Introduction to Geographic Information Systems

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Lecture – 04
Raster data model and comparisons with vector

Hello friends, and welcome to the fourth lecture. And in previous lecture I have discussed different types of a vector data, if you recall that I mentioned the data and GIS can be divided into two major components; one or two major types of data; one is spatial data, another one is non spatial data, we also call them attribute data. Then we discussed different type of vector data, and point data, line or polyline data, polygon data.

Now, in this lecture we will be discussing about what is basically raster data, and types of raster data as well. So, raster data is having two types; one is the grid type data, another one is the image type data. There are no much differences between these two, but still the differences between this two, must be understood very carefully, because otherwise while analysing the data, or handling such data may give you such problems. So, understanding about the integrities of two different types of raster data, is very important. We will be also comparing, seeing the advantages associated vector data as well as raster data, and this we will be doing little later part of our lecture. So, first the raster data as you know that as a continuous data, vector data I mentioned is a discrete data. So, there are two different way of representing the real word; one it is in discrete manner using point line or polygon, may be in the tin model which we will discuss later, but the topic which we are going to discuss in detail, is the raster, in a continuous fashion we discreet, we represent the real word.

Now, in raster world what are things which are there, or key things which are there, that it is a uniform grid? You can imagine that if it is a real world scenario, then a uniform grid is lead out on this two. The concept of this two is based on sampling theory which is called Senan. Senan was a mathematician, who gave this theory which is sampling theory. What does it mean here in our GIS parlance, is that if you represent the real word in a continuous equal size cell grid, then each cell is representing an average value of whatever present on that part of the earth.

For example, if you if you are having the agriculture land, within a say ten meter by ten meter area, there might be variation in vegetation or say wheat crop or some crop, but everything is average down; say for example, greenery or may be production over anything, is average down and a single value a value is assigned to that cell, that value becomes attribute value of our raster cell, and that is why in case of vector, we can have several attributes or theoretically n number of attributes which each vector entity, but with raster cell or raster pixel, we can have only one single attribute; that is one of the major difference between vector and raster. Apart from that a raster is a continuous vector is desecrated, discontinuous data.

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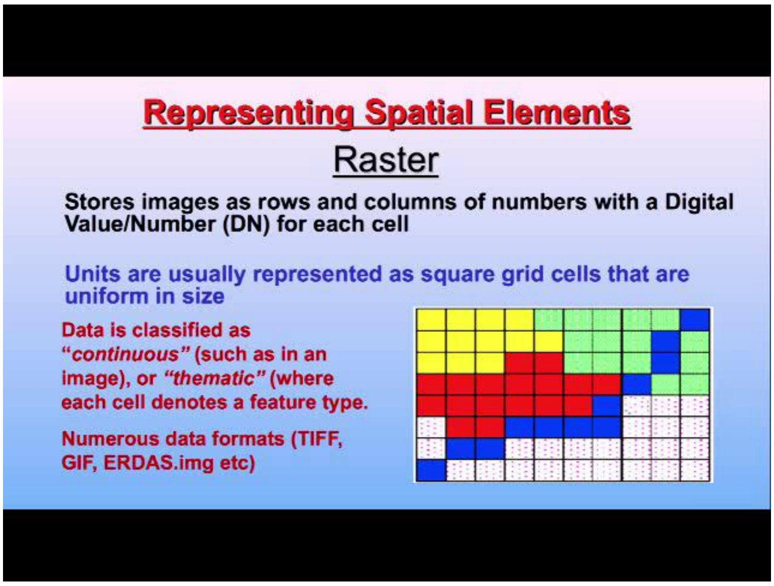

As you can see that data is stored here in a two dimensional matrix, which you are having a set of rows and columns. Now number of rows and number of columns need not to be seen, as you know in in the matrix and mathematics, this is also not compulsory; that means, I can have a rectangular size of my data raster data, or I can have a square shape, but apart from these two shapes, I cannot have raster in any other shape. However when we are representing raster for an arbitrary area, and then there are some concept are applied which we call as no data concept, and by using no data concept on our screen or our visual, we see arbitrary boundary for a raster. In fact, in the system for the outside area it is stored as no data, and for inside that polygon it is stored a real data.

So, fundamentally the raster overall shape of the raster will have to be always either rectangle or a square, because it is representing mathematically a two dimensional matrix. Now each cell in case of grid we call as a cell, in case of image we call as pixel, we will see little later all these details. So, each cell will represent one attribute one value it may be in case of remote sensing data, it may be reflection value, it may be emitted value, it may be temperature value, or in normal case may be rainfall value or any other value, but only single value per cell or per pixel, and the this cell or pixel becomes the unit of our (Refer Time: 05:58) or raster. And another important thing has to remember that the shape of this unit has to be square. So, overall shape of a raster can be square or rectangular; however, shape of a unit has to be always a square.

So, that we maintain the uniformity. Now though mathematician worked on this, and rather that constraining that each (Refer Time: 06:25) each unit has to have the same shape, they came with a new idea that instead of a square we can have triangles, of varied size and shape, and that brought the concept of tin which we will see little later. So, that a unit of raster is always is a square; overall shape of a raster can be square and rectangular, and a each unit of raster will have only one single attribute; not like vector data. So, raster is a continuous, and we are, generally familiar when we are handling the image raster,; then there are image formats like tiff g peg and g I f and different image processing software, are having their own format; like erdas is having its own image format which is very popular one is IMG format. So, there are you know there the data this is how it is represented and then the cells are having.

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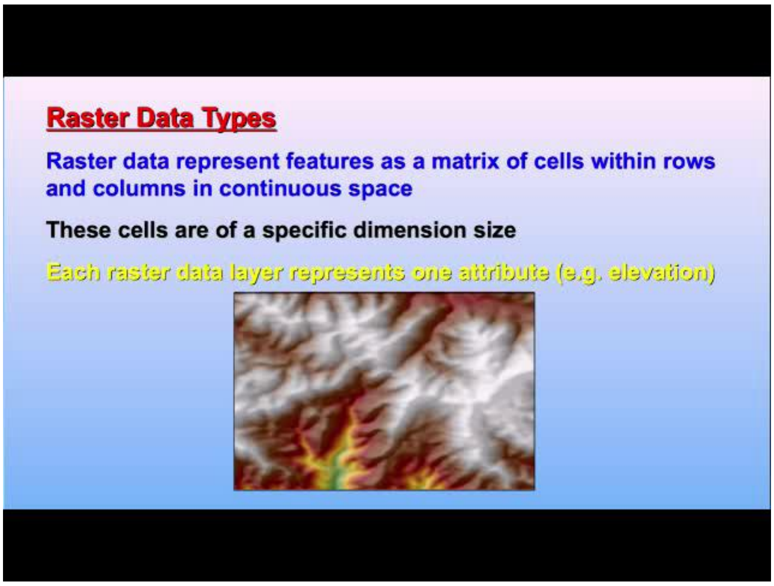

Now the size of a cell can vary, it is not always one meter one by one meter or two meter by two meter, but the shape is fixed which is square, but the size of the cell can change larger the area, the cell is covering of a raster. We say a smaller the spatial resolution, or poorer or courser the spatial resolution. Whereas a cell if it representing a very small area of the ground, then we call as a higher spatial resolution. For example, in a satellite image a one pixel might be representing ten meter by ten meter, and if we compare a another satellite image which might be representing, a pixel might be representing area of one meter by one meter; that means, the image which is having one meter cell or one meter pixels, is having higher spatial, relatively higher spatial resolution.

The spatial resolution term is a really a relative, for someone, for some applications hundred spatial resolution may be useful, but for another person even one meter spatial resolution may not be useful. So, we have to be thinking in this direction that is a relative term, as per our requirements we call as a higher spatial resolution, or we call a. About the spatial resolution how a different spatial resolution will bring the changes in our image which we will see little later in this presentation.

Now not only the satellite images which are handled in GIS, but there are other raster data, like a digital elevation model which is which is representing the undulation, or topography of a terrain, or part of the earth; that means, where are the higher grounds lower ground valleys hills slops and all those things, can also be represented in a form of grid or in raster, and each cell of that grid will be representing elevation value, and that is why it is called digital elevation model. Example is given here, and here that attribute of that cell of that raster or grid going to be your elevation value.

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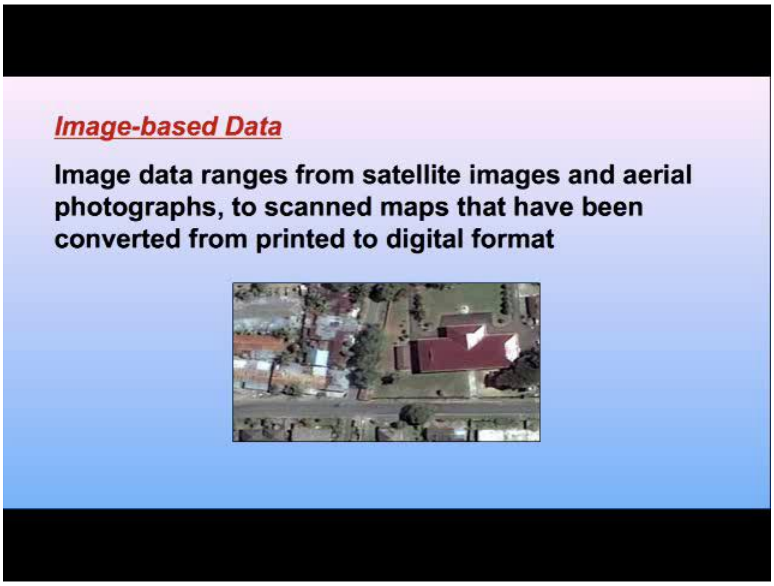

Whereas in case of image it might be having reflection value, or emitted value, or temperature value, or any other value is represented there, but in satellite images since this is coloured image; therefore, it is constructed using three primary colours, and therefore, you are seeing in colour, but still all are raster, and different type of raster which is a your image raster.

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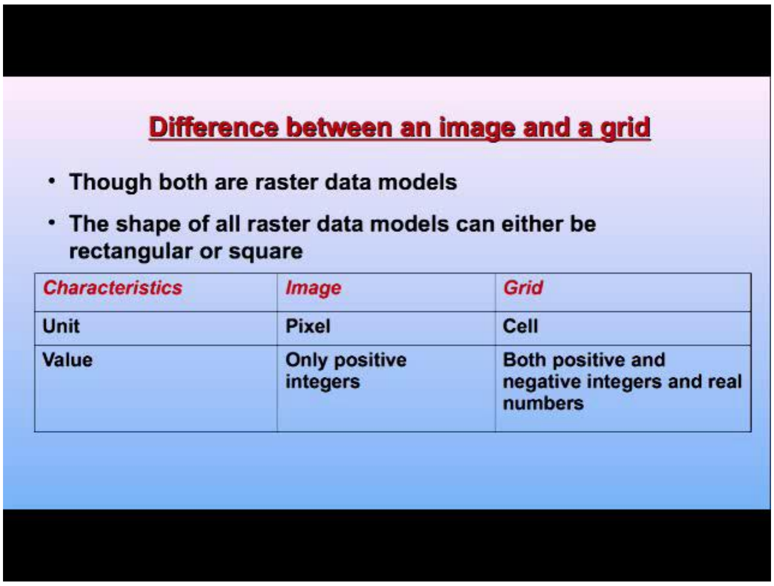

So, as I have already mentioned earlier that there are both, you know both are image and grid both are raster model, however there are differences in case of image, the unit we refer as pixel, pixel in aggravation, which is pixel element, and a the cell in case of grid the unit we call as cell. This makes a while you know calling differently and also gives us advantage or understanding, which is required for the next property, or next characteristics, which is the value of the image pixel or value of the cell. In case of image the value of the pixel can only be positive integer value. We cannot have no other value and; that is one another big difference between an image and a grid. Whereas, in case of grid the cell value; that means, the unit value, can be either negative or positive integer or real numbers. So, variety of value can go in case of grid data, but in case of image data only positive integer values.

So, these two major differences are there, when we say pixel; that means one is talking about image and once a person is talking about an image that the unit value of that image; that means, the pixel value has to be a positive integer value. And when I say cell value; that means, I am talking about grid, and the cell value can be either positive negative integers or real values. So, the grid is having more capabilities or bringing or handling all types of all types of integer and real numbers; whereas, the image can only handle the positive integer number. So, this difference has to be remembered, because if we do not a take care about this, then because the format for grid are different, then format for image.

Image format we are familiar because now a days we use these digital cameras, and which are also inbuilt in mobiles most of the time we are storing images in JPEG, but we can change the format, we can store the image, and all are these image formats and; that means, we are storing pixel values as positive integer values. If you get sometime you can open some images, zoom it and read the value, you would always find a positive integer value. Now, the next thing is which I test little bit about spatial resolution, which is very important to understand.

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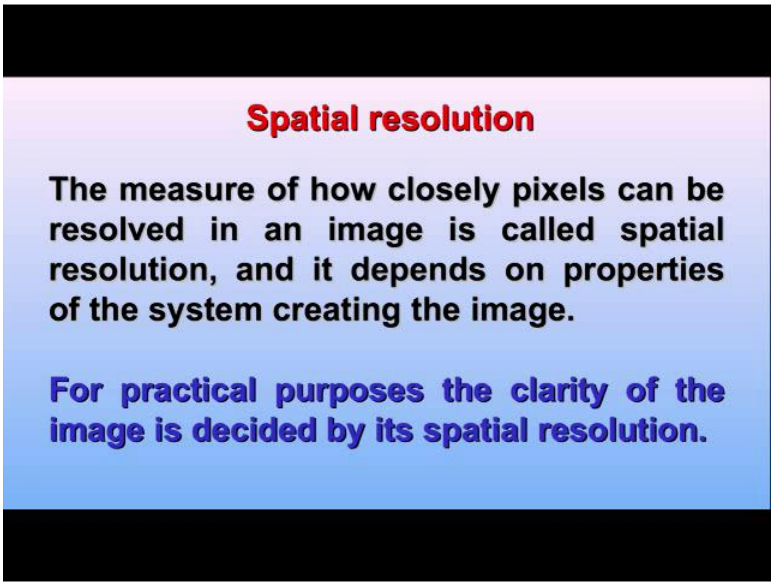

Because this is related to, though it is a related term, it plays a very important role in our day to day life as well as in GIS system. And as we go by the definition is a major of how closely pixels can be resolved in an image; that is called spatial resolution, and it depends on the properties of the system creating the image. Now if what does it mean that if there are two neighbouring pixels are there, and if they are having very you know a contrasting properties, they might appear in a particular scale, they might appear separately. So, if you take a digital image, may be taken by your mobile camera putted in computer zoom it to a very high level, after sometimes you might realize where the two contrasting things are there, you might realise, two pixel or neighbouring pixels are showing different colours or state. So, when you reduce the scale, or zoom out you know what happens that these starts resolving, and then individual boundaries of the pixels you will not see.

Now, in our domain that is in GIS or in remote sensing, this is what we say the clarity of an image, which is decided by the spatial resolution; that means, a an image which is having very high spatial resolution, should be looking much pleasing to eyes; that means, might be that it is having higher spatial resolution; that means, the number of rows in order to cover the same area, number of rows and columns are going to be more, and; that means, the ground area which that high resolution image is representing; that means, one pixel of that image is representing is very small, comparing to image which is having relatively low resolution. So, sometimes we like in digital mobile cameras we say; ten mega pixel, twelve mega pixel, eighteen mega pixel; that means, we are talking about the dimension of the image. So, larger the mega pixel, the clarity of the image would be higher, higher the spatial resolution.

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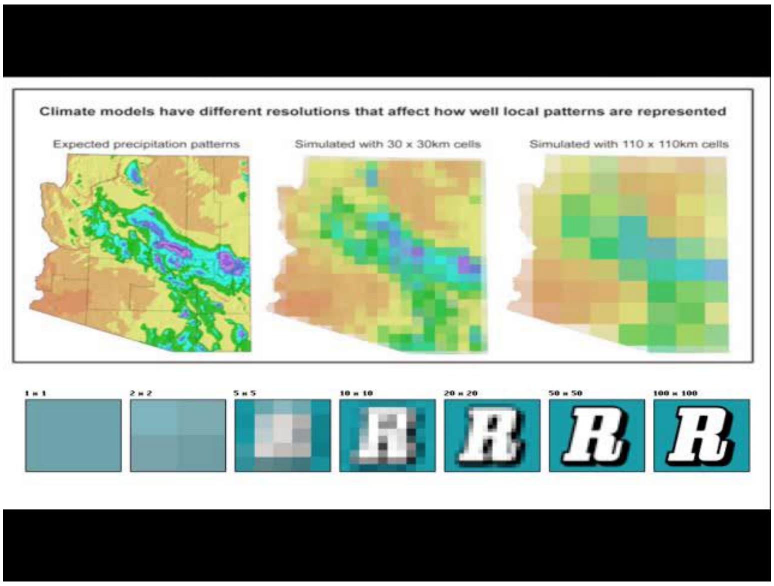

The example is given here, that here the spatial resolution is 110 by 110 kilometre and you are unable to resolve adjacent pixels; and therefore, you are seeing the boundaries of pixels it is a relatively very course image, but when you make this representation is a using a finer grid, and the having a resolution of thirty kilometre by thirty kilometre cells, then at least a some clarity has been introduced in this middle stage, but if a if a you improve further, and then a individual boundaries of two neighbouring pixels are resolved then you will start seeing a much more realistic image; and that is relative having much higher resolution image then the right most image.

Same thing here that, this is one by one; that means, there is nothing no differentiation is there one pixel only. Whereas, here two by two; that means, there are total four pixels, all are having different colours, but we cannot make out what it is written there, or what is what object is within this four pixels, but once we start moving and you know segmenting this area into finer size pixels an image start appearing. Here in 10 by 10 it appears may be r may be a alphabet, but here it starts appearing as a r much clearly, but by 50 by 50 and 100 and 100 becomes much (Refer Time:17:37). So, the right most here, is having very high resolution, relatively as compared to the first two three four or five. So, this is the major difference which resolution, especially spatial resolution causes in our representation of raster data, or that might be a grid representing a digital elevation model, or might be a satellite image, or photograph taken by your digital camera. Now as I have already mentioned that vector is a discrete raster is a continuous model.

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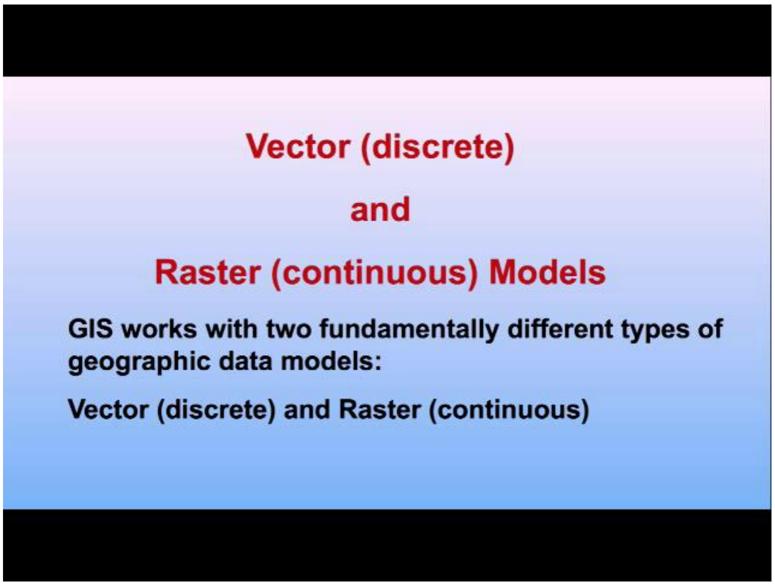

So, now, we will try to compare and see what advantages are associated with vector data, and what other advantages are associated with raster data, that these data sets are fundamentally completely different; vector and raster.

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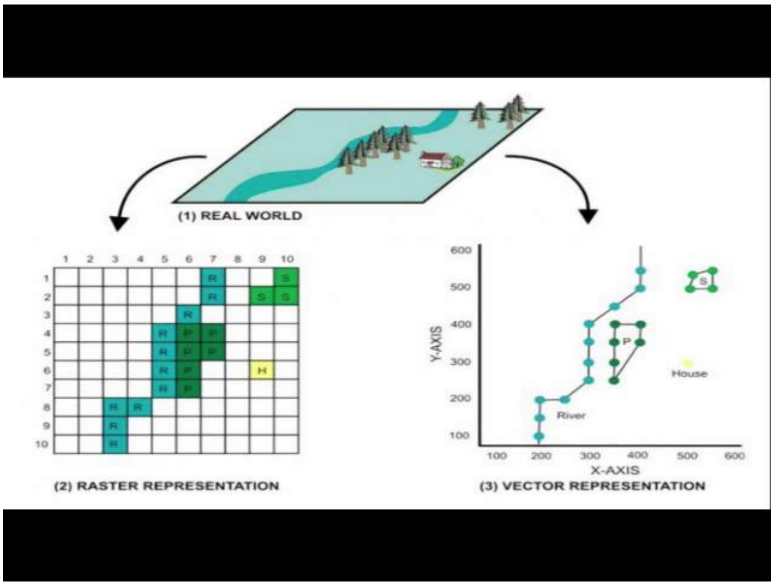

And if a real world has to be represented in these two formats then you can see that if real word is represented, which is very simple word of a real word that you are having a stream, you are having a say agricultural land in the background and forest and a house. If I have to represent that one in the vector, then the house is going an area here, depending on the scale in a smaller scale that house might appear as a point data, but here as a polygon, and same with the forest as a polygon. Whereas, a stream though in this state image, it is looking that stream is occupying an area, but here I am representing as a line feature; that means, only length no area. And if I have to represent the same real world into raster, then house will have this much size; one pixel is representing house, two pixels are representing forest, and then few pixels or cells are representing steam or the river here.

Now you will realize that I can increase number of nodes in case of vector, and can make my line very smooth, but in order to make my line smooth, or a steam representation much more a smooth, then I need to increase the spatial resolution; that means, the representation through my raster has to be with very small cells, and that means, I am going to occupy more space on my computer, if and more handling or processing time, if I go for higher and higher spatial resolution. So, it depends on your project requirements, Nowadays all types of all types means, all variety of spatial resolution data are available. For example, if I take digital elevation model, and I take the example of free available digital elevation models, then starting from one kilometre spatial resolution digital elevation model to up to 30 meter spatial resolution digital elevation models are available. Now but what is the purpose if you are going for a small are area and you are going in much more detailed analysis, then it is always better to go for higher spatial resolution digital elevation model.

But if you are covering a very large area a large region or a continent, then it is not birth going for a high spatial resolution, it is better to go for relatively course of spatial resolution may be ninety meter, may be one kilometre resolution. So, it depends on the requirements of your project and what kind of products you are going to generate after all analysis in g n a.

So, variety of spatial resolution, digital elevation model, same with the satellite images nowadays satellite images of 30 centimetre resolutions are available, and satellite images of one kilometre resolutions are also available. So, again if you are doing analysis on continental scale, then you need not to go for thirty centimetres, because the data handling is going to be very use, and you may not be able to handle data on a one single machine, using standard stand alone GIS software, having a very high spatial resolutions data for a continental area. So, it is always find out what is the best and then bring in your GIS software and do the analysis. All types of spatial resolution data nowadays are available.

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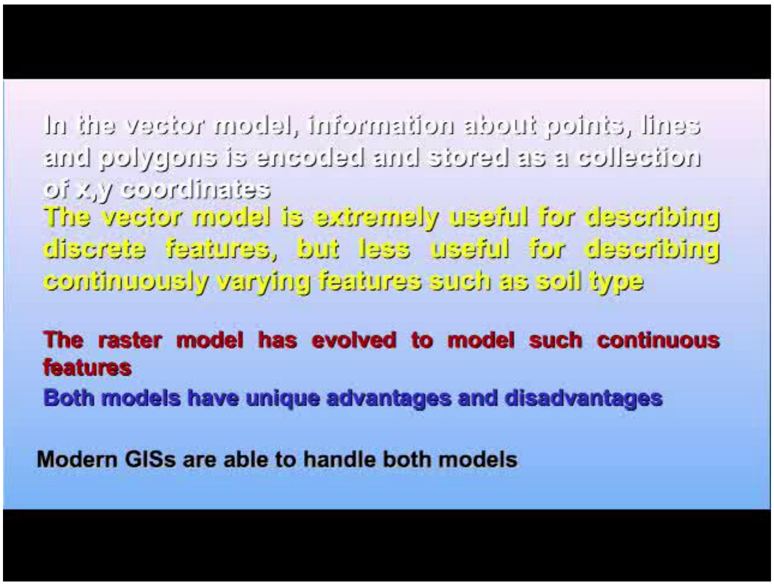

Now vector data models has been know that it keeps the data either point line or polygon, and which is a vector data for certain types of features is good, which are having discrete, but a certain types of things which are varying continuously, like for an example given a soil, may not be good to represent through the vector data, because soil varies in nature a very gradually, not suddenly, but if somebody is using for litho logical maps then we know, that litho logy changes suddenly sometimes, and therefore, may be vector may be useful in that way.

So, raster whereas, raster evolved is a continuous data, continuous features, both models are having advantages and disadvantages which we will see very soon, and the modern GIS are able to handle both types of data model, or rather three types of data model vector raster and tin. Another important thing is that a GIS are nowadays capable of transforming, or converting your raster to vector and vector to raster; however, with some limitations. So, little later we will be also seeing, how we can convert from raster to vector, and vector to raster. So, we start looking the advantages first with the raster data.

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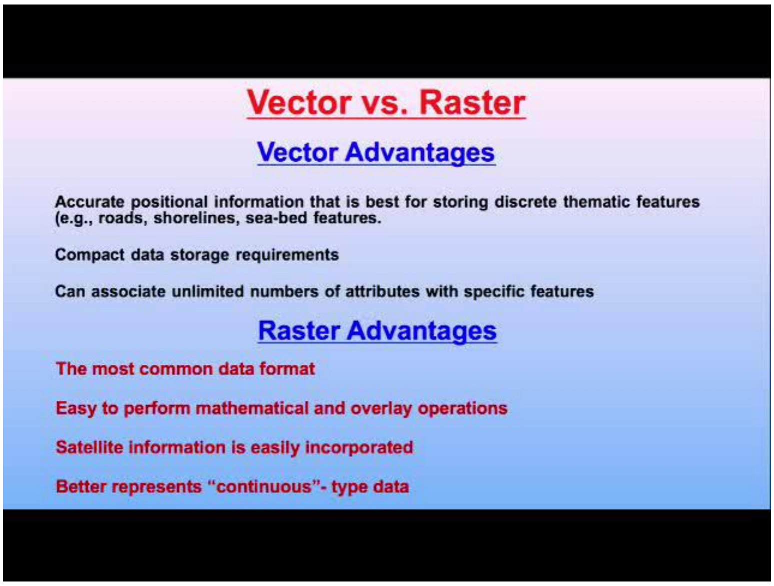

This is the most common and very simple to understand raster data easy to perform, because mathematically is a just simply a two dimensional matrix, and therefore, whatever the analysis tools which have been developed in matrix domain of mathematics, all can be implemented easily in GIS.

Secondly, all satellite images are also raster, and there are many functionalities algorithms and every capability have been developed, in digital image process software, and therefore, the same things have also been implemented into GIS. So, raster, because concept wise it is simple, and therefore, lot of tools are available to analyse the raster data. I have already said about the satellite data, because the satellite data becomes one of the very important data input into your GIS, because it is easily available, it is a continuous data and with almost you know every day you can have some satellite data, or another. Whereas, the advantage vector, the biggest advantage with vector is accurate, because even for a house which might be in the smallest scale map, might be represented as a point, but in raster it will have an cell; that means, area. So, even a point will have an area whereas, as per the definition in vector point is the zero dimensional entity.

So, raster is not that accurate as vector, positional accuracy is very high in case of vector data, and it is compact, but it is discrete. There is no redundancy in the data. In case of raster you are having lot of redundancy, and then therefore, there are compression tools are available, to remove that redundancy, or reduce the size of for storage of raster data, but for vector data there is no redundancy. Once the topology has been built then redundancy is completely gone, and no compression other things are required. So, vector data is very compact, and large area data in vector format can be stored on a small computer space, and it has another advantage that in raster you can have only one attribute, but in case of vector you can have multiple. So, that is another advantage.

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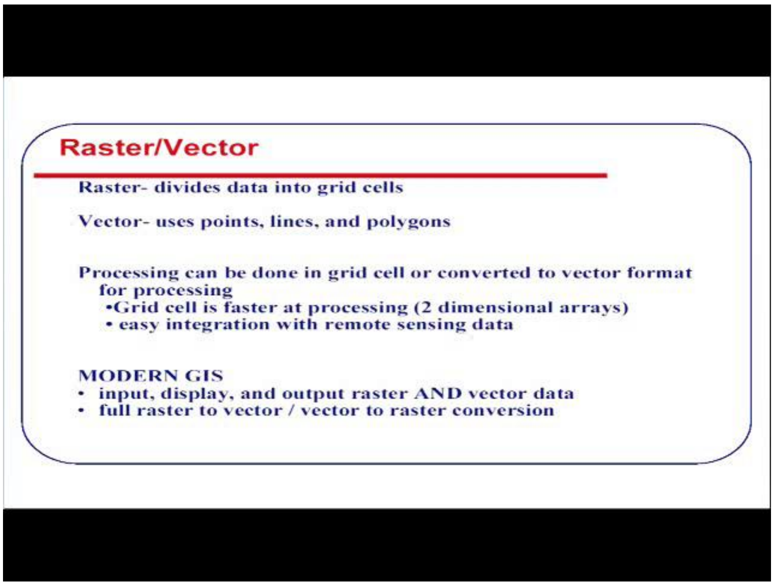

As we know that raster which we have already covered this part, the raster divides into grid cells vector uses point line polygon, units in case of vectors are point line polygons, in case of raster, either cell or pixel. And this processing can be done with grid and convert it from vector to raster, and all modern GIS software supports all three types of data handling.

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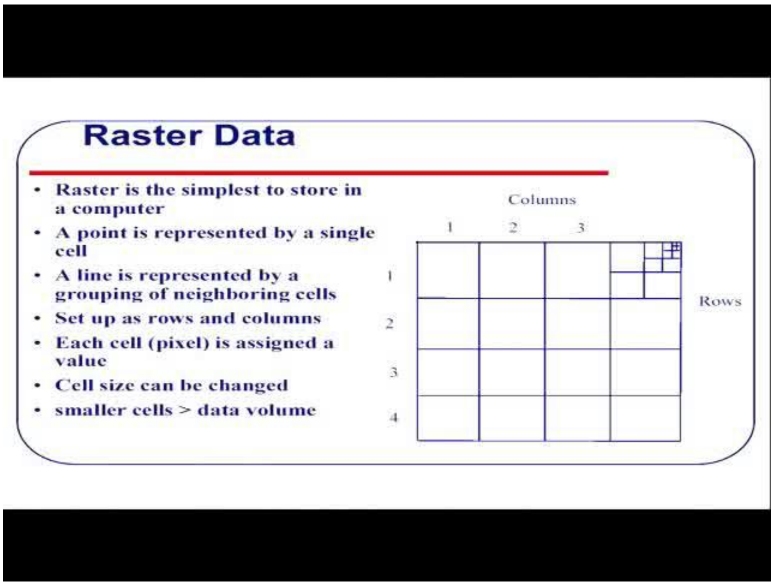

Raster has we go finer and finer in the grid cell or pixel size, we go for higher and higher resolution, and latter onwards, the size can be changed, but resolution spatial resolution cannot be real, in real sense cannot be improved, but on computer point of view you can create more number of rows and columns and therefore, a smaller size cells are there. Now, let me take an example of a soil map. As I have said that soil map, soil is continuous varying feature, but sometime we have to represent as a polygon map. So, example here is different types of soil map is represented in a polygon map, but if the same soil map, if I have to represent in a raster, then I have to represent something like that. So, both vector and raster representations are there.

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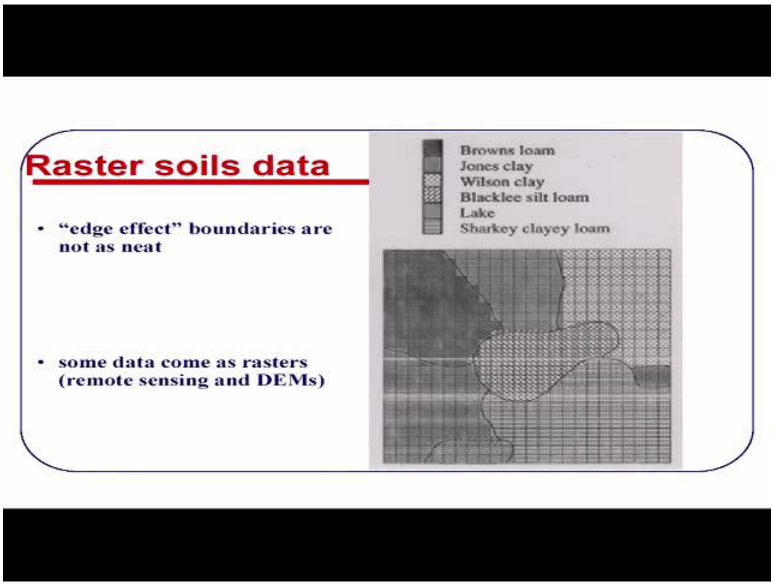

And what you will see the boundary line of two soil units in case of raster, you are seeing a starry steps case, or also called edge effect of the boundaries; that means, the boundaries are not sharp, and as mentioned earlier in case of vector, the positional accuracy is very high, relatively very high as compared to raster which you can also realize. So, on the edges of two different units, the boundary will have this edge effect or stair steps case, something like stairs which are there, but if you improve the spatial resolution that if you go for final spatial resolution, then it might not be that much obvious, but anyway at every state of raster, at the boundary then it is going arbitrary then you will have this edge effect. So, that is one of the disadvantages with raster.

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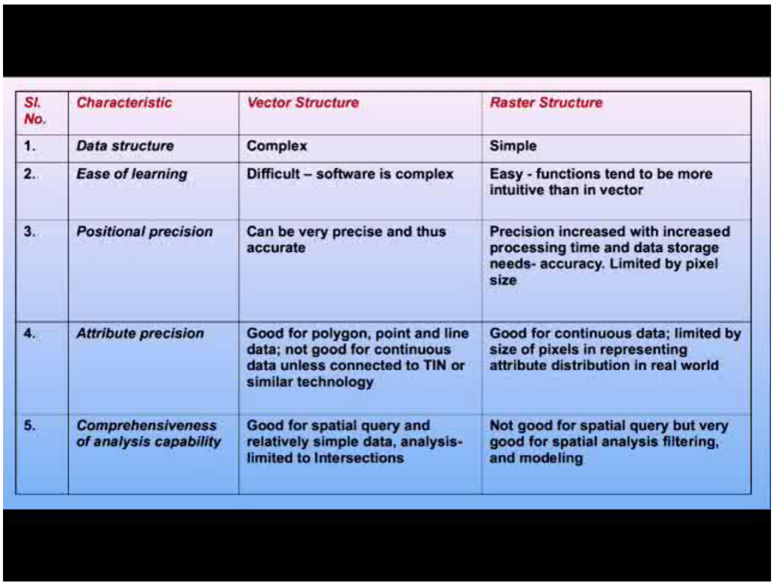

Sl. No.	Characteristic	Vector Structure	Raster Structure
1.	*Data structure*	Complex	Simple
2.	*Ease of learning*	Difficult – software is complex	Easy - functions tend to be more intuitive than in vector
3.	*Positional precision*	Can be very precise and thus accurate	Precision increased with increased processing time and data storage needs- accuracy. Limited by pixel size
4.	*Attribute precision*	Good for polygon, point and line data; not good for continuous data unless connected to TIN or similar technology	Good for continuous data; limited by size of pixels in representing attribute distribution in real world
5.	*Comprehensiveness of analysis capability*	Good for spatial query and relatively simple data, analysis- limited to Intersections	Not good for spatial query but very good for spatial analysis filtering, and modeling

So, finally, what I am going to do. I am going to run through all these things with the raster versus vector, using different characteristics one by one, and see that what are the advantages with vector and raster. First we characteristic which we take is the data structure. By now you must have realized that the vector, because of topology and different types of vectors, relatively vector data is little complex then raster, because raster it is easy to understand, it is easy to handle in computers. So, raster is very simple data structure compared to vector data structure, and therefore, anything which is simple is much easier to learn. So, the ease of learning is also accordingly, that a vector is having difficult.

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Sl. No.	Characteristic	Vector Structure	Raster Structure
6.	*Overlay ability*	Good, but overlaying many layers can cause many splinters, etc. in the result which are difficult to eliminate	Because all pixels line up, overlay procedures do not create problems
7.	*Storage requirements*	Relatively small but complex	Relatively large and simple but may be complex
8.	*Ability to work with image data*	Poor - data must be vectorized first	Good - uses same kind of data structure
9.	*Conversion to other map projections*	Usually included in package and relatively simple to do	Difficult and quite often creates warped images which do not fill the raster, causing problems with neighborhood functions
10.	*Ability to work with network data structures*	Good - because system can handle lines	Poor - raster structure not amenable to network
11.	*Cost*	Expensive	Inexpensive
12.	*Output map quality*	Very good - looks like a map	Poor - doesn't look like a map to lay people

Softwares are complex and expensive, whereas, raster one is much simpler. Positional precision as discussed already that a vector provides very high precisions, and when your data representation is very accurate, precision wise, accuracy wise then you will have a better outputs. In case of raster the output also becomes little difficult. So, precision increase with increase processing time, and data storage, also precision here will also increase with increase of a spatial resolution. Now, attribute precision it is very good in case of vector, and you can have n number of attributes associated with each vector entity point line polygon, but in case of raster it is limited only to one entity, or one attribute value.

Compressiveness of analysis capability, it is good for a special query with some limitations, when it comes for intersections, especially when you are overlaying two polygons together. We will say some examples for such limitations. How these have been resolved in GIS that we will also see, but still it is limited in GIS. Whereas, in case of raster; no issue, no problem, because this raster will stack one of another one thing, and if they are belongs to the same coordinate system and same area, even the spatial resolution is different, does not matter they will stack, and you will not find any difficulty while analysing such raster data layers.

The another characteristics which is overlay ability with vector is good, but after sometime you start seeing splinters; that means, lot of polygon will come after overlaying four five polygon layers, and interpretation or uses of such maps becomes very difficult, but in case of raster that problem will never arise. Now storage requirements as we have already realized that vector require little less storage. it is discrete data it does not require much storage, and therefore, though it is complex, but it is easy it requires less space. Whereas, raster is simple, but it requires more space, because of redundancy in the data, and when we will discuss the raster data compression techniques then we will go in detail, how what basically redundancy affects the raster data, ability to work with the image data. It is a not as good because image data is raster and, when you are working with the image data and vector data you will have problems. whereas, if you are having a image data image data is also a raster, your grid data is also raster, no problem what is (Refer Time: 32:37).

Conversions to other map projections map projection we will discuss in another lecture. So, when we go for different map projections, vector is very good, and most of the GIS modern GIS softwares include change of projection from one projection to another. And if you are having data in vector format it is very easy to convert from one format to another, one projection to another, but with raster data it is rather difficult, and it becomes, note the accuracy part will also come in between.

Now ability to work with the network data structure, because the vector data why I say, because line data I gave the example that most of this networks, like power grid or sewage line or telephone lines or o f c line all are networks, and they are stored in computer or in GIS softwares as vector data, and therefore, if you are working in that domain then it is very good with the vector data, but it is with the raster; obviously, it is very poor. Cost expensive vector is expensive, because each and every node has to be digitized; either wise some semi automatic method, because yet there is no fully automatic method to convert vector data from analogue to digital.

So, maximum the best possible methods are available, semiautomatic methods with the human intervensense, lot of human intervensense, and therefore, and the vector data is expensive. Whereas, as raster data is much easier, and that is why lot of free digital elevation models which are in grid format, which is raster free satellite images are available on the net now a days. So, it is not that expensive, because in one go a satellite can cover a large area, but it is not possible with vector data, and also the output map quality. Here now vector is having advantage very good and looks like a map; whereas, you raster are poor and does not look like a map.

Another problem with a raster data, vector, because a laymen or normal people, those who do not know much about GIS or a such a fields, they are familiar with the vector data maps. They have being seeing since very long, maps which are having vector data, but people are not very good on seeing or interpreting satellite images or raster data. So, that is why many times though we may be doing lot of analysis using raster data, but in order to make it is much simpler we might be converting finally, into vector. So, that our map quality becomes much good or better, and looks like a conventional map; otherwise a raster data, those who understand raster data for them it is no issue. Now, I want to cover this about the overlay ability, that I mentioned here that vector is having vector is having limited overlay.

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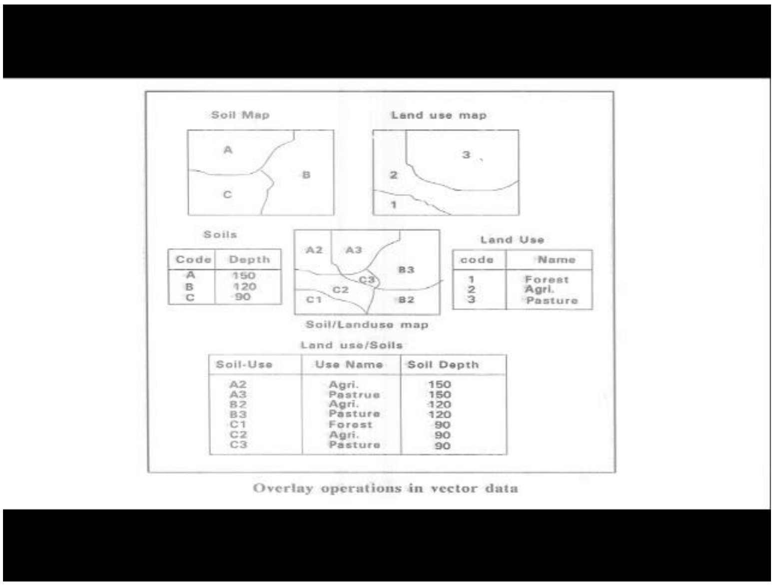

So, what does it mean here? That if I take example of two maps both maps are having three units each, so here there are three units a b c, and in landaus map there are three units one two three. They are very simplest example in real GIS operations this kind of simple operations are not perform many complex operations, and may be that you might be having node three units, might be 30 units in one map or 60 units in one map, but anyway in this example, which is very simple example, attribute one set of attribute which is for a b c, the depth of soil is given here. Whereas, in case of land use which are coder or iodiser for different polygons; are one two three, and what kind of land use in different unit of polygons are used for as agriculture and pasture. When we overlay this one on another, using like a transparent seat, using your set theory concept or Booleans logic, then this kind of intersection map will have a seven units now in this particular example.

So, we started with three units, and we ended up with seven units, seven polygons. Some have become very small, and imagine that you are having thirty units in one map and say thirty or forty units, or polygon in another map and such overly operations then you perform then you will end up with hundreds of such polygon, and therefore, the interpretation of such maps becomes difficult. In earlier versions of GIS even overlay of two vector polygons was not very easy, but nowadays it is not that difficult. So, one more field has been added; that means, one more attribute has been added, and initially each has single attribute now it is one more, under this id have also changed. So, you are having soil and land use. So, a 2 is having part of a and soil map and the second unit two of the land use map, and likewise you can have overlay even in vector data, to certain limits.

But if you overlay many vector polygon vector maps and then you will end up with very small a small polygon splinters, another interpretation of such maps or utility of such maps becomes very difficult. Now I also mention that a it is, now a days it is possible to convert from vector to raster and vice versa; however, with some limitations and whenever you convert from one format to another, one model to another you will introduce some errors, but only when it is most essential or compulsory, then convert from one format to another; otherwise originally if it is available in a raster format, keep it as a raster. If it is available in vector format keep it as a vector, because once you convert from one format or one model to another, you are bound to introduce errors, errors are inevitable, and as mentioned in the previous lectures that error propagates in GIS. So, our aim should be to keep the error at their minimum level anyway.

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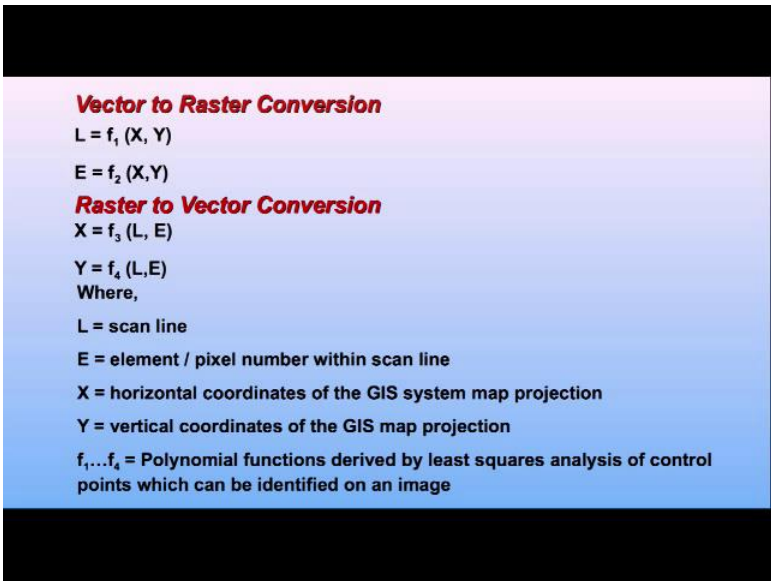

So, if I want to convert from vector to raster what I need to determine, I need have the row number and column number; and that is what here is, l and e l is the line number e is the element; that means, the column number, and these are the two functions f one and f two which are polynomial functions. So, again mathematical concepts are coming here again; polynomial equations are used not only in the conversions, later on extensively polynomial equations are used in geo referencing as well. So, when we will discuss we will go through different orders of polynomial equations, there also. And. So, here the input are x and y from your vector data which are your coordinates, and by using polynomial functions you will get line number and row number. Similarly in case of raster to vector conversion which is a just reverse, that we need to determine these two coordinates appear x and y.

So, again there are polynomial equations, and l and e; that means, line number and row number will go as input, and this is what it is, the line is the scan line or line number e is the element or pixel, x is the horizontal coordinate in the map projection, y is the bi coordinate vertical coordinate, and f 1 to f 4 are polynomial functions. So, this is how the conversion from one model to another model, is possible in GIS, but as I have mentioned, any conversion is not fully transparent; that means, it is going to bring some errors, because you know that now you know that vector and raster data models are two different contrasting data models, and therefore, you are bound to have problems when you convert from one to another format, and this brings to the end of this my presentation.

Thank you very much.