DEM because the data structure is simple and therefore, a lot of applications have been developed on it, plus lot of digital elevation models. Specially, the free global digital elevation models at different spatial resolutions are also available.

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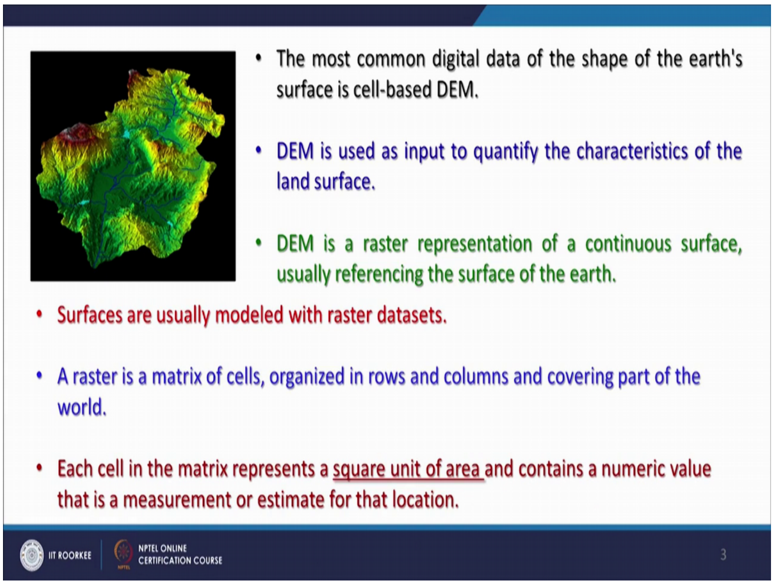

So, DEM is used as inputs to quantify the characteristics of the land surface and DEM is a raster representation as I have already mentioned of a continuous surface usually referencing the surface of the earth. As you know that in GIS we have discussed that there are two three main types of data structures, and which are handled in GIS one is the vector data, but it is a discrete or discontinuous data, another one data is the raster data which is a continuous data. Our DEM our DSM or DTM all are the continuous data or raster data and third model is 10, which is all which can also be used to represent surface using triangulated irregular network.

So, a say irregular network of triangles can be used to represent a surface. So, there are a various types of models available to represent surface, but here in this particular course we will be more focusing on the raster structure, that is a typical a grid based structure and that is the DEM. So, surface has we know that are usually modelled with the raster data sets, a raster is matrix of cells a two dimensional matrix organized in rows and columns and covering part of the world. Or a not only the earth as I have mentioned may be like a using satellite data the digital elevation model of surface of moon as well as surface of mars have also been prepared.

So, it can this is the technology which can be used to prepare surface models of any natural surfaces. Each cell in matrix represents a square unit of area; this is very important that the unit of a digital elevation model or raster is always a square in shape. However, overall shape of raster can be either a square or rectangular, but the unit has to be square in shape and the, it contains a numeric value; that means the cell value that is the measurement or estimate for that location. So, we can have a measurement about a say elevation above mean sea level or can have estimates; that means, that through interpolations we can fill those cell values and therefore, the estimation is also possible using point data.

So, using point data through interpolations, we can also create such surfaces or digital elevation models, which we will discuss when we will discuss how digital elevation models can be created. This is the typical example of a digital elevation model which we are seeing and same model can also be represented in color very soon we will see.

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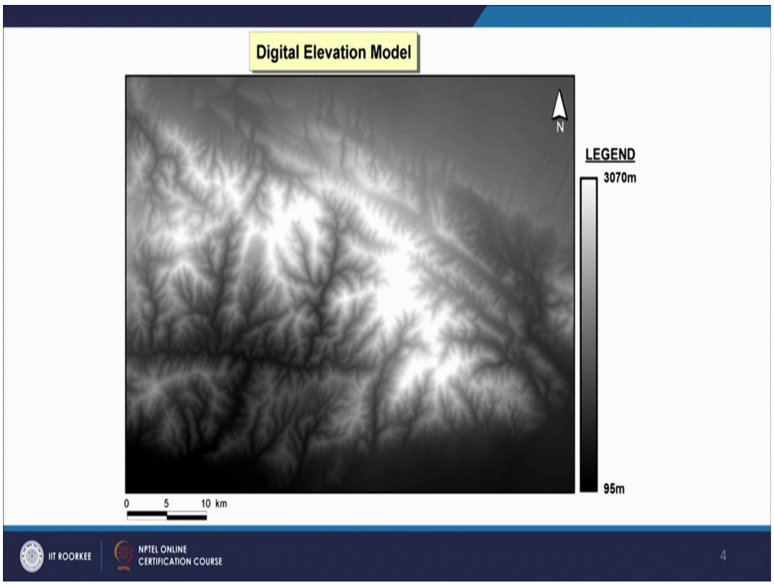

Here the values are represented; that means, the high elevation values are having brighter tone whereas, the low elevation values are having darker tone, here the minimum value is 95 meter and the maximum value in this particular example is 3070 meter. And a though we can assign different colors or sets to different values, but here we have used one scale which is continuous, and these two extreme values that is the 95 and 3070 meter are have been scaled in between black and white .

So, they say two extreme members have been assigned these two colors and rest of the values are in between and therefore, we are seeing a grey digital elevation model. Lot of features can also be seen while we seen here a digital elevation model, but by doing some more processing, the same model can be made more useful and lot of information can be extracted using this. As I have mentioned that the same digital elevation model has been now represented on the right side in color.

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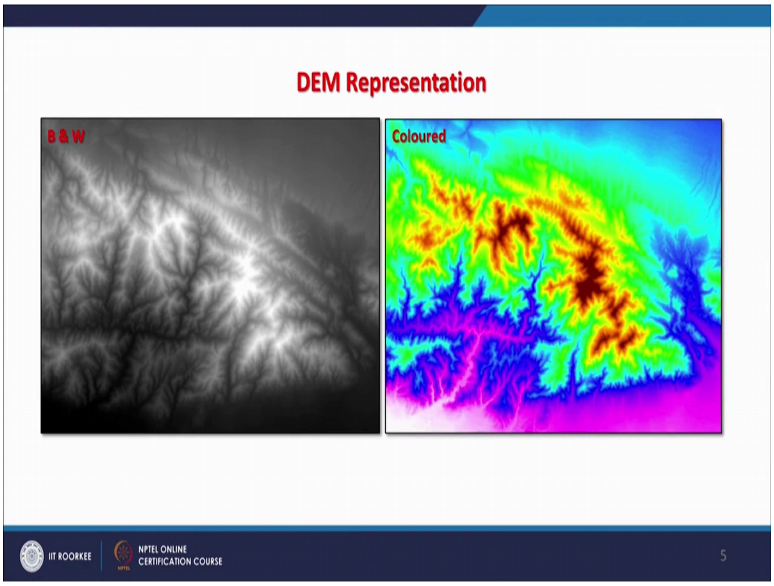

But instead of assigning black and white you can assign a color palette, and there are different color palettes are available in different softwares, and then the entire thing is represented in color here also.

Now, one thing one has to remember always, that is what is important here is the cel value. And the way you are projecting using whichever the palate the original values are not changed. The original value will remain intact whether you are representing in black and white mod or in sets of grey or in color or different color palettes, that original value of cells; that means, elevation value in digital elevation model will remain same. Except that while you displaying on a screen or though projectors you can change the colors.

So, as I have already mentioned that DEM is a raster grid data and it is a two matrix, though we can use and can use that z value that is the elevation value, and can create 3 D also. So, some people call as a two and half d, some people would like to call as a 3 D, but unless we do not if we use that z axis and a give some vertical exaggeration, then only we will start seeing in 3 D. So, those example we will see also little later.

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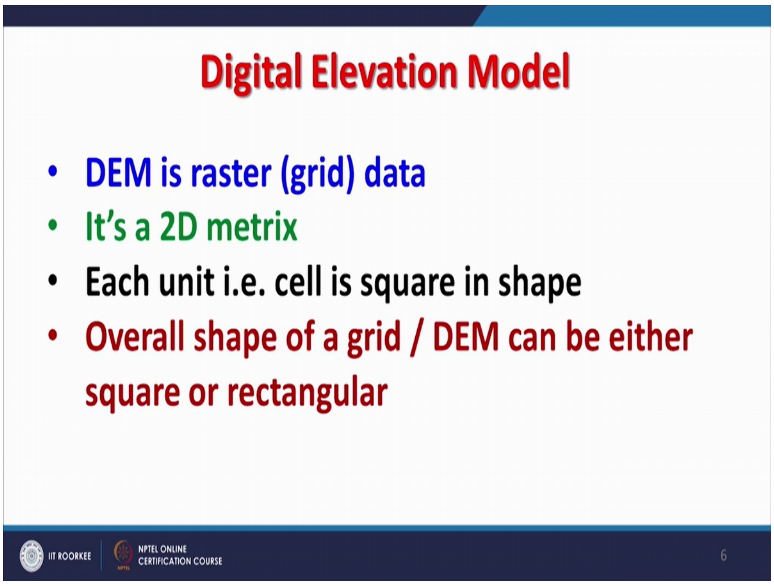

As mentioned also that each unit the cell that is the cell is always square in shape, overall shape of a grid or DEM or raster can be either square or rectangle.

So, these things have to be remembered, these are the fundamentals basically and when we will go for further analysis and applications these things will be utilized there. So, they are very important. So, DEM can be represented as a raster 2 D matrix grid of a square cells also known as height map when representing elevation, but as I have mentioned it is not necessary all the time, that we only use the elevation value.

We can have values of certain concentrations of chemical quality quantities, we can have also you know the water table or a any other value can be used to create a surface or as I have also mentioned that we can represent a surface using a different model, that is the ten which is a some people call as vector waste or its not truly a vector based model, but for a classification purpose because a it is not a typical raster. So, we can say it is a vector waste tin model.

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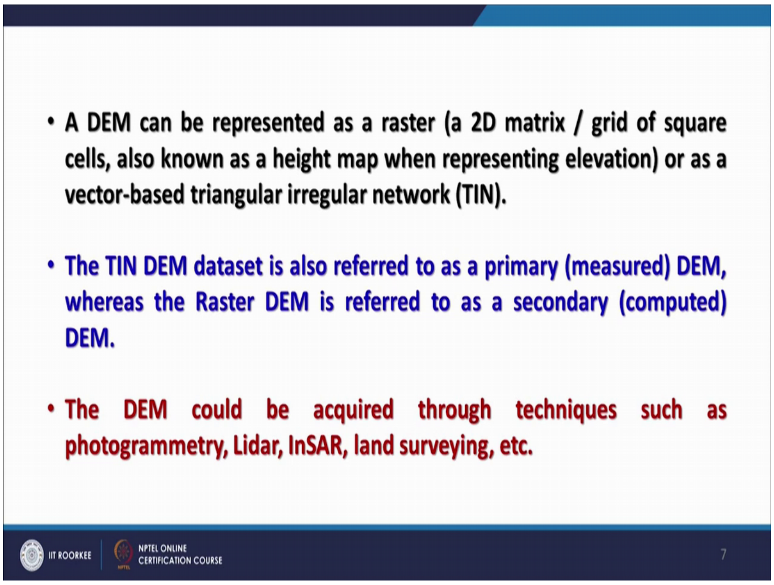

Tin DEM that is means the DEM or which has been created using tin, is also referred as a primary or major DEM and whereas, the raster DEM is referred as a secondary or computed DEM, because a it is not directly created either through interpolations or using some remote sensing techniques, and then further processing, and after that we create the digital elevation a typical digital elevation model and therefore, it is called the secondary product or computed product. DEM could also be acquired a through techniques such as photogrammetry using a stereo pair data and Lidar data, InSAR that is SAR interferometry techniques, we has discussed in the course of introduction to remote sensing and land surveying by using typical topographic survey techniques, various techniques are available and latest ones based on the electronic theodolites or differential GPS can be implied to create digital elevation models.

But the most popular one now a days is based on remote sensing; that means, the either using photogrammetric techniques or InSAR techniques to create digital elevation models. Various models for the entire globe have been created at different spatial resolutions using remote sensing techniques. So, in subsequent lectures we will be discussing those as well.

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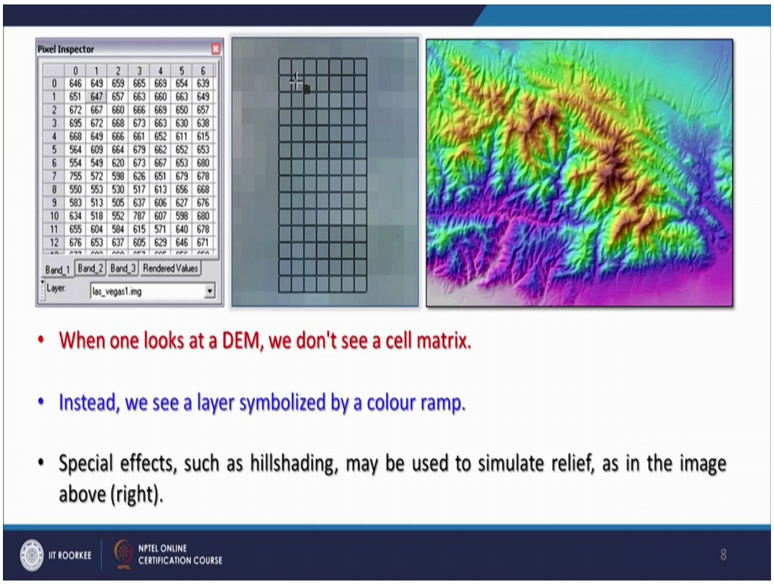

This is how a DEM looks, when we zoom it and we want to read the values then we can see here that a these values though there is a lines which are marked here, but in fact, these lines are not there at all. It is just for our own understanding the lines have been shown here for this matrix, but they there is a cell of a square shape, and each cell will carry away a value that value might be elevation value.

Now, so, we do not see this a lines as I have mentioned instead we use or see a layer symbolizing by a color ramp or may be a grey scale, and a spatial effects such as hill shading which is a product or after processing of digital elevation model can be created quite easily we will see how it can be done or may be used to simulate relief as in image which is this is the example. So, the DEM which you have seen earlier one in the black and white or in shades of grey, one in the color, if we imply this a hill shade or shaded relief model in short we call as SRM.

Then we can illuminate that surface and therefore, the same digital elevation model can be represented something like this. So, now, it is giving you much more depth perception as compared to the simple digital elevation model as shown earlier in black and white. Now because a both image may be remote sensing image or a digital photograph and a grid, both are raster and some people get confused. Definitely both are raster, but there are some differences between a raster and a means between an image and a grid.

These are the things that both are raster models and the shape of all rasters, raster data models can be either rectangular or square and unit of raster or DEM is always square in shape, this we have already discussed. Now what are the differences? The major difference between an image and grid is it depends on the value the cell value. So, in case of image we call as the unit we call as a pixel, and a pixel you know is abbreviation which is picture element because the value in a settle remote sensing image or in a digital image is not as the cell value in a grid or in a DEM.

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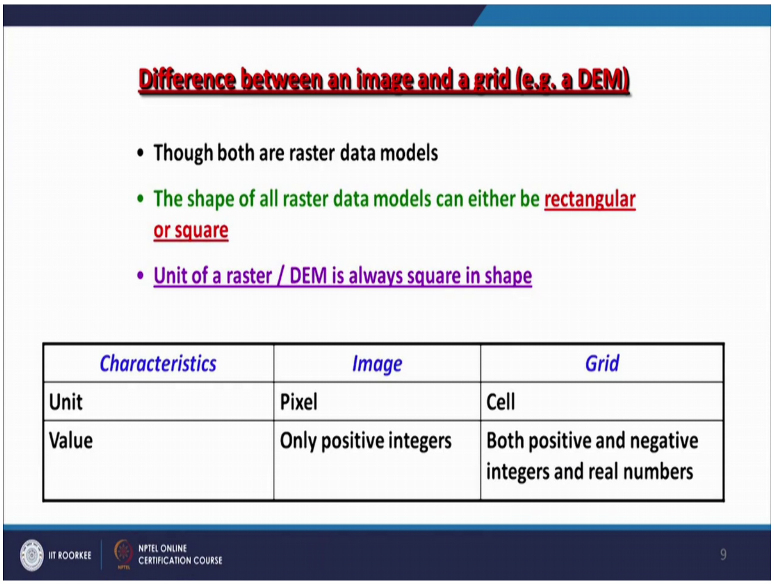

Characteristics	Image	Grid
Unit	Pixel	Cell
Value	Only positive integers	Both positive and negative integers and real numbers

So, that is why a different name is given for the, that is picture element or pixel. And value a in terms of a you know the, what value it will carry in case of image it can be only positive integers values whole numbers. Now if it is a eight bit image then the values can be for individual cell can be between 0 to 255, but if it is less than that then we will have less variations in the values, but if it is a more than that then we will we will have more variations in the values. But all cell values or pixel values in case of image will only be positive integer values. But the advantage with grid structure though that is also raster like for example, digital elevation model we call the cell as cell instead of pixel and it can carry both positive and negative and integer and real values.

So, all kinds of values a grid or DEM can carry what is the why it is required, because if we are preparing a digital elevation model or handling a digital elevation model which is of a coastal area. Now some values are above mean sea level some values are going to be below sea level therefore, we require positive values as well as negative values as well. So, that is why a the structure has been made in such a way that these positive and negative elevation values can be accommodated, further that we also require in a digital elevation model not only the least count is a say 1, we can have even 0.5 0.25 and so on so forth.

That means instead of integer values we also want to have real values of a my requirement, may be one place of decimal may be two as per the accuracy of a models are there. So, therefore, grid cell values can be either both positive and negative integers as well as real number. These things have to be remembered because otherwise both are raster, but these two major differences are there. We call as a pixel instead of cell in case of grid we call as cell and the values in case of image are only positive whereas, in case of grid positive negative both integer and real values are possible.

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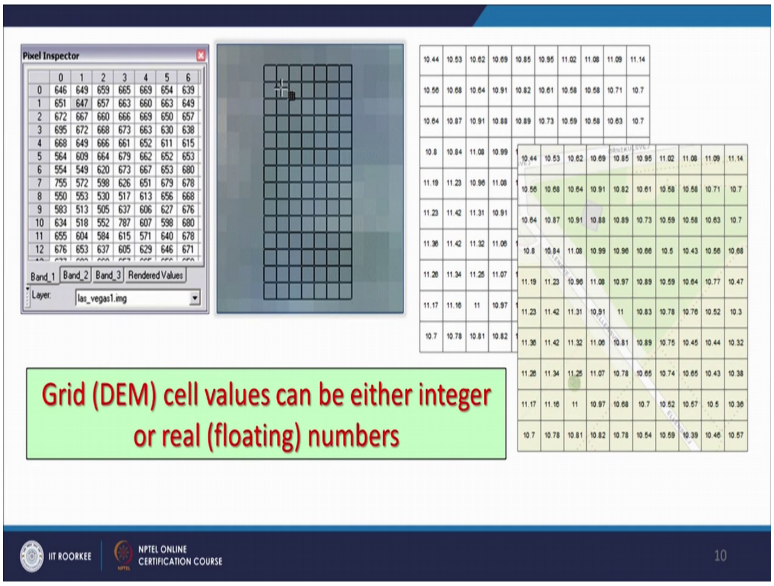

Examples are given here that the on the left side it is a repeat example all values here are positive, and a this is representing this is how it is represented in a n mage whereas, on the right side you are seeing the values r in real numbers. In this particular example we do not have some values which are in negative, but they are not a integers they are all in real numbers only up to two decimal places, but if it is required we can have more precision in our data and can go for three or four decimal places.

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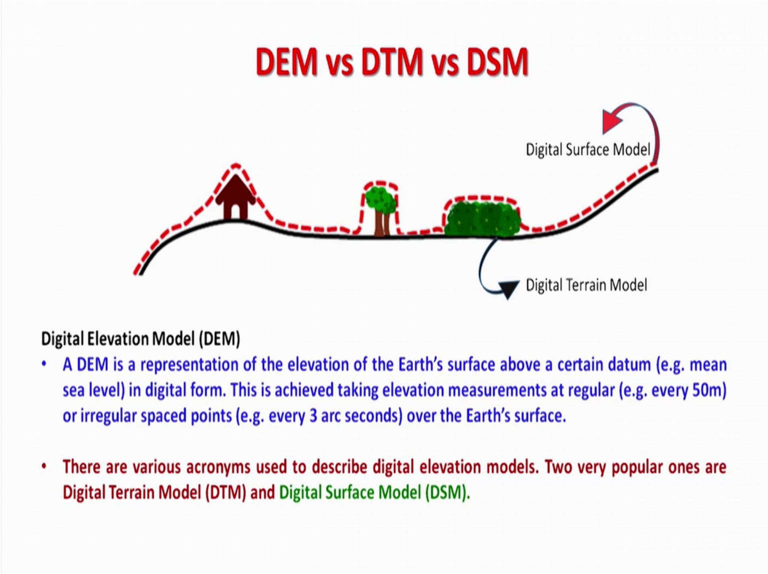

So, grid values cell values can be either integer or real floating numbers, now there were three terms which were we used some people use interchangeable sometimes it is very difficult to even demark it, the boundary between DEM and DSM, but the none the less we will try to see the whatever the minute differences which exist between these three terms digital elevation model DTM that is the digital terrain model, and DSM. As you can see in this figure is schematic that this the digital surface is encompassing whatever is on the surface of say for example, surface of earth that; that means, the height of the house height of the tree or both all are in incorporated in the digital surface model.

So, it is truly a representing a digital surface model, where as in case for digital elevation model it is only minus all these objects it is incorporating only the digital surface of the earth. So, this shows that; what is the difference between digital surface model and digital elevation model. A DEM as you know is a representation of the elevation of earth surface above certain datum that is above mean sea level in a digital form. It is achieved taking elevation measurement at regular that is every say for example, 50 meter depending on the spatial resolution acquirement or irregular space point that is for every arc second 3 arc second for example, over the earths surface and there are various as I have mentioned acronyms used to describe digital elevation models and two very popular ones are digital terrain model and digital surface model.

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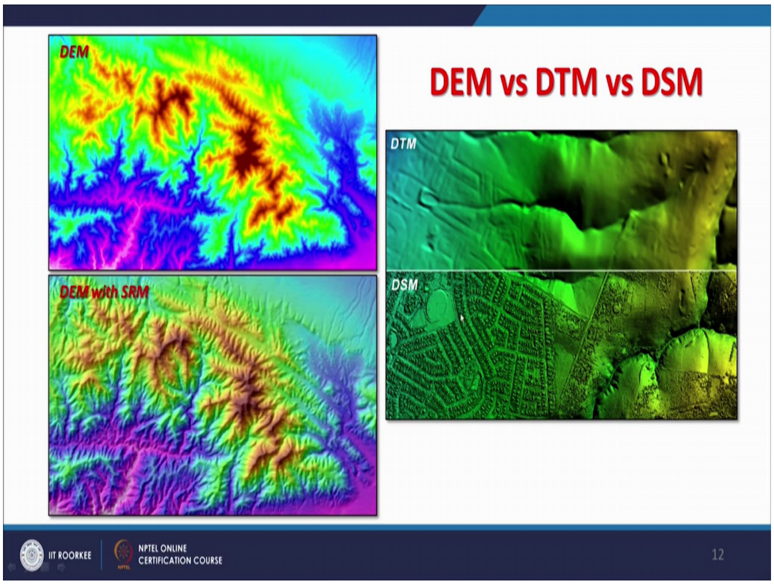

So, these two terms are also there, like here one is this DEM with a SRM that is the shadow relief model we are having in the. So, this is a typical DEM represented in color this is the same DEM here hill shading has been done and a therefore, we are seeing better representation of the terrain otherwise in the top example it looks like a flat. Except the different colors values are telling some elevation, but here in the shadow relief model or in hill shade things becomes very obvious.

So, this is very good a output of a DEM, and a this is this is these are the differences which one would observe in case of DTM and DSM as I have mentioned DSM represent the top surface of the earth. So, whatever the objects which are present all that surfaces included, in case of like Lidar and other when we imply these techniques to create a surfaces, we generally create a product which is called DSM whereas, for the may for the same area DTM will look like this.

So, this is, but generally what we the processing which we perform ultimately is on digital elevation model. So, there we use or assume a bare surface without humanly created a objects or vegetation or any other thing.

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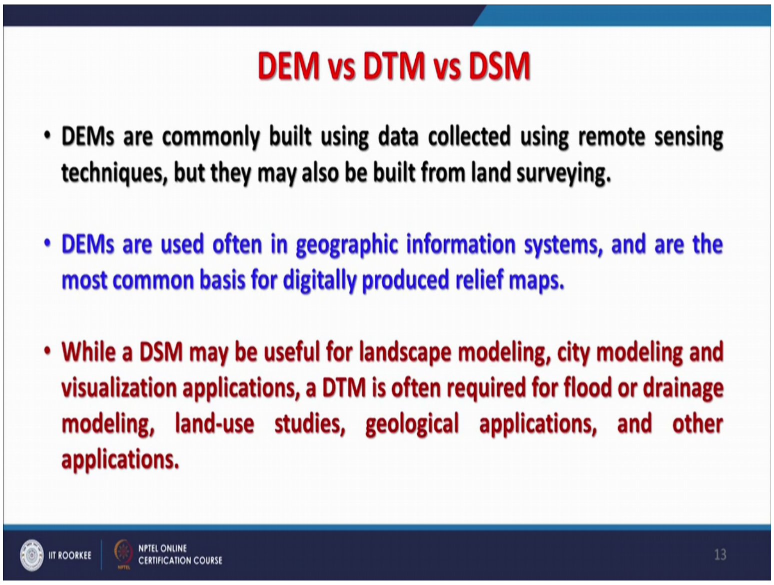

So, DEM are commonly built using data collected using remote sensing techniques which is has become very popular in recent years, and we will be seeing earlier we used to have a land surveying techniques may be using you know like a theodolites or a later on these EDMs or electronic distance measuring machines or a electronic theodolites total stations, and now also we employ digital this differential GPS or DGPs.

Remote sensing technique is most popular therefore, it became possible to create even digital elevation model for almost all parts of the globe. And DEM are often used as I have mentioned in the beginning, in the GIS we use extensively DEM drive various products or derivatives from DEM and then use these products along with some other datasets to create some new scenarios. So, that is in length we have discussed a about a how a GIS works, how different things are there, but in this particular course we will be more focusing about mainly about the digital elevation model. And most common basis for this is a digitally produced relief maps because this give you the feeling DEM will give you the feeling of a terrain surface and therefore, while employing this thing we can drive various products and plan things accordingly.

While a DSM that is digital surface model may be useful for a landscape modeling, city modeling, visualization applications, a DTM is often required for flood or drainage modeling, land use studies many geological and other applications there we employ these. Further there are a as I have mentioned also, that there are no universal uses of term digital elevation model. Some people still call as digital terrain model and digital surface model and a, you will find the usage of these terms, but the most common one in most of the cases people call as a digital elevation model, they would like to prefer to call as a digital elevation model.

So, digital surface model as I have mentioned that using Lidar technique that creates the digital surface model later one can remove that surface over the earth surface and can create a digital elevation model. So, there are a DTM represents the bare ground and whereas, DSM includes a your whatever is present on the surface of the earth, and DEM is also used as a generic form generic term for DSM as well as for DTM.

So, DEM is a most common term which is used and sometime instead of calling DSM people just in simple terms it calls a DEM. Basically one has to remember the structure the values it carriers and how it has been created. Because then it while using DEM you will realize that these things will matter lot while creating products from DEM as well.

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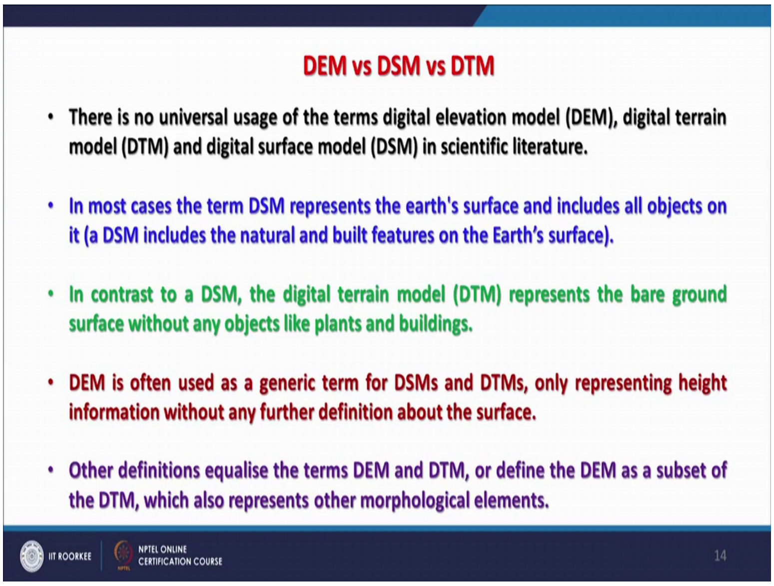

So, other definitions also equalizes the term DEM DTM define the DEM as a subset of DEM, some people prefer like this which also represents other morphological elements.

There are also definitions which equalize the term DEM and DSM, it is also define that that DEM is a regularly spaced grid.

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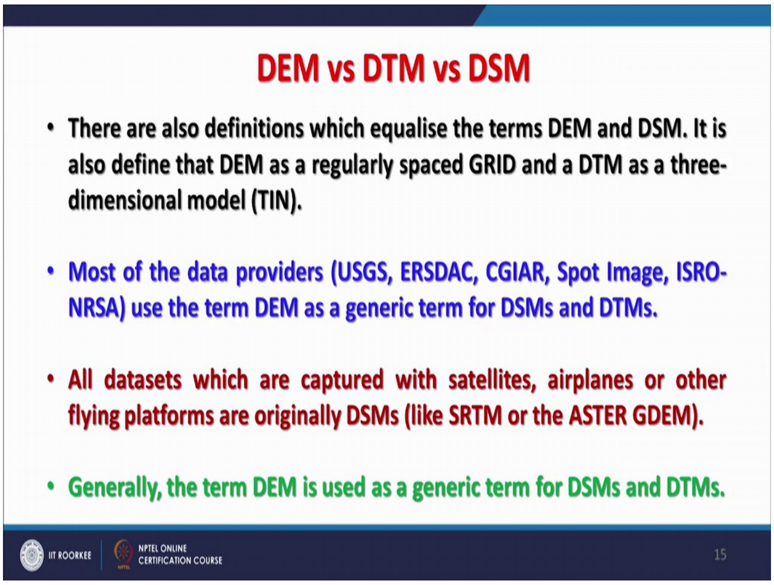

And DTM is a three dimensional model, but as I have said that if we use the z value that is the elevation value present in the DEM, and you implies some vertical exaggeration we too can create a 3 D model. And best example is like in Google earth the two main datasets are there one is the, a satellite image is acquired from various satellites dragged over a digital elevation model, and when we zoom it we see in a 3 D, because that the z value or the elevation value is enhanced through this vertical exaggeration, and therefore, we start seeing things in 3 D.

So, DEM can also be used to represent terrain in 3 D as well. Most of the data providers for example, USGS, ERSDEC, CGIAR, Spot Image, ISRO of our own India which is through an RSA use the term DEM as a generic term for DSM and DTM, because this is most popular term for all these terms. So, DEM is the most popular which encompasses this thing, but there are differences as we have already discussed. All datasets which are captured with satellites a aero planes and other flying platforms are originally DSM because they encompasses the surface vegetation house or any other thing, but later on a through processing we basically create DEM.

So, there are examples of like a SRTM, which was a mission and this global digital elevation model for about 80 percent part of the globe was created, and other example is Aster GDEM which has been created using photogrammetric techniques using stereo pair data. So, different techniques all are remote sensing techniques employed and different digital elevation models have been created.

Generally the term DEM is used as a generic term as DSM and DTM. Now as we can see further that DTM is a DEM, now this is another way of explaining that a DTM is a DEM that represent the elevation of the bare earth without taking into account any over ground feature that is tree or buildings man made and whereas, the dc DSM encompasses the, everything.

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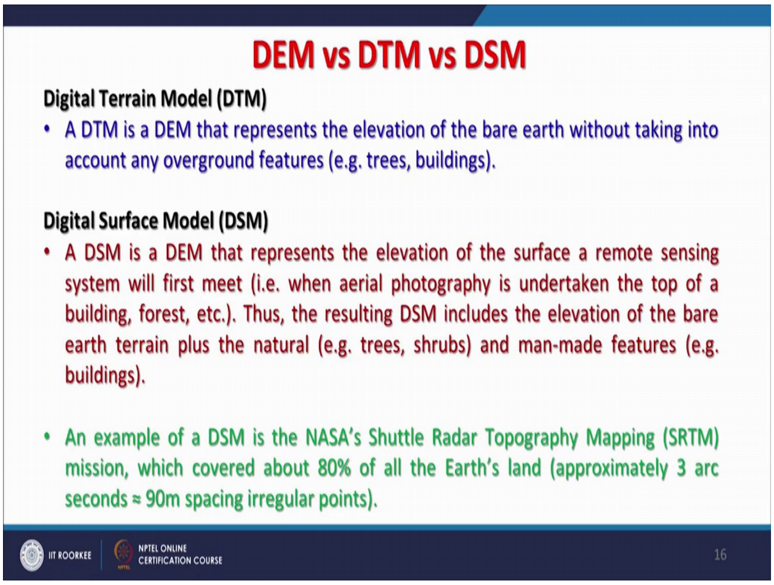

So, DSM is a DEM that represents the elevation of a surface or remote sensing will first meet when aerial photography is under taking or top of a building forest etcetera.

Thus the resulting DSM includes the elevation of the bare earth, plus the natural that is the tree shrubs and manmade features for example, building. So, in example of DSM is the as this SRTM which was created this SRTM DEM was created implying the sar interferometry technique, and which have covered about 80 percent of the earth and at 3 arc second that is 90 meter spacing later on also 30 meter spacing; that means, thirty meter spatial resolution DEM from this SRTM mission has also been created for 80 percent of the globe only the polar regions were missing because of the orbital designs.

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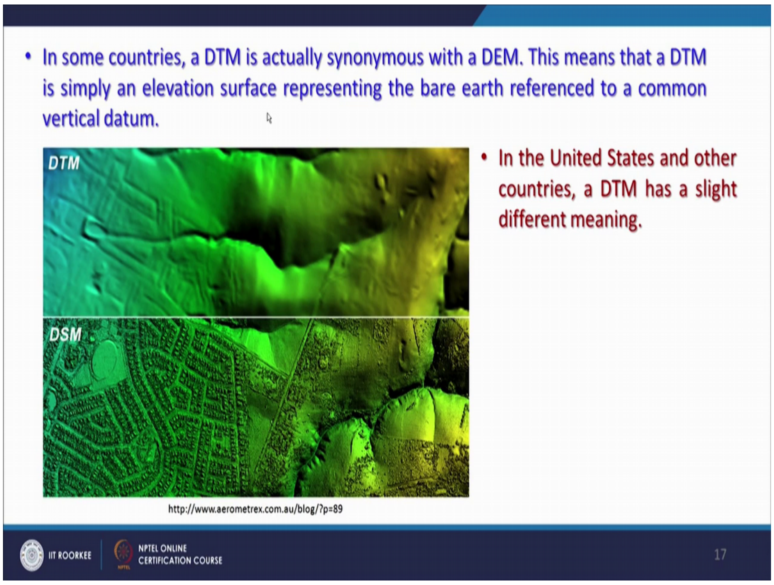

This on the left this figure we have already seen in. So, that just to again recall that how DTM will look how DSM will look, and in some countries DTM is actually synonyms with DEM this means that DTM simply an elevation surface representing the bare earth reference to a vertical datum. And like a in US or in other countries a DTM has a slight different meaning DTM is a vector data set, which is a not a really true in that sense because by definition all these are raster. So, different meaning will be there the best term which we find is using DEM.

Now, I will be doing some demonstration through softwares, how it looks over DEM, how in black and white it looks later on also u DEM with color, how we can change it without changing the original values.

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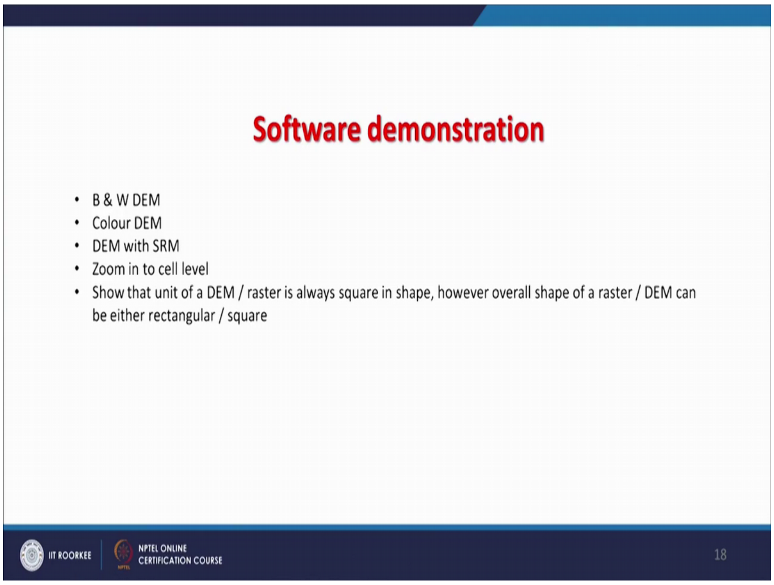

How a DEM and SRM that is schedule relief model or hill shade can be combined together and a new product very easily can be created, also we will be discussing how when you zoom to the cell level that is the unit level how it will look, how we can read the values, and that will show us a unit of a DEM and also it will justify that overall shape of a DEM can be either rectangle or a square whereas, a cell where cell level that is unit level is going to be always square.

A in this a demonstration of GIS software, I am going to use a very popular software which is called a arc GIS it has got three components arc map, and arc catalog and arc tool bar. But initially in this particular demonstration I will be using only arc map and will show the how DEM looks and when we zoom it and other things then how we can see the details here.

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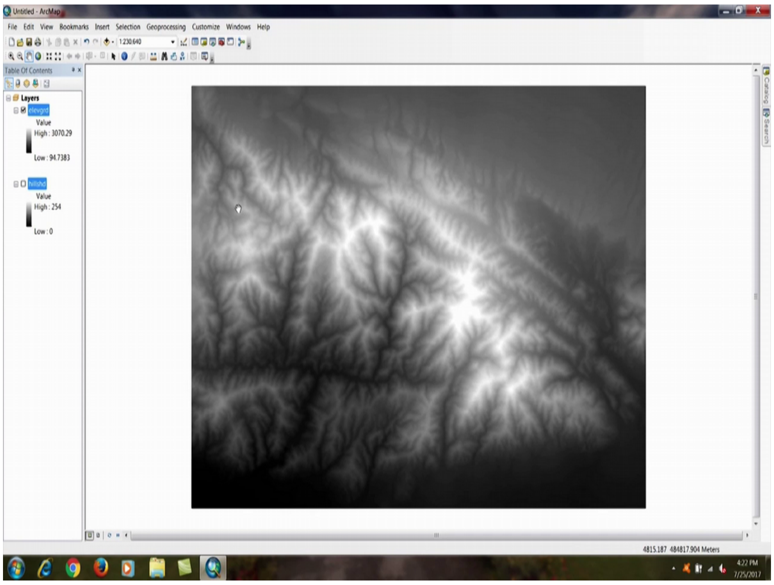

So, when I add a DEM file digital elevation file, it this is how it looks and as you can see that overall shape here is rectangular.

So, we can have basically any shape of on the display, but in the background because it is a two dimensional matrix and therefore, a the overall shape of a DEM or a raster has to be either rectangular or a square. But suppose if the area is arbitrary then how we will display, but the computer will store as a rectangular or a square, but the other areas which are falling about out of our boundary will be assigned no data. And if we assigned no data values to the color of the screen then we do not see or the background. So, therefore, we can see an arbitrary, but that demonstration will be done little later, but first here that overall shape of a raster is always either rectangle or a square because it is a two dimensional matrix, and if I zoom then we can see even up to unit level.

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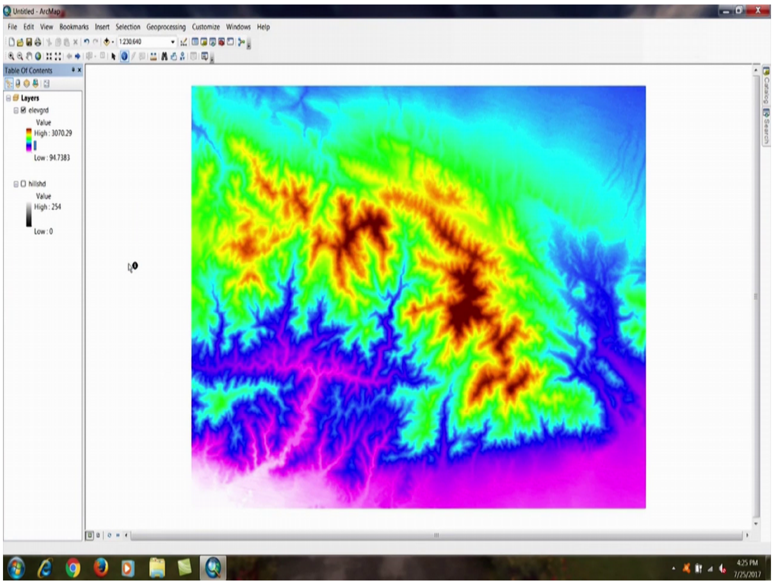

So, if I am like I zoom here and zoom further, now I can see individual cells of this grid. And we know that we have reached to the pixel cell level and therefore, with in a cell the cell value will be always same here.

So, like here in this case the value say coming 142, in this cell wherever I will click it will be always 142. But if I go here then this is the next cell and definitely a new value will appear. So, another important thing is the shape of the cell that is at unit level in case of raster or in case of DEM, it is always a square. So, as mentioned in earlier also that the overall shape of a raster or grid can be either rectangular or square, but unit of raster or DEM will always be square, but in case of 10 triangulated irregular networks, the unit triangle and all triangles might have different shapes and sizes. So, that thing we will be seeing much later.

Now, as also mentioned the DEMs can be either displayed in the then gray scales like here currently or we can change the palate. So, if we want to say display the same DEM in a already available palates, we can do it by applying this one. The important thing is that the cell values have not changed except the palette has changed. So, only the instead of assigning colors between two extreme members black and white, now here the colors have been assigned between say magenta true dark brown color.

So, this is one palette scheme we can choose many there are many palette scheme.

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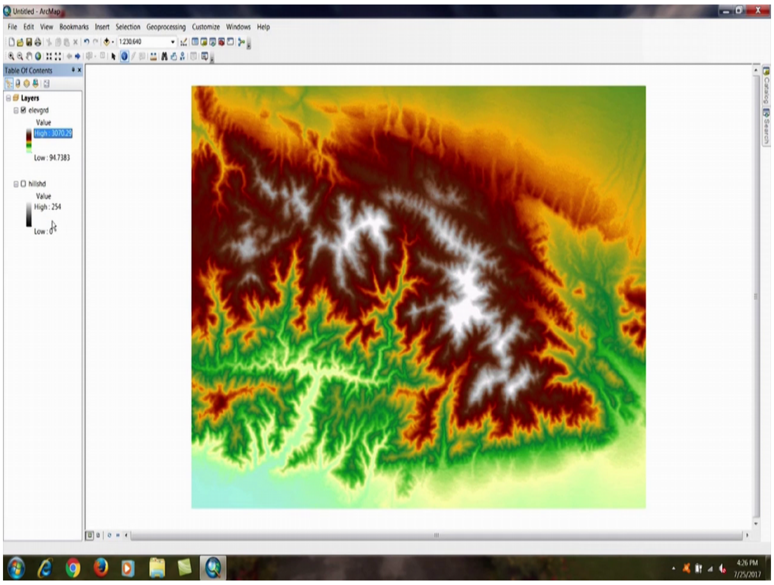

Some are standard palette schemes are available for relief representation. Because it is a DEM, this is that color scheme which is used for relief representations. So, here and by some standards we know that at certain level we get the snow fall another thing. So, therefore, these areas have been shown as void indicating that these are the very high grounds, and some lower grounds are there at they at those levels the vegetation is expected therefore, these are being displayed as green. But and in nature it may exactly it may not be there, but in this DEM model we have this one

So, I am going to as showed to you, I can display in any of these color palates and there is a not much problem.

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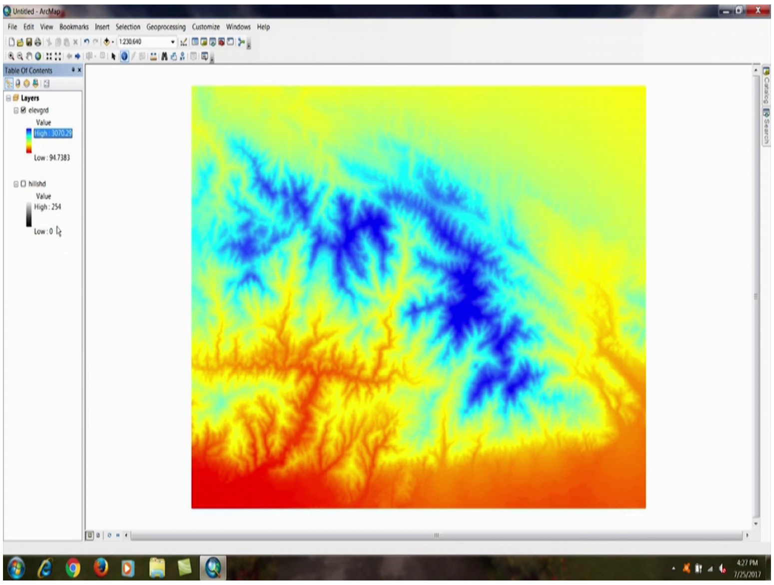

Now, thus the same DEM can be used to prepare a hill shade like this.

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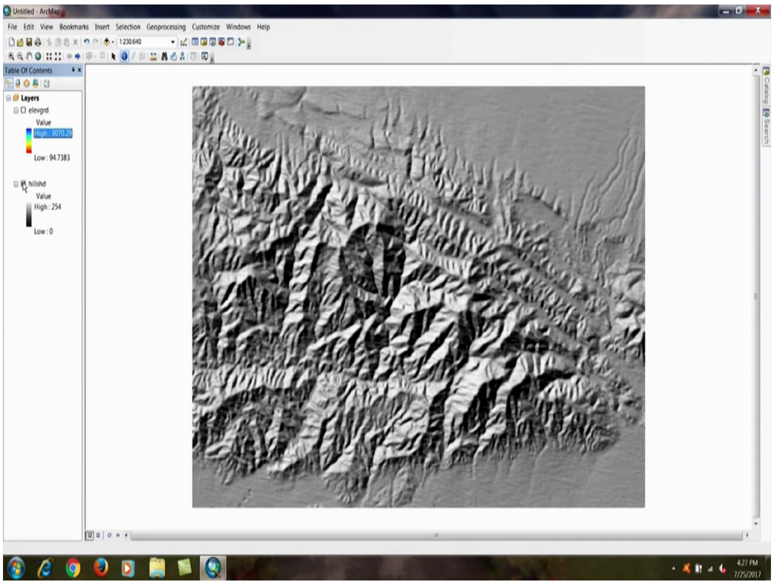

One and here the shadow of the slopes will also come, and that is why it is called hill shade or shaded relief model, how these are generated that we will be seeing in subsequent lectures. The important thing is here by exploiting the capabilities of softwares, we can generate some beautiful products here this is black and white this is having colors. So, when I display one top of another then I see only the top one, but if I go and change that transparency level here like here in the display I go for 50 percent transparent that top layer that is the simple DEM is now having 50 percent transparency. So, what will happen the hill shade which is just below will also start seeing here, and this is what we see.

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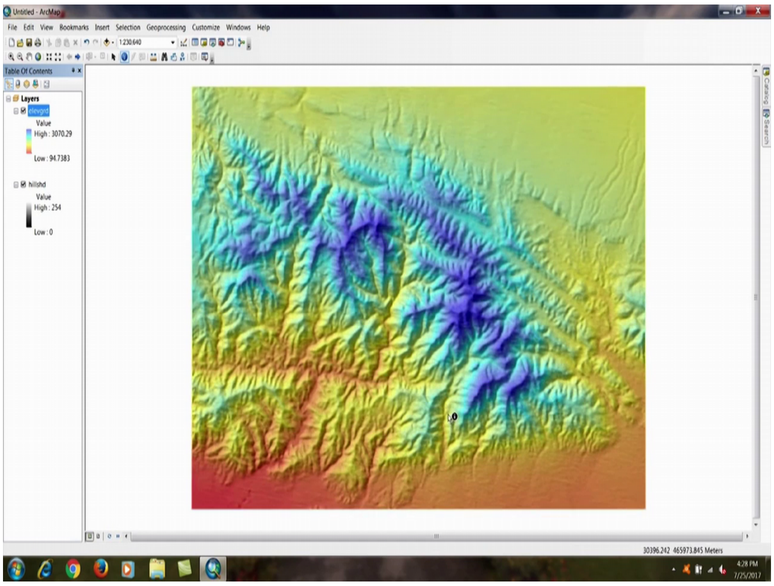

So, now we are having a shaded relief model with some beautiful colors. So, just playing with the capabilities of software different tools, we can really bring a lot of a new things in to our presentations. Important thing here is we are only doing all these changes which I have demonstrated here through this particular software, is only at the visual level at the screen level. The data that is the digital elevation model or the product or digital elevation model that is hill shade, will are will remain intact no change in the values except in the colors.

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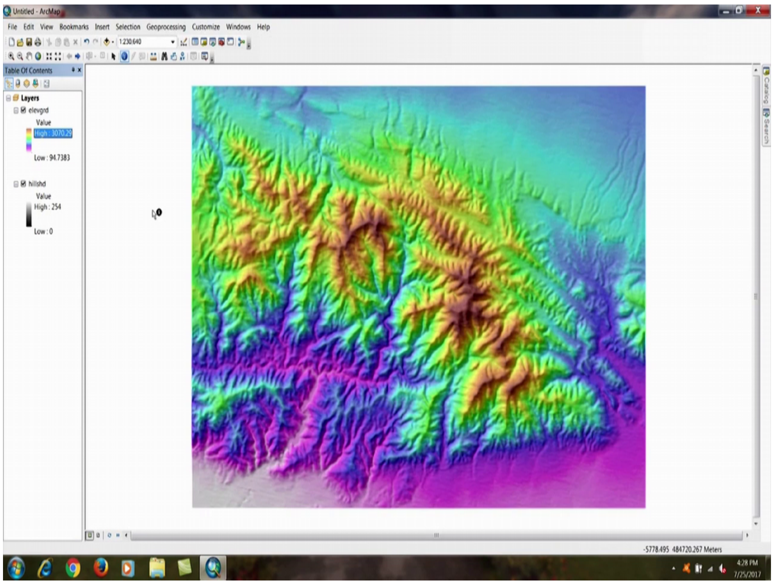

So, that is the advantage of this thing and this is achieved by a technology or concept which is called a look up table. So, through look up table we keep changing these things we can save also, but not as a separate file, but as a project. So, project of if I save as a project, the project will store the look up table. But it will not create a new dataset and therefore, it will not unnecessarily occupy your hard disks.

So, this a care we have to take that all the time we need not to save a as a new file, but just will shape the whatever we have perform the processing which we have done like in this case hill shading, and that to in color. So, by taking this advantage we can really develop lot of beautiful products for various uses plotting and other things.

So, in this particular lecture as we have discussed basically what is DEM, how it is represented, what are the different terms used, and what are the differences between DEM, DSM and DTM and at unit level what are how cell values can vary and so on so forth.

Thank you very much.