Geo Spatial Analysis in Urban Planning

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Module – 04
Modeling Geographical Space and spatial analysis
Lecture – 18
Urban Sprawl Characterization using Landscape Metrics

Welcome back dear students. Today, we are in the 18th lecture, in module 4, where we are going to see, how the Urban Sprawl can be Characterized using Landscape Metrics. So, in our last lecture we had talked about landscape metrics and we had seen that there are different types of metrics which can be used to characterize the landscape, in terms of the different patches of land use or land cover categories that we have in an urban area.

So, we can do a characterization of those patches using this particular index which is known as landscape metrics. So, let us see some of the applications of landscape metrics today.

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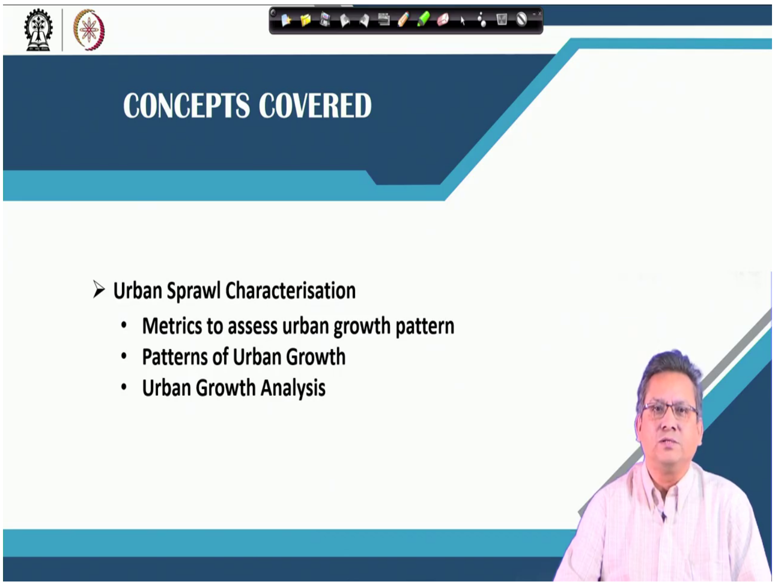

So, today's lecture is going to cover concepts and the very first one that we are going to talk about is urban sprawl characterization. Now, the next that we are going to look into is the metrics that can be used to assess the growth pattern in urban areas. We would be looking into the patterns of urban growth and we can do a urban growth analysis using such landscape metrics.

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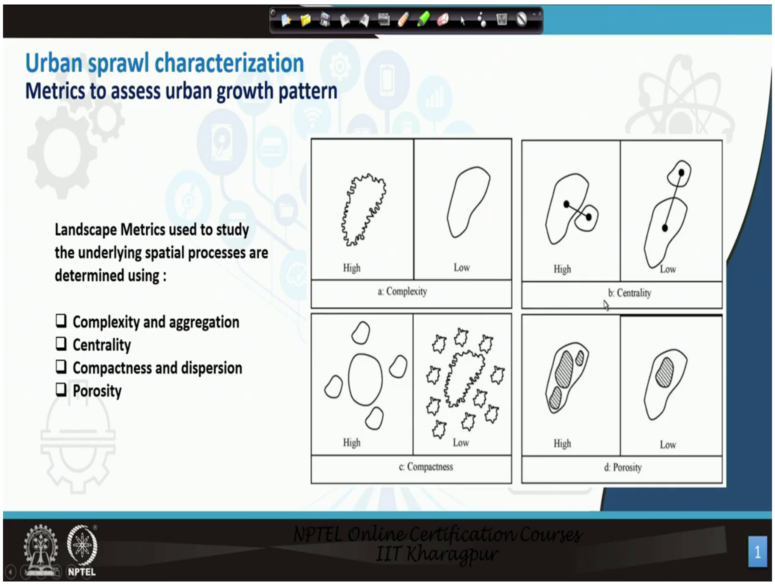

So, let us see first, what are the different types of metrics that can be used to characterize or assess the urban growth pattern. Now, there are different types of metrics which can be used to characterize the underlying spatial processes and we can determine these spatial processes, I mean by spatial processes we mean that the land use may change, it may evolve as, I mean compact forms into compact forms or it could be broken up into small fragments, what is the I mean your combination of the different types of land use in a given area.

So, all these can be studied. So, first we can assess the complexity or aggregation in a urban area, so, using this particular metrics. Then we can assess the centrality, how central this feature is or that particular patch is, we can assess the compactness and dispersion of the different patches in the urban area.

We can also look for parameters of porosity which basically gives us whether the your I mean whether there are any gaps to be in the urban area, where it could be seen as pores. So, in the first image you can see the example wherein, you can see in this particular image the form is highly complexed, it is serrated and the edges are really complex. So, this is an example of a complex shape of a particular patch, on the other hand you can see this is a particular very simple shape. So, its shape complexity is low.

Talking about the centrality, you can see that these patches are very close to each other. So, in this case the centrality measure of centrality is relatively high compared to another patch, wherein the centroidal distance of the patch is relatively on the higher side. So, here in this particular case, the measure of centrality as you would calculate using urban metrics would be on the lower side.

Now, if you come back to the next image, we can see an example of compactness in this particular figure. So, here you can see that the figures are aggregated and they have the shape complexity simple and they are aggregated, they are not dispersed and not fragmented. So, this compactness in this first case is high where is whereas, if we see the next image you can see the different patches.

So, if we imagine this to be an urban area, you may have different scattered patches. So, in this case the compactness is relatively low. The next one is the case of porosity. So, in case of porosity we may have a particular land use, which is land use or land cover which is given by this outer boundary and then we may have different classes within this particular class.

So, in this case you can see there are more than one classes or there are too many polygons inside this particular class or patch. So, in this case the porosity is very high, this particular class is porous. I mean there are other classes lying within this particular class. So, on the other hand if you see the adjoining image, in this case you see that you have this class which is bounded by this outer line outer edge and you have a internal polygon which belongs to another class.

So, in this case if you do a comparison between these two images on your left and right for this porosity assessment, you can see the porosity of this particular class that is given as white is much less than the porosity of this particular patch. So, in this case you have more number of pores of other class in this particular catch, patch.

So, we can do I mean study the spatial processes, depending on the complexity, depending on the centrality of the patches, depending on the compactness of the patches and also depending on the porosity of the patches.

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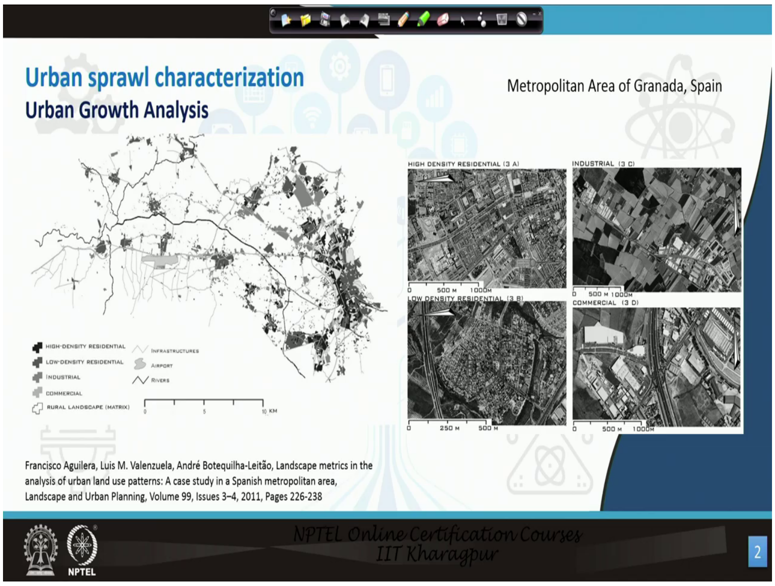

So, if we I mean do a growth analysis, I mean we can use these kind of measures to assess, I mean how the growth is evolving over time. So, let us see an example of metropolitan area of Granada in Spain and this study has been done by Francisco Aguilera.

So, you can see that this is the your I mean the land use plan of Granada city in Spain. So, in this particular region you can see that there is a, I mean compact centre and then you have outlying areas and you have speckles of growth. So, we can analyse this using the different types of metrics. So, I mean if we take images, you can see that within the image you can see high density residential areas, you can see the low density residential areas, you can see the commercial area and I mean industrial area and the commercial area at the bottom.

So, you can see that all these different images have got characteristic spatial I mean your distribution of the different land use patches.

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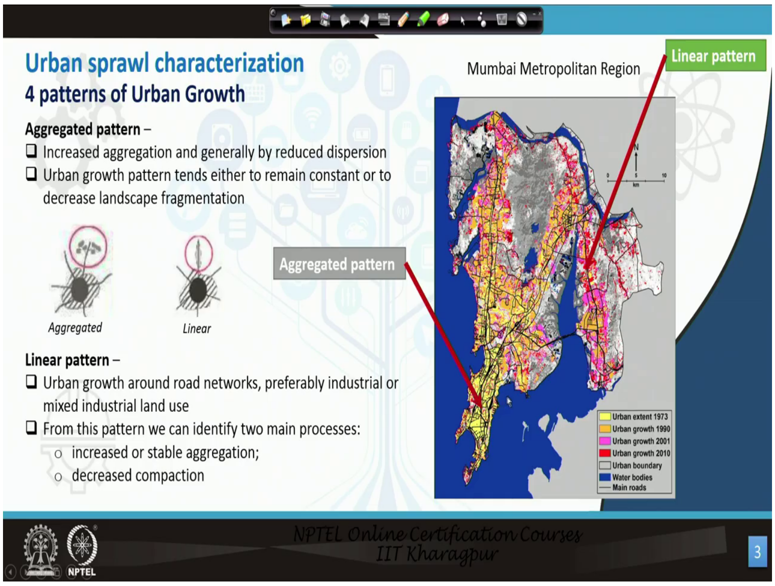

So, these can be analysed in the using your spatial metrics. So, there are four patterns of Urban growth in the last image we have seen the land use plan of Granada and there you can identify four patterns of Urban growth. So, we shall try to see the Mumbai metropolitan region and find out what are the different types of patterns of urban growth in the Mumbai metropolitan corporation metropolitan region.

So, first is the aggregated pattern which I mean is gives an increased aggregation and it is generally by reduced dispersion of the different patches, you can see the, result outcome as aggregated patches. So, in this the urban growth pattern, I mean it either remains constant or I mean there would be infill development and as a result it would reduce the fragmentation in the landings landscape. So, we can see in this particular example that we have this aggregated pattern.

Now, we have the next pattern we are talking about four patterns of organ urban growth the next pattern is the linear pattern. So, these patterns generally these kind of development generally happens along the road networks generally, these type of developments are industrial or mixed industrial residential land use. So, these happen along the major network corridors.

So, we can identify two processes from this linear pattern. The first one is increased or stable aggregation and the second one is decreased compaction. So, you can see this particular image, wherein it shows a linear pattern.

So, we are talking I mean we are seeing an image of Mumbai metropolitan region, wherein you can see that in the Navi Mumbai area along the major transportation spine you have most of the development. So, this is the linear pattern of growth and in the Fort region or the Colaba region you can see high dense development wherein the landscape fragmentation has decreased over time.

So, this represents the aggregated pattern. So, the different colours gives you an idea regarding when and how the Urban transformation has happened in a temporal way in a timeline.

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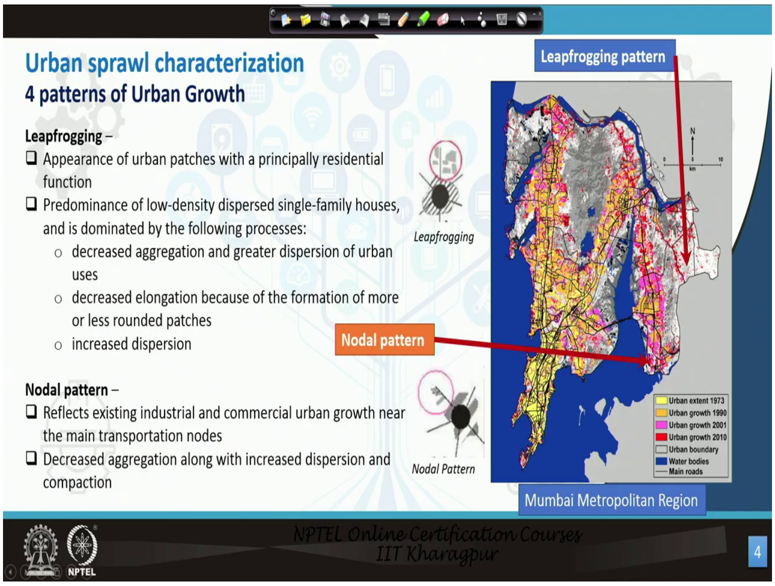

So, let us see the next two patterns, the third one is the leapfrogging pattern. So, in this pattern the urban patches of residential use appear as I mean in a dispersed fashion. So, I mean it is low in density and generally, you would see come across a single family houses and it is dominated by process of decreased aggregation and greater dispersion of the urban use. You will also see the process of decreased elongation and which is result of the formation of more or less rounded patches.

So, you would also see the process of increased dispersion in this particular case. So, here you can see an example of your leapfrogging. So, in this case you can see the patches are dispersed. So, the dispersion is more, the elongation is not there and the, I mean these patches are more or less rounded in nature and there is a increased dispersion in this patches. The next and the final pattern of urban growth that we can see which is manifested in different cities is the nodal pattern of growth.

It reflects the existing commercial or industrial urban growth along the main transportation nodes.

So, this leads to decrease in aggregation along the along with increase in the dispersion and also your increase in compaction. So, this is how it happens, I mean as a nodal pattern. So, you can see that most of this growth would be in the industrial or the commercial urban growth centres. So, we can see this as an example in case of Mumbai metropolitan region again. So, here you can see there are some speckles of leapfrogging pattern that we have discussed earlier and then you have the nodal pattern of growth happening in the new nodes of the new Bombay region.

So, again you have the temporal growth which is shown in this particular region. So, we know that there are four different patterns of growth and by characterizing these patterns using special metrics we know that whether it is a nodal pattern whether it is leapfrogging whether it is aggregated pattern. So, we can assess what is the nature or the what are the processes that is going behind in the those Urban areas, I mean which would result in a particular nature or pattern of growth.

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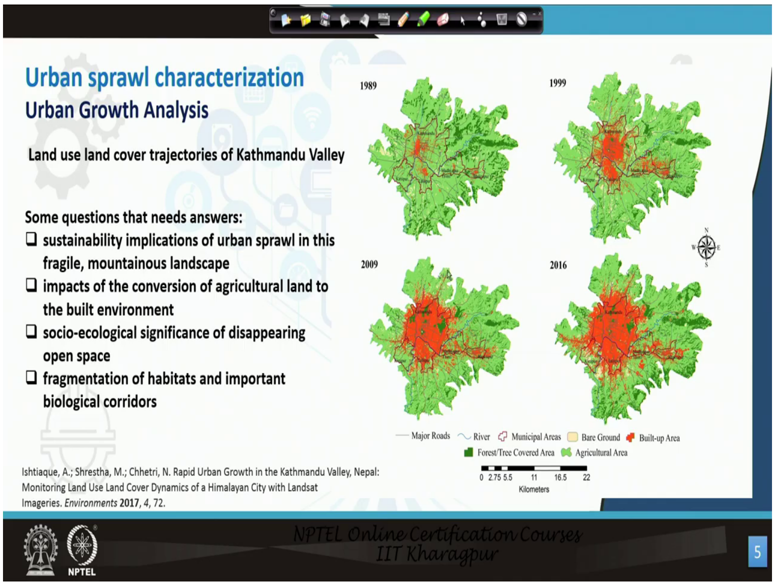

Now, let us see I mean how we can do a growth analysis. So, this particular example is of Kathmandu valley and this is a study by Ishtiaque, Shrestha and Chhetri you can refer to this particular research article. So, in this particular research what the authors have done is they have tried to identify the urban growth in Kathmandu valley and use your landscape metrics to assess how the growth pattern is varying over time.

So, there are several questions which can be further evaluated based on this particular study ha, which can be further I mean delved into I mean there are some research questions like, I mean the what are the sustainably it implications of urban sprawl in a fragile mountainous landscape like Kathmandu, then we can also explore the impacts of conversion of agricultural land to built up areas.

Here, we can also do an analysis of the socio ecological significance of how the open spaces are disappearing. Also, we can study the fragmentation of the habitats which are important biological corridors where in it supports the fauna and the flora in this particular region.

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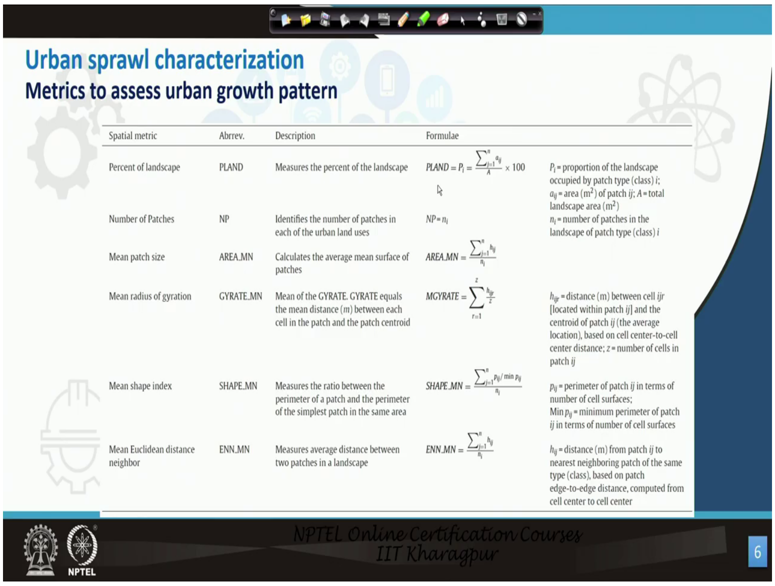

We can also do the metric, I have the metrics to assess the Urban growth patterns. So, the first one that we see is the percentage of landscape. So, it is given by the proportion of area of a patch to the total landscape area and it is expressed as percentage, then we can count the number of patches in of each land use.

So, you can see it is given as ni subscript i then we can calculate the mean patch size which is the summation of all the areas of different patches divided by the number of patches. Now, we can find out the mean radius of gyration which is the mean distance between each cell in the patch and the cell centroid. So, I mean your hijr is the distance between cell ijr that is located within patch ij and the centroid of the Pi ij which is the average location.

So, based on the cell centre to cell enter distance we can calculate this hijr and your zi t represents the number of patches in number of cells in patch ij, then we have the mean shape index which gives us a measure of the ratio between the perimeter of the patch and the perimeter of the simplest patch in the same area. So, this again is a ratio and does not have any unit, then the next measure that we come across is the mean Euclidean distance neighbour.

So, it measures the distance or the average distance between two patches in a landscape. So, again you can find out hij which is the distance from patch i to the nearest neighbouring patch of the same class type. So, based on the patch h to h distance I mean we can compute the cell centre to centre distance. So, this is summed up for all the different patches and it is divided by the number of patches of a particular class type. So, we divided by n i that gives us the mean Euclidean distance and it could be this is measured in terms of distance metrics like either meters or kilometres or any other units of distance measure.

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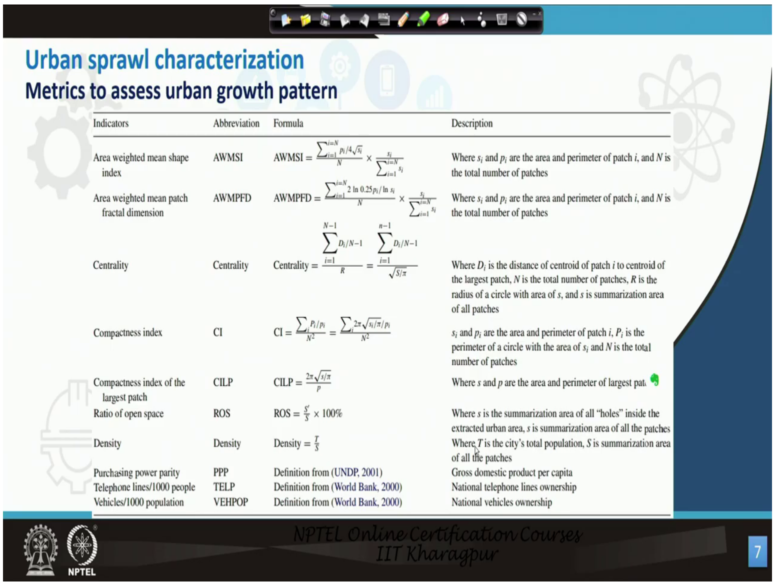

Now, we have few other measures to assess the urban growth patterns which are commonly being used. So, the first one is the area weighted mean shape index, wherein it measures the, I mean shape complexity of a particular patch, wherein si and pi are the area and perimeter of patch i and N capital N is the total number of patches. The second metric is the area weighted mean patch, fractal dimension wherein we try to measure the fractal nature in the landscape, wherein it gets repeated at different scales, si represents the area and pi again represents the perimeter.

So, it is a we take a logarithmic function of the these ratios of perimeter to the log of your area and we divide it by the total number of patches and it is further multiplied with the area of the individual patch type and it is divided by the aggregated some of the different patch types. So, it gives us that freak, fractal dimension.

So, the next measure is the centrality wherein you guess you can see we find out the centroid distance of patch i to the centroid of the largest patch. So, I mean it is normalized and divided by N minus 1 where is N is the total number of patches and your R is the radius of the circle or with the area S. So, I mean sometimes your patches may not be a regular circle. So, what we can do is we can I mean take the area S and divide it by pi and take a square root of that.

So, that this gives us a measure of the centrality of a given patch to the biggest patch with of the same class type. The next measure is the compactness wherein we find out the area and the perimeter, I mean we do a ratio of that and I mean your pi in this case is the perimeter of the circle with the area si and again N is the number of patches. So, in the denominator we take square of N, because we are I mean I mean taking the ratio of the perimeter of the circle.

So, I mean in this case, you do not have a unit for this particular measure. Next is the compactness index of the largest patch. So, like in the earlier, I mean index we had seen the compactness index. It is very similar to it, but we in the denominator we have the your perimeter of the we divided by the perimeter of the largest patch instead of dividing by the square of the number of patches, we divided by the perimeter of the largest patch.

The next metric that we are talking about is the ratio of open space. So, I mean it gives you a measure of the porosity. So, in this case your S is the summation area of all the holes inside the urban extracted urban area.

So, if you have a I mean built up area. So, wherever the gaps are there I mean unbuilt areas are there that would integrate to give you the measure of S. So, this S is the summation area of all the patches so, I mean we do a ratio of S dash by S for finding out the ratio of the open area and it is a measure of the porosity. Next, we can measure the density which is very simple that is we take the measure of total population of a city and S is your summarization area of all the patches. So, I mean we can find out the overall density or we can find out patch wise density as well.

So, we can find out the purchasing power parity which is the gross domestic product per capita, we can measure parameters like your number of telephone lines per capita or per thousand persons, we can also find out measures such as vehicle ownership. So, these are some of the metrics which are used to assess the urban growth pattern.

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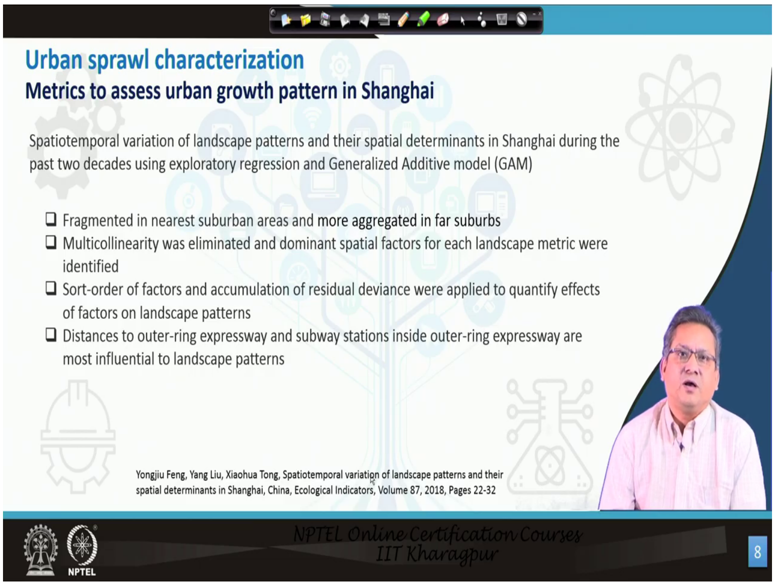

Now, let us see another study, wherein the these metrics have been used to assess the growth pattern in Shanghai in China. So, this is a study by Feng, Liu and Tong.

So, I mean this has been published in ecological indicators. So, this particular article studies the spatio temporal variation of landscape pattern and the spatial determinants in Shanghai region in the last twenty years and it uses a exploratory regression and generalized additive model. So, we see that this particular region of Shanghai is fragmented in the sub urban areas and in the far suburbs it is more aggregated. We also see that some of the parameters of your metrics, landscape metrics are multi collinear in nature. There is collinearity between the variables that we had studied if these people had studied.

So, this collinearity was eliminated, I mean those variables which were collinear and which were give me giving similar kind of relationships, some those variables were eliminated and the dominant spatial factor for each landscape metric had been identified in this particular study.

So, the sort order of the factor and the accumulation of the residual deviance where also I mean studied to quantify effects of factors on the different landscape patterns. So, they also worked on the distance, I mean this was one of the factors which the assist or that is the distance to outer ring expressway and subway stations inside outer ring expressways which were found to be the most influential to the landscape patterns.

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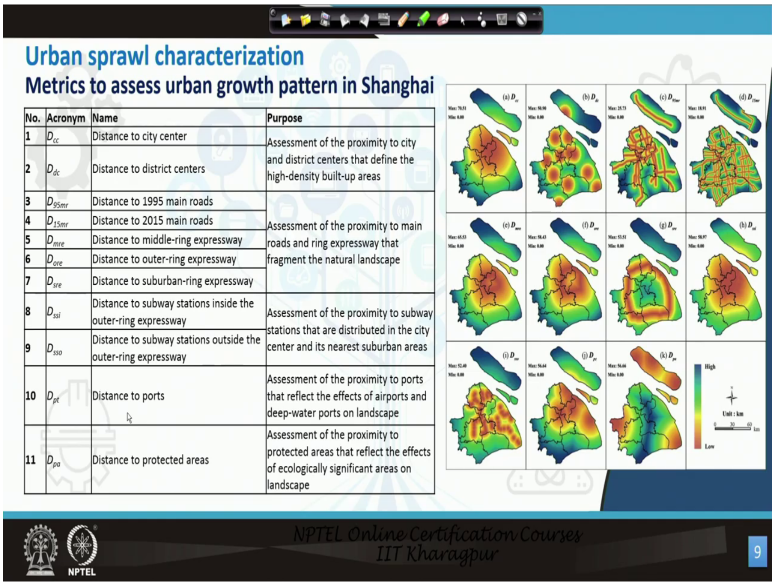

So, we can see that these are the different measures, which were used to assess the proximity characteristics. So, the distance to the city centre, distance to the district centre, distance to the main road in 1995 and 2005. So, these measures were used to identify the proximity to the roads then there are measured such as D ssi and sso which gives you a proximity to the subway station and which are distributed in the city and in its nearest suburban areas. They also measured the distance to the ports which is measured using this particular I mean metric D, I mean variable D pt. So, and then distance to the protected area that is ecologically seek significant areas.

And what is the distance in terms of proximity measures, where I mean tabulated using this D pa measure. So, you can see the how these measures are dispersed in the city of Shanghai. The first one gives you the measure of the distance to the centre of the city which is a buffer gradient buffer and we had already talked about creating this different types of buffer maps in our earlier lectures, where we were talking about raster and vector data modelling and I mean your different operations using raster and data, vector data where being I mean studied.

So, you are already familiar about it. So, these processes can be implemented to study the distance to the city centre, you have the distance to the district centre in this case, distance to the road in different time periods, then you have distance to the outer ring road, express road, the suburban express road, then you have the distance to the subway stations so distance to the ports and the protected areas, distance to the protected areas, all these factors were studied and then what was what was done was the generalized additive model which is given by this particular equation, where in your beta in this particular equation is a constant.

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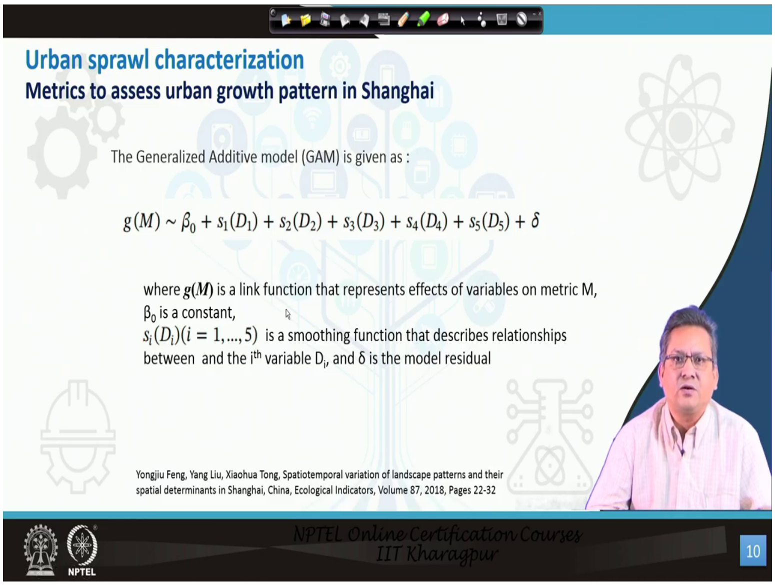

And on the right hand side we have DI which is the ith variable and we have another error term which is the model residual which could not be accounted by all these different parameters is written as delta. So, this g M is a link function that represents the effects of variables on the metric, on a specific metric, on the different each of the metrics we can identify what is this what is the link function that gives you an idea regarding the impact of these various variables that D 1, D 2, D 3, D 4, etcetera that we had just seen.

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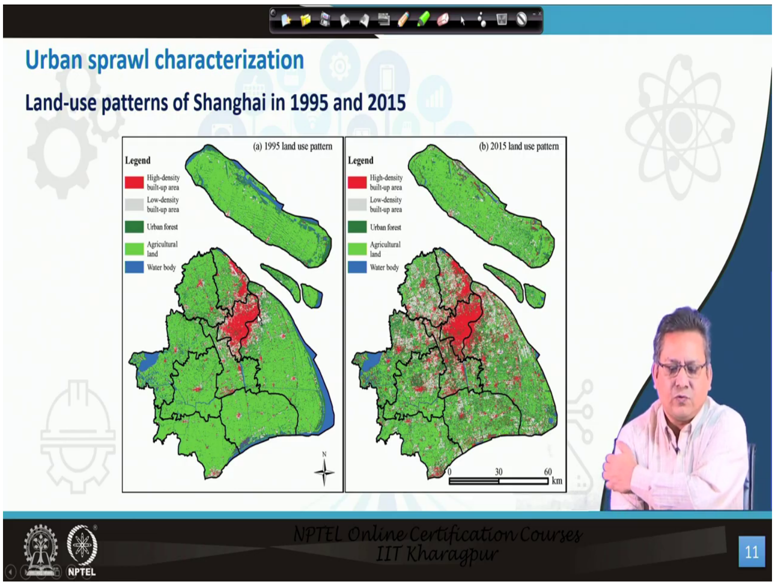

This has been identified and you can see that it was implemented for 1995 and 2015 in Shanghai, where in you can see different land use categories and how they have been evolving over time and you can see that slowly the low density built up areas have been permeating in the outskirts around this nodes, where in you had high density built up areas and then you have the core which is expanding and there is infill of the core which is getting compact. We had talked about the four different types of urban growth models.

So, in this you can see the central core is becoming compact and it is evidenced from the study using landscape metrics.

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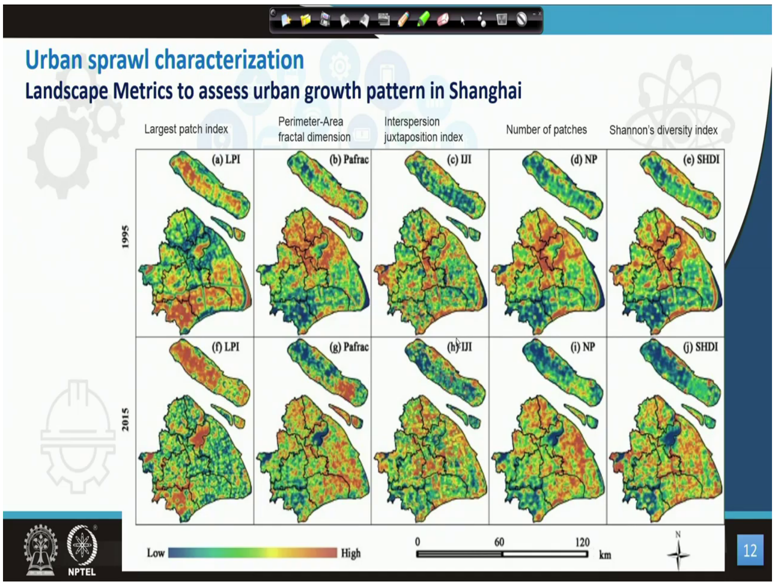

So, we can do this assessment of studying the landscape, different parameters, the different metrics. So, for 95s and 2015 the landscape largest patch index, perimeter area fractal dimension, interspersion juxtaposition index, number of patches and the Shannon diversity index was calculated for 95 as well as 2015 and you can see the results for the different areas.

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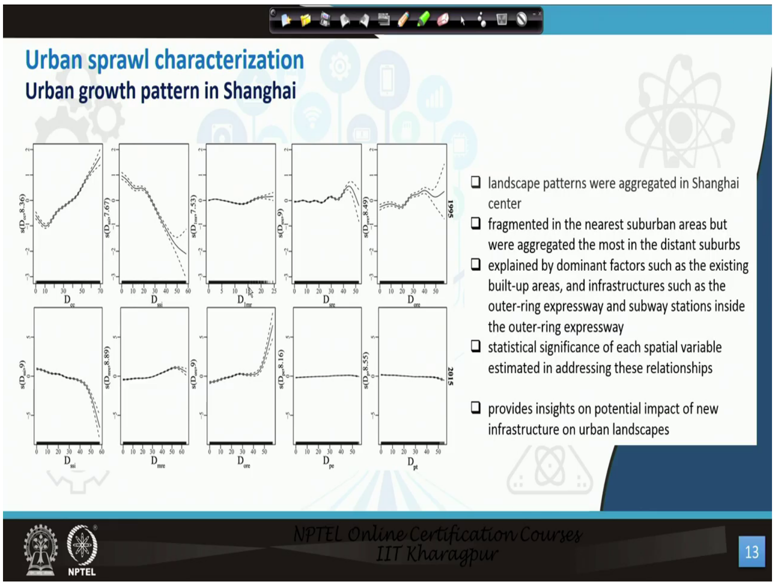

So, this led to the relationship between the earlier model kind of a regression model that we had talked about. So, it gives us the kind of dependence of the function factors that we had talked about that is the distance functions with respect to the spatial metrics. So, how it varies based on a fraction of a factor of distance can be studied over here. So, these are different ranges of this factors and these are the mean values of this parameters, your the landscape metric parameters with respect to the different variables, the distance function that we had talked about earlier.

So, these landscape para patterns were aggregated in the in the shanghai centre as evidence from the this particular study. The, if the fragmented in the nearest suburban areas this patches are fragmented in the suburban areas and it is aggregated in the distant suburbs. So, these is also explained by the dominant factors such as the built up area or the infrastructure that we are I mean assessing like the outer ring road or the roads and the presence of subway stations.

So, the statistical significance of each of these spatial variables, it estimated the relationships between these different parameters and it could be used as a measure to address the different issues in urban planning regarding density control. So, this I mean particular study it provides an insight, I mean using landscape metrics, it would give us an insight into the potential impact of a new infrastructure development like you have an outer ring road or you have a suburban I mean your M R T S corridor. So, you can get an insight on the impact potential impact on your urban pattern due to the infrastructure that is going to come up. So, it can be used for simulation.

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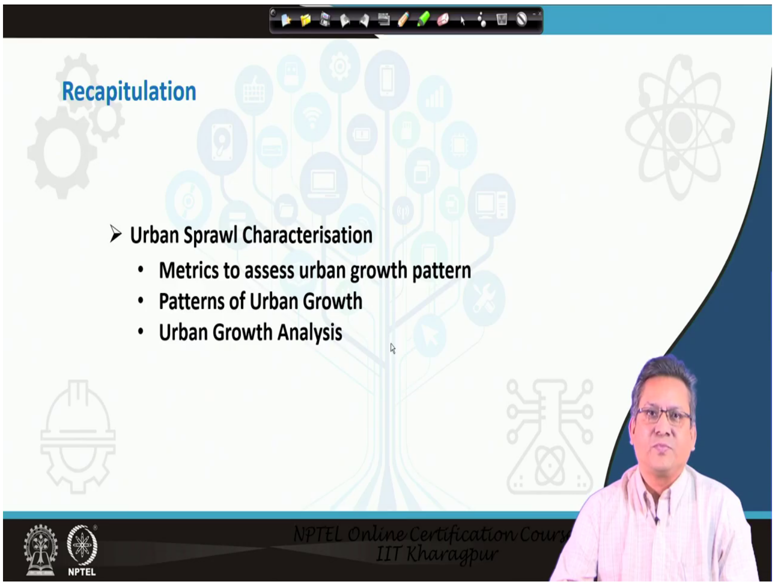

So, a recapitulation of what we had covered today. First, we had talked about the Urban sprawl characteristics. In that we talked about metrics to assess the urban growth pattern. We had also talked about the patterns of urban growth in this particular lecture and then we did urban growth analysis for two or three different I mean urban regions.

So, you can read on this and there are lot of different studies doing different types of analysis and simulation on growth, urban growth. So, I mean we shall look into, the different other modelling techniques in our next lecture.

So, thank you so much.