REMOTE SENSING FOR NATURAL HAZARD STUDIES

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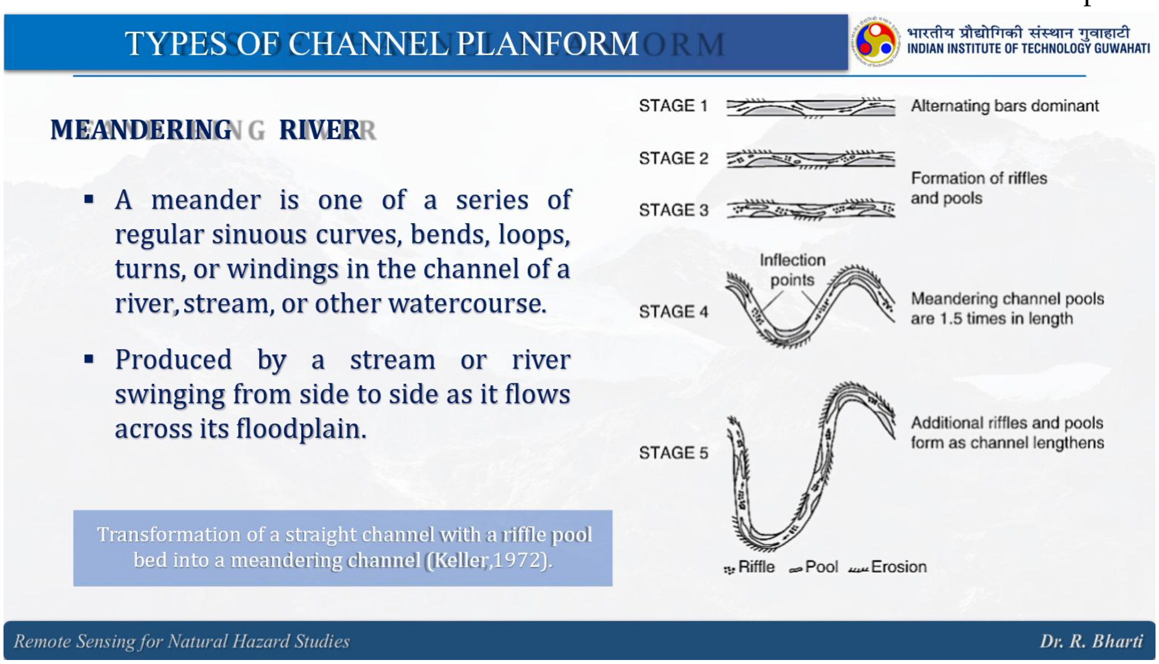
Lec 15b: Remote Sensing for River Planform Studies- Part B

Hello everyone, welcome back to Part 2 of Lecture 15. So, we were discussing the different types of channel planform. Now, we will continue this with the meandering river, So, a meander is one of a series of regular sinuous curves, bends, loops, turns, or windings in the channel of a river, stream, or other watercourse. It is produced by a stream or river swinging from side to side as it flows across its floodplain.

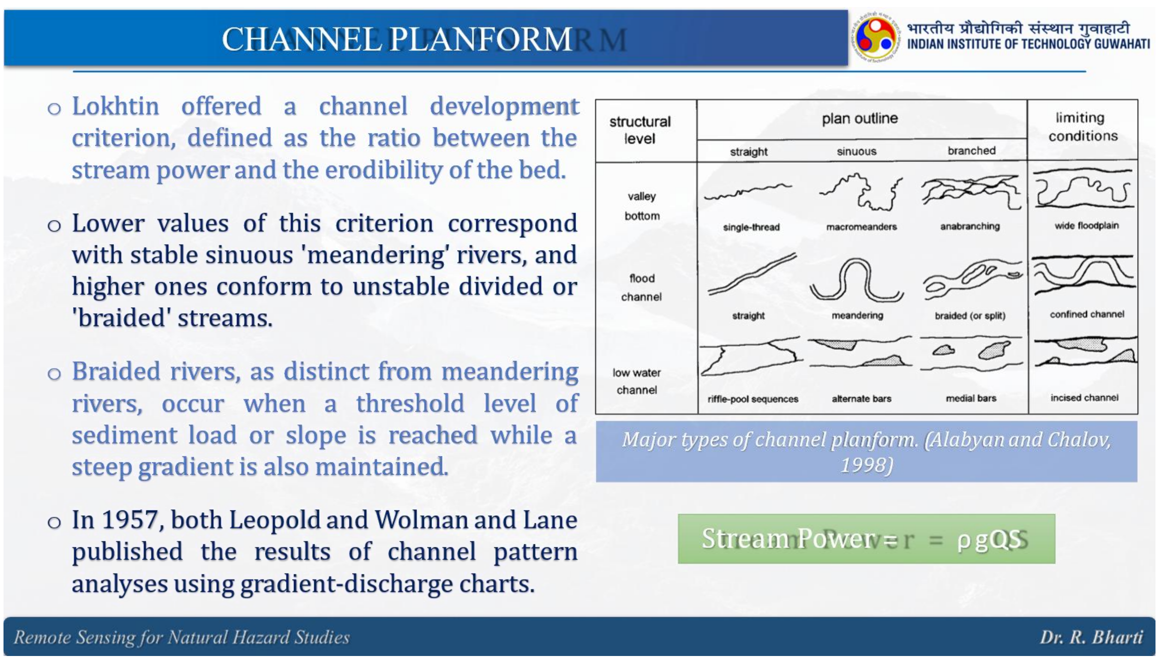


So, here you can see how it happens. So, the transformation of a straight channel into a ripple pool. Bed into meandering channel; this is from Keller, 1972. So, here you can see stage 1, stage 2, stage 3, stage 4, and stage 5, showing how a straight channel is becoming a meandering channel. Then comes the braided river. A braided river or braided channel consists of a network of river channels separated by small and often temporary islands called braid bars.

So, these braid bars can easily be seen in the non-monsoon period. Lane in 1957 concluded that there are two primary causes of braiding and explained why this braiding is happening. So, the first one is that overloading a stream may supply it with more sediment than it can carry, and hence some may be deposited. The steep slope causes a wide, shallow stream in which bars and islands may readily form. So, here you can see the mechanism of braid development, and this is from a particular paper.

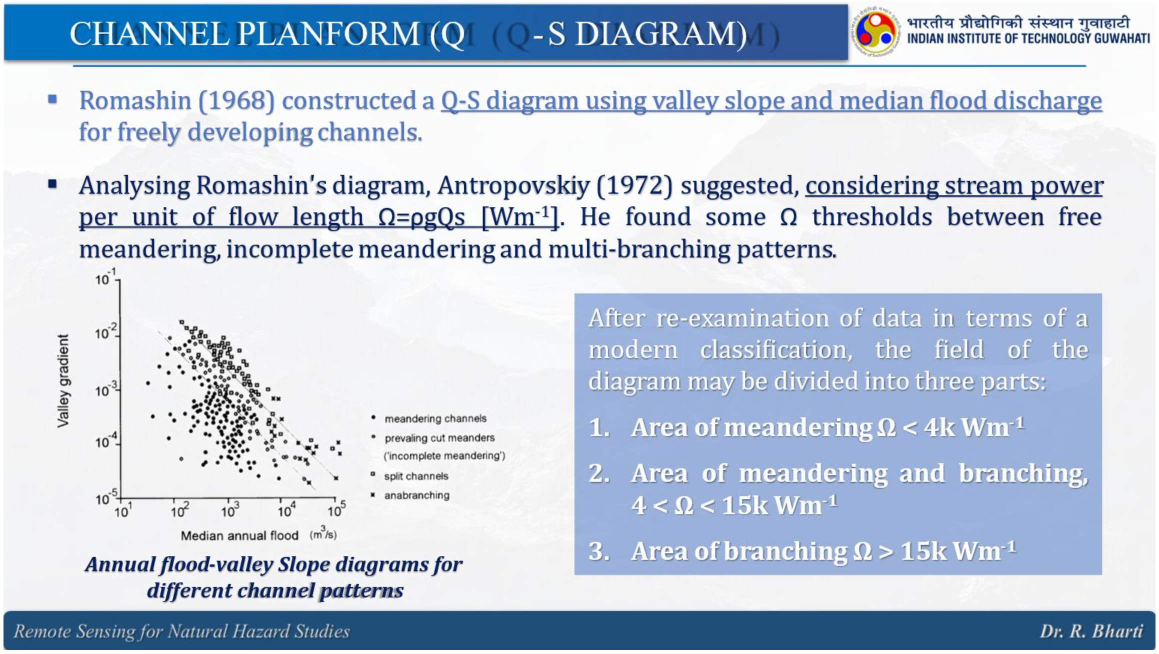
So, mainly the braiding, the braid bars are generated for two reasons. The first one is the overloading, and the second one is the steep slope. So, Lockhtin postulated that river forms reflect three main independent factors. So, this is very, very important. So, here you can see this particular diagram explains 3 main characteristics.

So, the discharge depends on climatic and soil conditions. So, this will be the slope or gradient conditioned by the relief of the area crossed by the river. So, the bed slopes. Then comes the erodibility of the bed, depending on the sediment properties and the types of sediments present in this water, which will determine and actually cause this erosion. These three controls determine the features of the river and the hydraulic condition of the flow.



So, these three are very, very important. So, when we talk about stream power, we all know that we can quantify it using this equation. So, locked in offered a channel development criterion defined as the ratio between the stream power and the erodibility of the bed. Lower values of this particular ratio indicate a stable, sinuous, meandering river, while higher values confirm an unstable, divided, or braided stream. So, this ratio is very, very important.

Braided rivers, as distinct from meandering rivers, occur when a threshold level of sediment load or slope is reached while a steep gradient is also maintained. In 1957, both Leopold and Wolman and Lane published the results of channel pattern analysis using gradient discharge charts. So, here you can see this is a different structure label. So, the valley bottom is a flood channel and then a low water channel. So, here you have straight, sinuous, and branched, and here the limiting conditions are a wide floodplain, a confined channel, and an incised channel.



And here you can see all these different characteristics. So, this is the major type of channel plant form, and it nicely represents all the plant forms. Now let us see the QS diagram. So, Romasin, in 1968, constructed a QS diagram using valley slope and median flood discharge for freely developing channels. So, this annual flood valley slope diagram for different channel patterns can be seen here. Analyzing this diagram, it was suggested to consider stream power per unit of flow length, which is omega equal to rho g Qs, and the unit is watts per meter. He found some omega threshold between free meandering, incomplete meandering, and multi-branching patterns. And after re-examining the data in terms of a modern classification, the field of the diagram may be divided into three parts. The first part is an area of meandering, where omega is less than 4. The second one is the area of meandering and branching that lies between 4 and 15, and the area of branching that is greater than 15. So, this is further advancement in the QS diagram.

CHANNEL PLANFORM (Q-S DIAGRAM)

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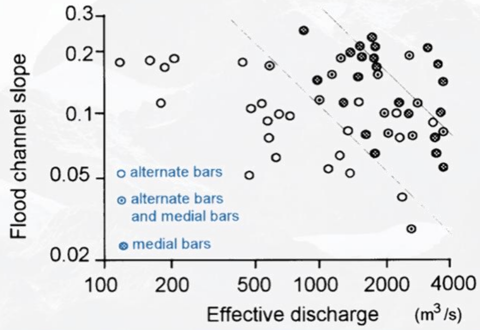
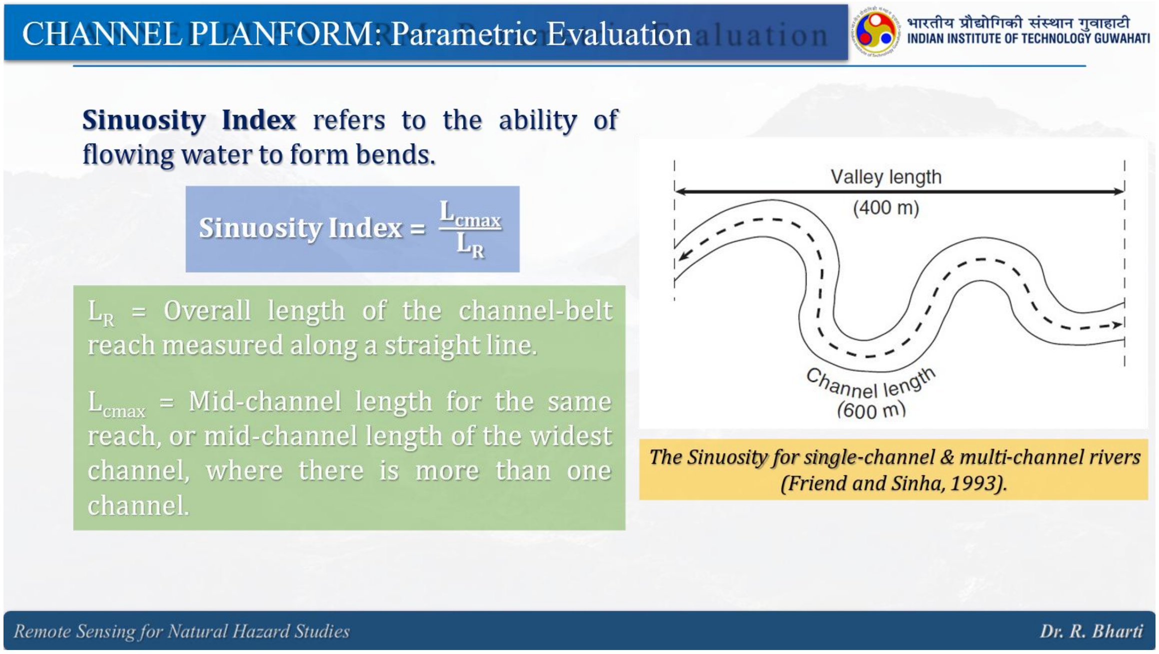
- They demonstrated that braided rivers plot above meandering ones. Straight channels are plotted either on both sides of the meandering-braided transition or below the meandering channels.
- Any slope over this threshold created a braided stream, while any slope under the threshold created a meandering stream or, for very low slopes, a straight channel.
- So the main controlling factor on river development is the amount of sediment that the river carries; once a given system crosses a threshold value for sediment load, it will convert from a meandering system to a braided system.



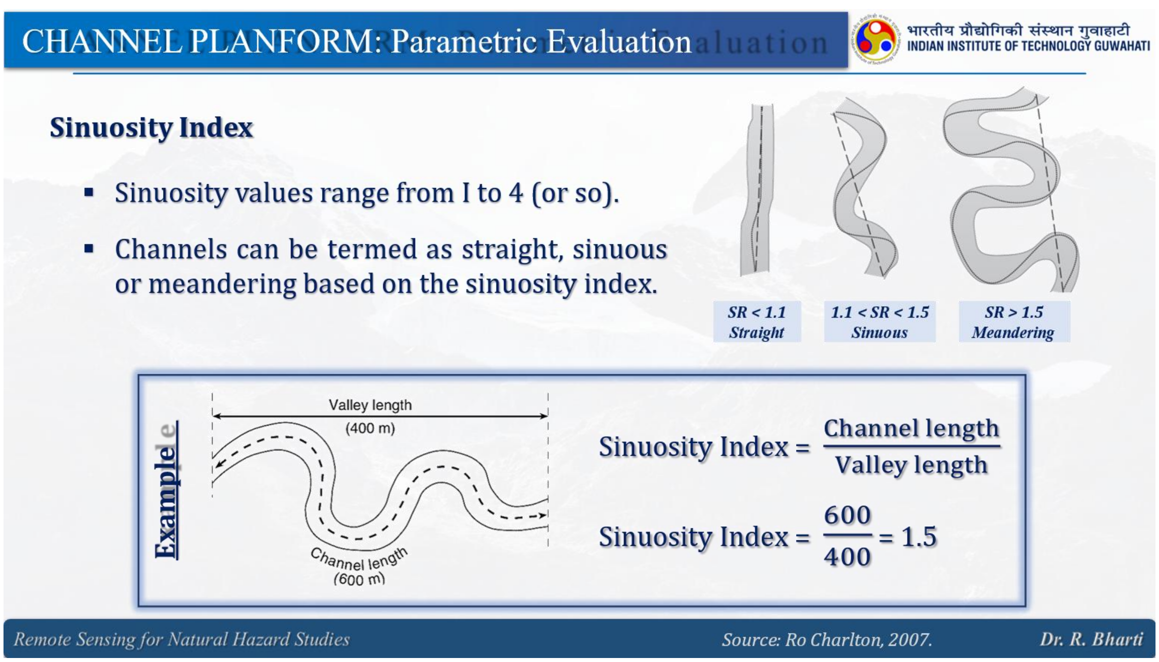
Annual flood-flood channel slope diagrams for different bar-level classification

The annual flood channel slope diagram for different bar level classifications can be seen here. So, the y-axis is the flood channel slope, and the x-axis is the effective discharge. So, they demonstrated that braided river plots of ever-meandering once-straight channels are plotted either on both sides of the meandering-braided transition or below the meandering channel. Any slope above this threshold created a braided stream, while any slope below the threshold created a meandering stream or, for very low slope, a straight channel.

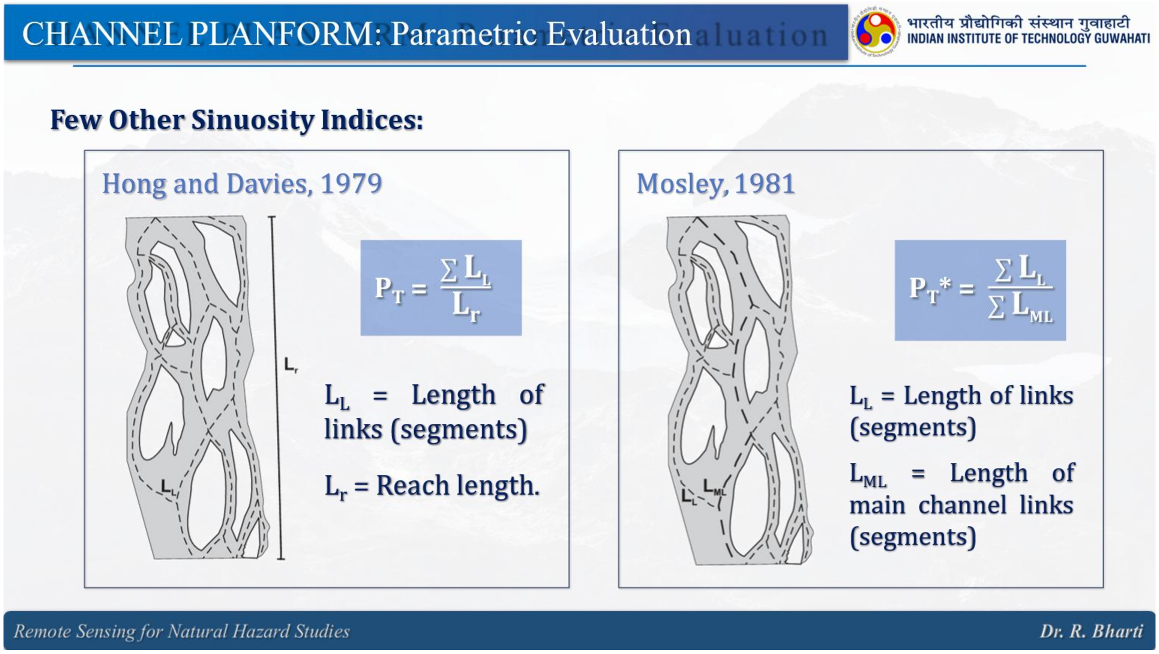
So, the main controlling factor in river development is the amount of sediment that the river carries. Once a given system crosses a threshold value for sediment load, it will convert from a meandering system to a braided system. Now, let us talk about the parameters which represent the planform. So, how do we evaluate the planform? So, the parametric evaluation will be discussed now. So, you can see the first one is the sinusoidal index, then the braiding index, the braid channel ratio, then the channel width, and finally the bank line shift.



So, this sinuous represents the meandering and curvy nature, while braided represents the formation of islands or bars. So, if you remember this, you will not have any confusion about the different types of planforms. Sinuosity Index. Refers to the ability of flowing water to form bends. So, this is basically how we are evaluating its bending. So, the Sinuosity index can be calculated using this, and here, what we do is try to take the channel length. So, let us say this is the main channel of this particular river. So, this distance is 600 meter, and the valley length is the straight distance between the starting and ending points. So, this is coming around 400 meter. So, this is what is used in the Sinuosity index.

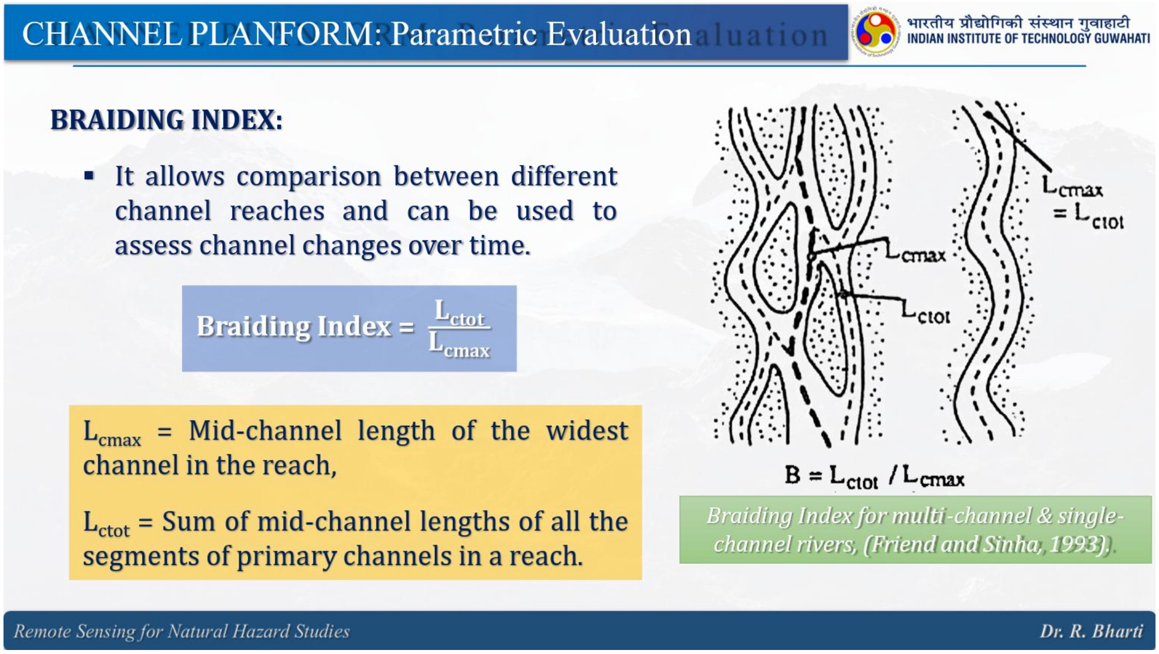


So, here you can see that sinuosity values range from 1 to 4, and channels can be termed straight, sinuous, or main ring based on this sinuosity index. So, here if the value is less than 1.1, it is straight; if the value is between 1.1 and 1.5, then it is sinuous, and if the ratio is greater than 1.5, then it is meandering. So, using this, you can identify what type of river system you are looking at.

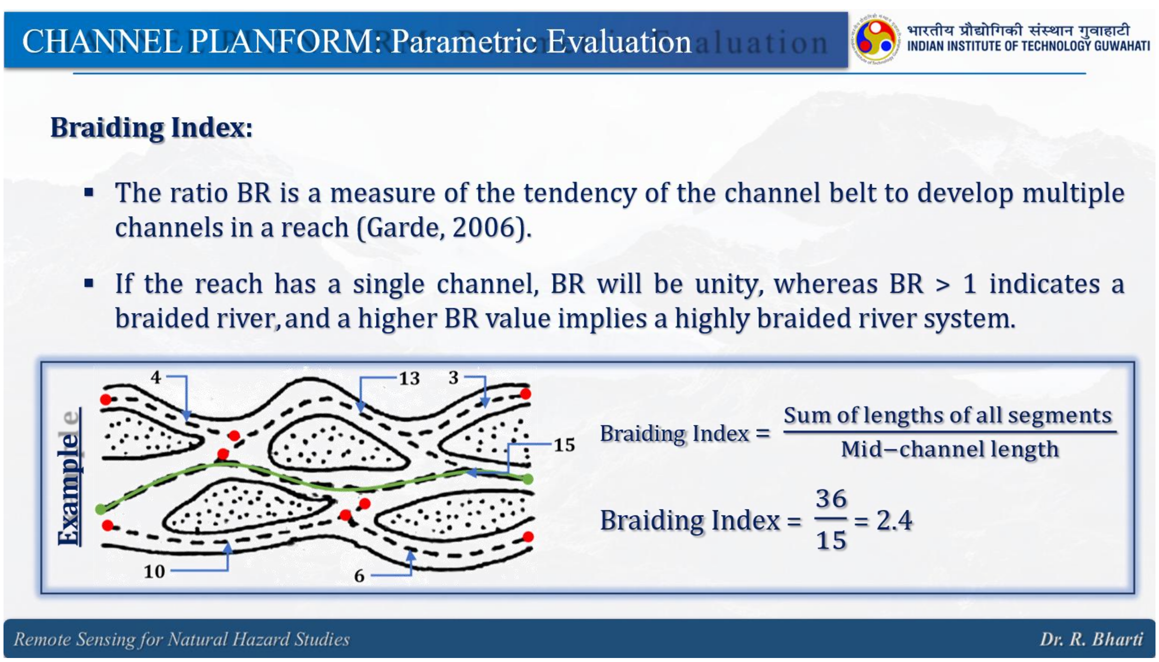


So, this is the same example I am using here to calculate the sinuosity index. So, earlier, if you remember, we had the valley length and the channel length. So, the main channel length, and then we had the valley length of 400.

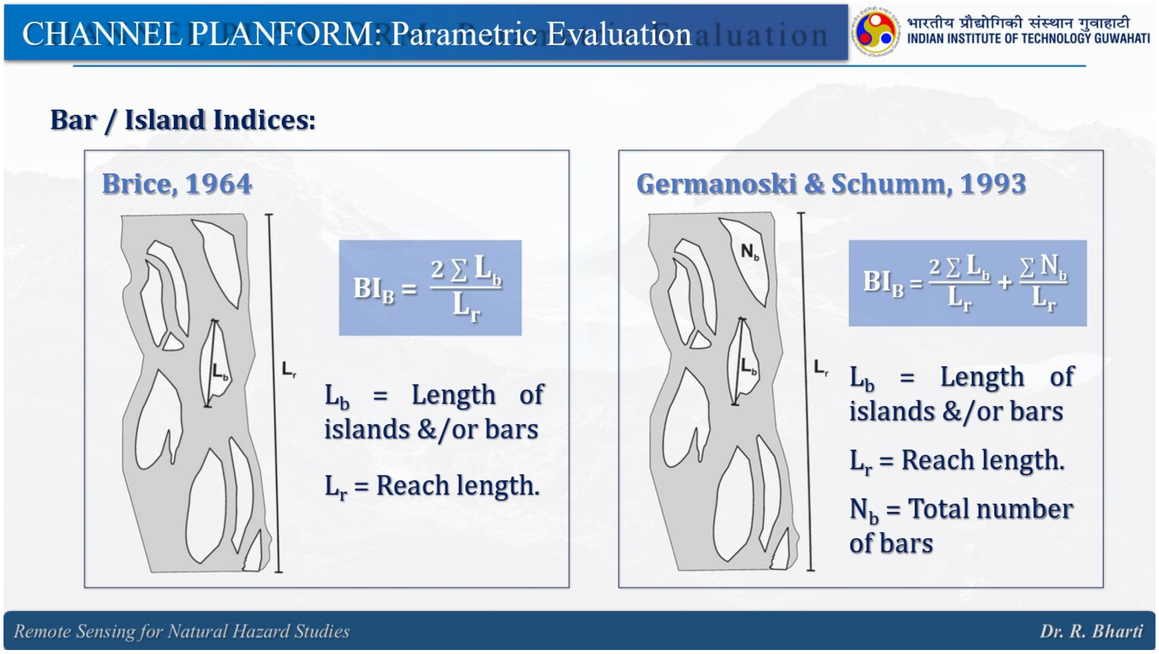
So, this is coming 1.5, which is here. So, this is sinuous. So, this is a sinuous river, few other sinuosity indices are also available. So, here is the one: the length of links and the reach length that are used, as well as the length of main channel links that are used to calculate. So, these are two different methods besides the previous one.



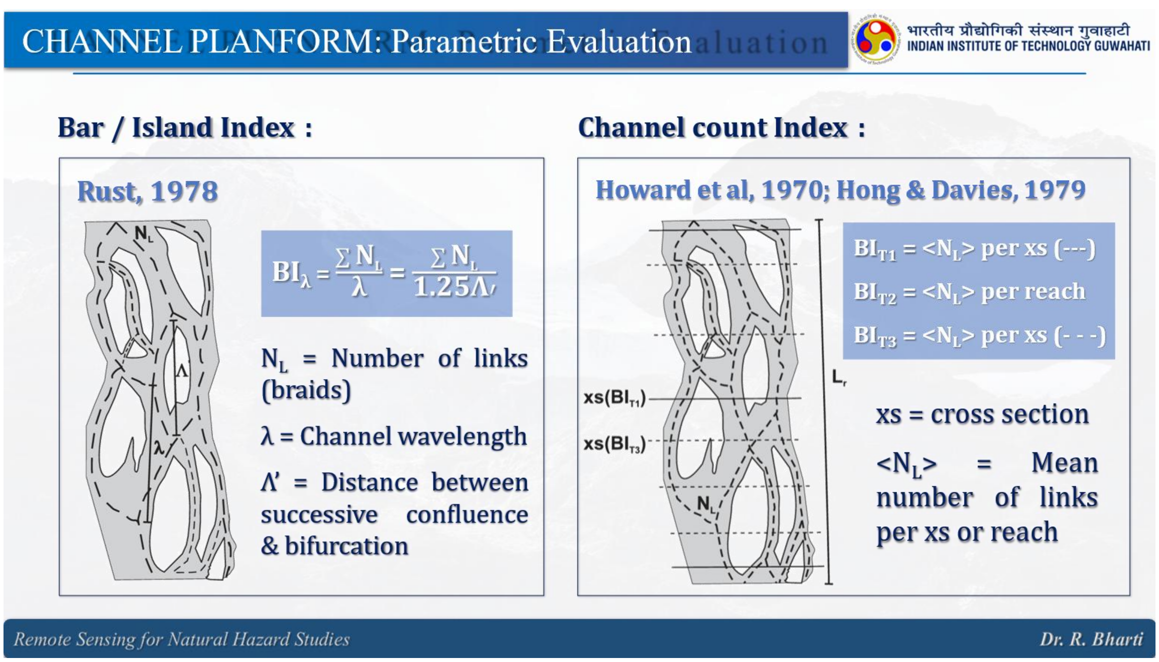
Now, let us see the braiding index. So, it allows for a comparison between different channel reaches and can be used to assess channel changes over time. The braiding index can be calculated using this equation, so here we are using the mid-channel length of the widest channel in the reach, and then we are using the sum of the mid-channel lengths of all the segments of primary channels in a reach. So, here you can see that Lc_{total} and Lc_{max} are being used. So, this defines the braiding pattern.



The ratio BR, the braiding index, is a measure of the tendency of the channel belt to develop multiple channels in a reach. If the reach has a single channel, BR will be unity; where BR is greater than 1, that indicates a braided river, and a higher BR value implies a higher braided river system. So here you can see the braiding index and braiding index value; this is 2.4. If the value is higher, then it has a higher tendency to braid, Bar island indices.



This is from Brice, and here you can see the length of islands or bars, the reach length that is used, and the total number of bars that is also used. So, this is bar or island indices. And some other indices are also available. So, here you can see then the channel count index comes.



So, this is given by Howard et al. (1970) and Hong and Davies (1979). So, here they are using the cross-sectional area mean number of links per access or reach. So, now you must be comfortable with how to extract this information which is required to quantify these values. Because we have learned that the remote sensing datasets can be downloaded, they can then be used to generate this information: the cross-section length, valley length, and water flowing length. So, all these values can be generated.

Now, let us see the bank line migration study. The spatio-temporal variation of the geomorphology predicts the future trajectory of the channel platform and its vulnerable zones. Because this spatio-temporal data shows how this particular river is behaving over time, it will help you predict what will happen in the future. This flashy river is characterized by a large sediment load generated by the Himalayas. This is from the coming river, which forces the river to change its flow pattern and channel morphology.

The downstream section of Kameng River has been subjected to channel migration for the last 40 years, which has generated a severe bank erosion problem. If you remember when I was showing you the summary for the Ganga, Brahmaputra, and Mahanadi, the Brahmaputra has the major problem of bank erosion. So, you can see the 1988 remote sensing data here. It helped us demarcate the boundary of the river. Then, with respect to 1988, how this calming river is shifting and how it is changing its course.

So, in 1992, this is with this orange color. So, how has it been shifted? So, sometimes only one bank is shifting, sometimes both banks are shifting, and sometimes the width is changing. So, that kind of analysis can be performed using this remote sensing data. Now, when you see 1988 and 1997. Then in 2002. So, that will help you analyze what is happening with the river system you are interested in studying. So, in this study, we tried to understand the morpho dynamics of Kameng River between 1988 and 2022 with remote sensing data and field investigation. Some cloud computing techniques were used. The Landsat satellite imagery from USGS was used and then processed to evaluate the annual bank migration rate. On the right and left bank, I will show you the graph.

So, the right and left banks are digitized manually, and this process has been carried out carefully by marking the external boundaries of the bank-attached geomorphic units. So, this can be done automatically also, but we thought of doing it manually because we also have done this automatically, but manually we have more confidence on our results. So, the study area is divided into 47 and 23 segments in the hilly and plain reaches, respectively. The segments are spaced at an approximate interval of 1 kilometer, which can effectively capture the morphological variation of bank-attached geomorphic units. Now you will be able to perceive this. What I have already discussed. So, this is the coming river, and here you can see how these reaches are designed correctly. So, it is approximately 1 kilometer. So, this is the hilly part, and these are the low-lying areas, and then it meets the main Brahmaputra River. So, here you can see the migration rate we have analyzed, the segment number is also given, and this particular reach is showing negative. So, you can see the color. So, this is number 15 and this color is here. So, between this time period, there was a change in the bank line. The migration of the bank between certain time periods is measured at every point by overlaying the digitized image of the bank lines. Inward movement of the bank line is considered deposition.

So, this is the inward right. An outward movement of the bank lines as erosion. If it is going to this side, then it is erosion. The negative and positive notations are adopted for deposition and erosion, respectively. So, this is how we have analyzed the entire Kameng river system. So, right bank migration, you can see here that this is for the left bank. So, again, the negative values are for deposition, and positive values are for erosion. So, here is the bank erosion you can see. So, this is how you can analyze the bank line shift or bank line migration. In the hilly region, the river passes through valley confinement; therefore, the bank migration rate is minor and close to 1 to 2 meter per year. At a few upstream reaches of part 1 in those hilly areas, the river has abandoned the old flood channels, and depositional behavior is observed at segment number 15 of part 1.

A deposition rate of close to 400 meter per year is observed due to the shifting of the primary channel between 2014 and 2016. The maximum erosion rate is generally observed at the junction of the hill and plain sections. So, this is a reach number of 30 to 40. The erosion-prone reaches are segments 33, 35, and 36 between 2014 and 2016, segment 46 from 2010 to 2014, and segments 33, 34, 38, 39, and 43 between 2002 and 2010. At present, from 2016 to 2022, the spatial average bank erosion rate is close to minus 4 meters per year, which shows the gradual emergence of bank protection work and stability characteristics in the upper Jia Bhorali River.

So, in the plain region, the Jia Bhorali River is dynamic in terms of bank line migration, braiding behavior, and geomorphic adjustment. In the first time period from 1988 to 1992, the river had a spatially averaged bank migration rate of 77 meter per year, with the highest bank erosion rate of 378 meter per year at segments number 19 to 21; this is in the lower reaches, In the next epoch from 1992 to 1997, the spatial average bank migration rate of 24 meter per year, with a maximum erosion rate of 190 meters per year, was observed close to segments number 15 and 16. During the next two time periods, that is 1997 to 2002 and 2002 to 2010, the river continued its westward migration between 7 and 18 reaches, with the right bank subjected to intense erosion and the left bank witnessing gradual deposition. At the present epoch of 2016 to 2022, the Jia Bhorali River has an average channel migration rate of 4.25 meter per year with erosional behavior at the upcoming Brahmaputra confluence.

So, why I am showing you all these results and analysis of my work is because this kind of analysis can provide you with more insight or detailed information about the characteristics of your river, its behavior, and then you can go for the modeling of this particular section. Some of the linear aspects that I have listed here. So, stream ordering, and here all the details are given. So, I will not go into detail, but I will just show you so that if you require, then you can refer to these methods, and I have also written the author's name; this is a compiled work. This is a compilation of all the different indices that are available for morphometric analysis.

So, you can just take note of this drainage frequency, drainage texture, form factor, elongation ratio, drainage density, length of overland flow, texture ratio, basin relief, circularity ratio, constant of channel maintenance, and infiltration number. Then gradation ratio, ruggedness number, relative relief, and then hypsometric curve. All these methods can be used for morphometric analysis, and the aspect is the relief right. Then come the morphotectonic aspects, so how we identify whether your particular section of the river is tectonically active. So, for that, we have different methods: valley floor width-height ratio, asymmetry factor, transverse topographic symmetry, channel sinuosity index, mountain front sinuosity index, linear mend density, hypsometric integral, stream gradient index, normalized steepness index, channel steepness index.

All these methods can be used to evaluate the morphotectonic aspects of your river systems. Here you can find the list of datasets that are used in such studies. So, we have a series of Landsat, a series of Sentinel, and you also have a microwave dataset in this. Then comes the topography: the digital elevation models, which are available from various sources. So these are popular in this kind of study. So, we have already discussed this. I hope you will remember this. And then you will be able to utilize this knowledge in your research. So, this is one of the examples from this paper. So, you can see here that Landsat 8, Sentinel 2, and Sentinel 1 data sets are used to monitor the same river channel with different data sets, and here you can see how this is changing. Then the dry and wet periods are from another work. And here you can see the false color Sentinel-2 imagery for the dry season and wet season, and you can see how the rivers are changing. This is an example of Landsat images used in the Google Earth Engine visual workflow for extracting the active channel from a series of Landsat images in Google Earth Engine. So, this is a spatio-temporal analysis. This is another example of how it is changing with time. So, you can see how this is changing from 1989 to 2019, this is another example from this paper, and here you can see the compiled work from 1972 to 2014, including the years 1972, 1999, and 2009.

So, this is a bank line change. The bar erosion and bar migration can be studied using such a data set. This is from the Jamuna evolution. So, here you can see the Ganga and Brahmaputra, the junction that is being studied. So, 1973 to 2014, and the confluence migration that is also studied, So, these are some examples of the application of remote sensing in river platform studies, and people are actively using satellite images or geospatial techniques as tools that can help derive the information required to study bank line shifts, channel migration, or in particular, channel platforms. So, these are some of the suggested readings that you can go through if you are interested in working in this particular domain.

The next slide will have the references that I have been using in this particular lecture. So, with this, I will end this lecture.

Thank you. Thank you very much.