Remote Sensing and GIS for Rural Development
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Week – 12
Lecture – 03
RS and GIS Applications for Rural Development Water Quality Assessment

Hello everyone. Welcome to the NPTEL course on Remote Sensing and GIS for Rural Development. This is Week 12 Lecture 3. We are concluding our lecture series by showing some applications and links to data that you could use quickly for specific concepts.

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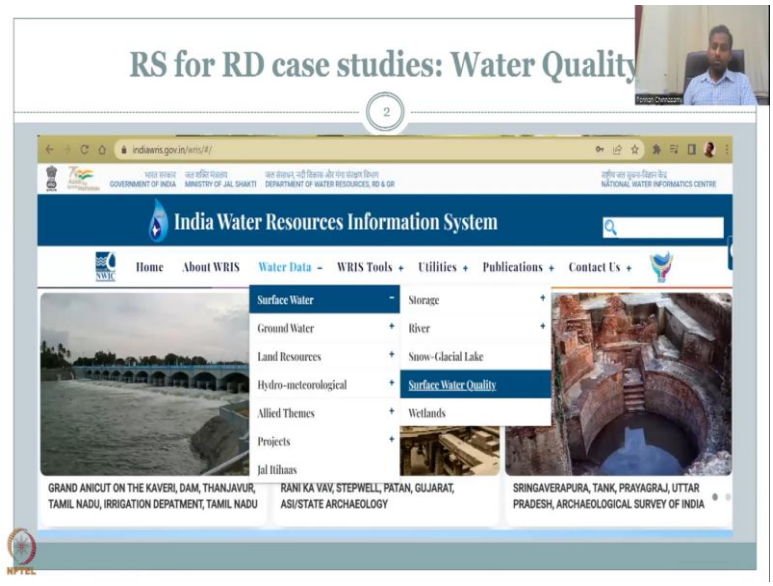

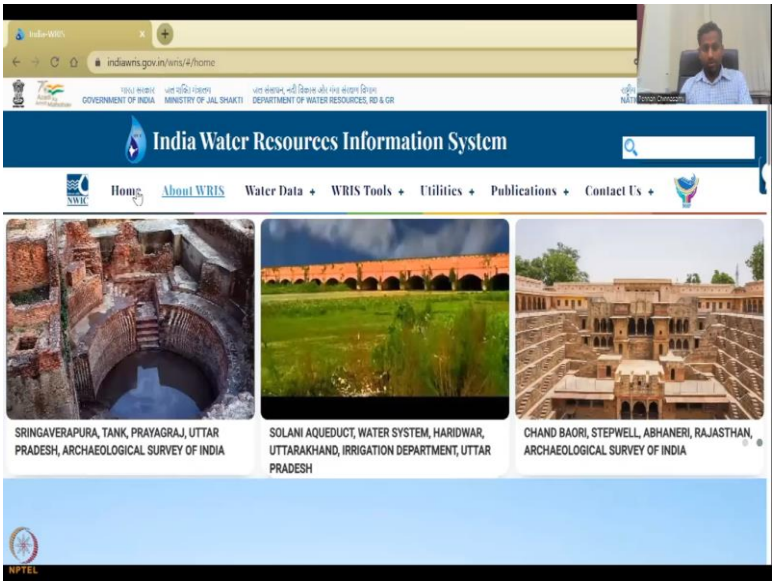

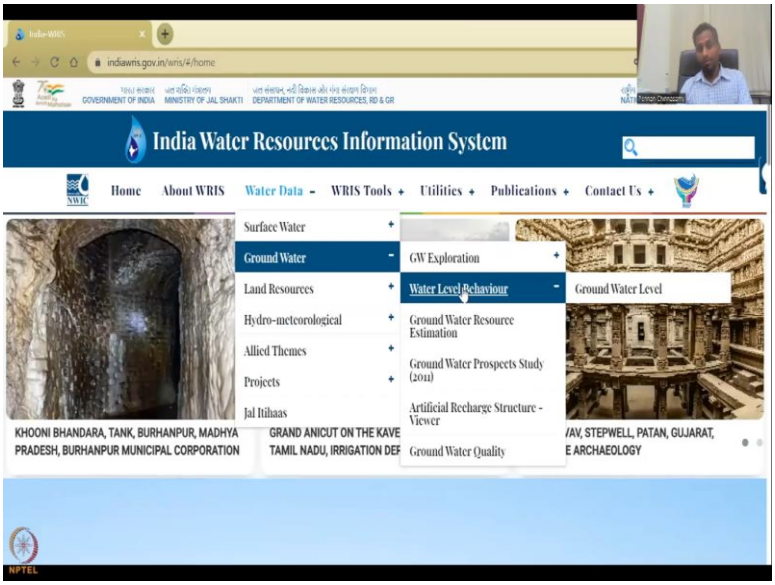

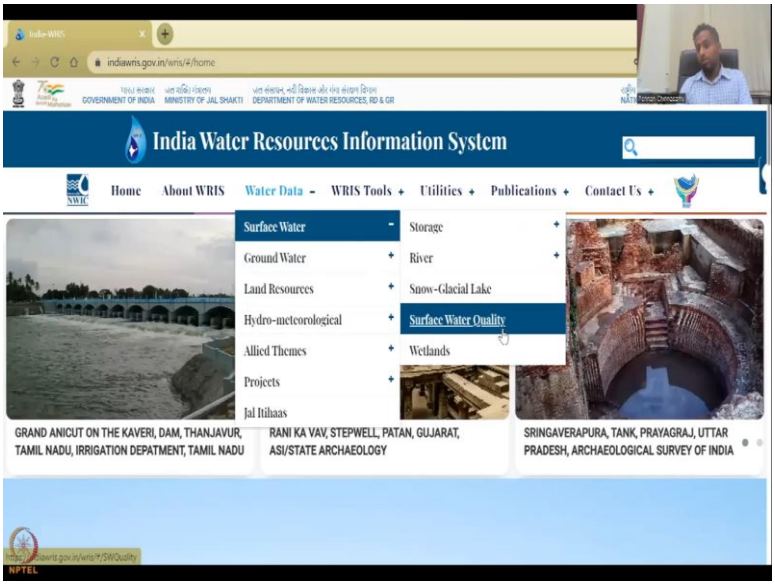

One such concept that we will be looking in today's lecture will be the use of remote sensing for rural development case studies as in water quality. I have always said that water quality is not given as much as importance as water quantity has been given which is a concern. Because you cannot use bad water. Water may be available but it is unusable.

For example, while I was working along the Ganges borders and rivers in the Nepal region, I could see a lot of water black in color. And then it confluence into streams and rivers and then came into the Ganges. So, Ganges is huge maybe a lot of water comes and the pollution is not seen. But upstream where the water comes there is a lot of pollution. And there people are not using that water and using spring water for drinking.

So, it is as important to monitor the water quality as the water quantity is monitored and measured. However, that could be itself by a course. So, I would just introduce where you could get data and how you could get data and how remote sensing can fill the gap of data limitedness.

First of all, we will be using the W R I S website by the Government of India where initially, as I said when I was studying and doing my PhD, these data were very very difficult to get because this dashboard was not available. Right now the government has made it publicly available and is happy to share this data to everyone so that they could use. So, we could also open it and then showcase how we could get the data online.

So, now, you could see that I have clicked India W R I S home and in the home, you could go to W R I S data, come down to groundwater. First let us look at groundwater, there is not much issues in terms of getting the level behavior which we have seen already but let us do surface water first. Because that is what we are going to do here.

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What do you mean surface water is a water body like lake, pond and rivers are called surface water. So, let this populate, it does take a little bit time based on the internet and also the data available. And you could see slowly the data points populating for the entire India. So, you can see here the numbers are coming up, it is still populating and there it is. So, 3649 stations have been monitored and in the last 10 years active session are 3610.

For a country as big as India, we should have more but again as I said it is a lot of expensive to monitor and maintain and also to collect data. So, installation is expensive, collection is expensive and maintaining the data is also expensive. Unlike water quantity, water quality involves chemical labs and setups to test the data and that is where it becomes a little bit harder on the government's pocket to monitor.

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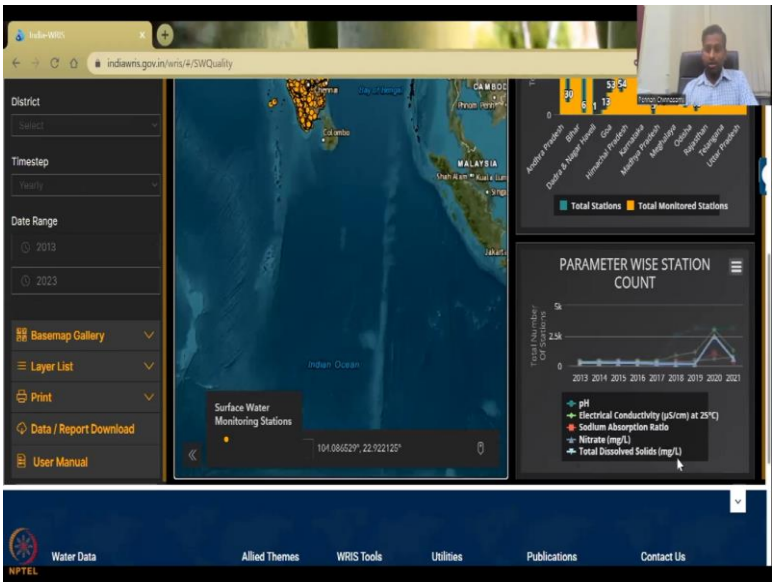

So, here we have entire India, you could see that the whole of India you could see the number of stations is 3649. You can come down and see that what are the major parameters that have been taken, Ph, electrical conductivity, sodium observation ratio and nitrates and propyl dissolved solids. These are kind of very rudimentary in terms of starting but when you go and look at the wells you will see multiple other parameters.

Because just these monitoring is just very less. So, they it is not like only these parameters are measured. They are putting the main physical quality measurements but we will see how the data comes up. So, the background is creating a lot of internet issues because of speed and loading.

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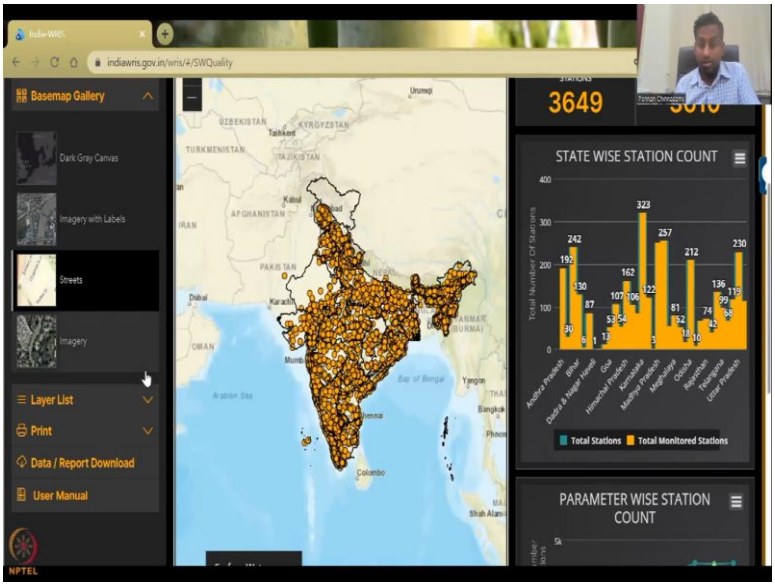

So, for that let us go down here and you can see the base map. I am just going to click on the base map and take streets. Streets is just a normal image, it does not take that much. So, now, you can see that it moves very freely and it does not get stuck. It is not my internet. It is the, there itself it is happening.

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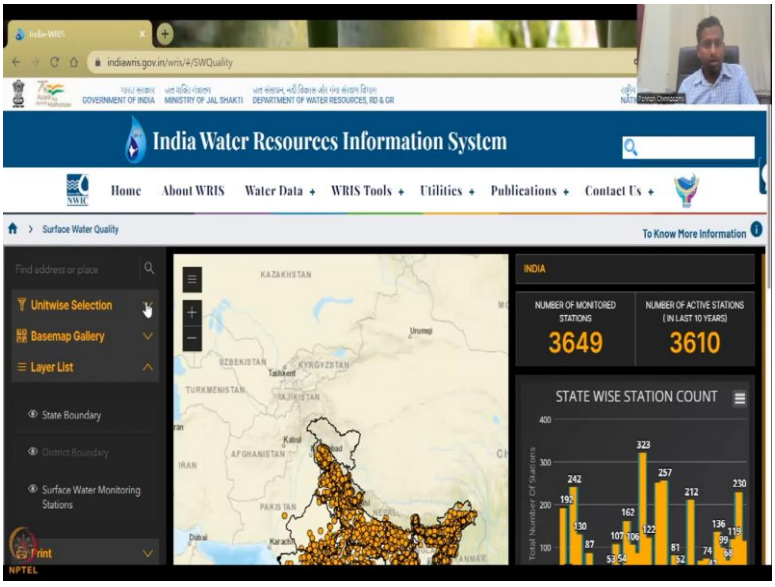

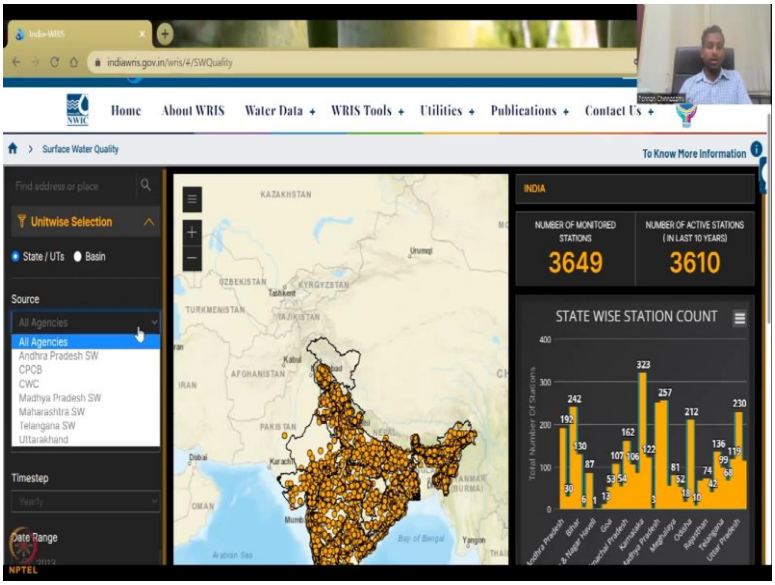

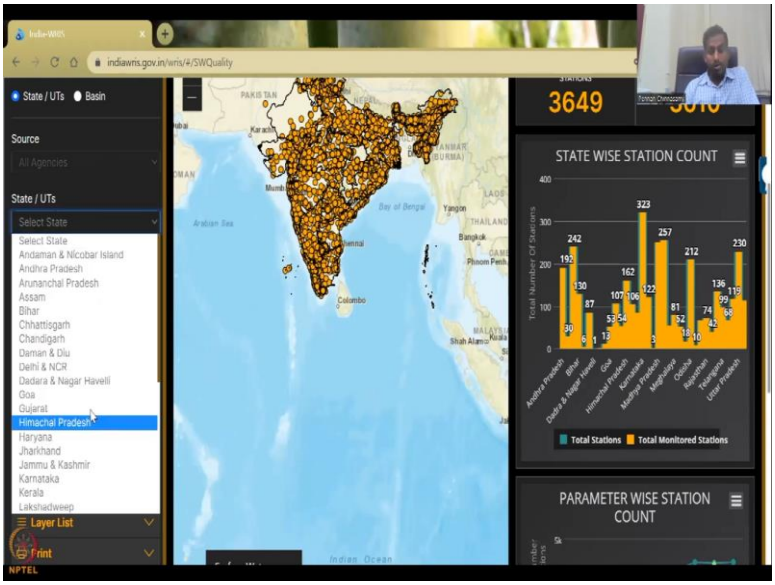

So, you could come here and then the layer list is there, what layers you would like to see the boundary, surface monitoring stations which is all on. And you will go to unit wise selection. So, you can particularly look at a state. So, you can if you click on the sources you can see like what are this data they have.

So, normally, the water quality is monitored by two agencies, one is a central agency which is the CPCB, Central Pollution Control Board and in the state agencies. The Central Water Commission may also have some stations which is a CWC but again CPCP has a mandate to monitor and some state agencies as mentioned here Andhra Pradesh, Madhya Pradesh, Maharashtra, Telangana, and Uttarakhand have their own boards that are monitoring.

This is concerning because it is not that much data or that many states represented given the number of states India has we can only see around four or five, one, two, three, four, five, five states and not the big ones, so all are missing, either they are not putting it on the dashboard or they are not fully collecting the data. So, let us take agency all and then maybe we could see Gujrat because I am going assure they perform, Gujrat.

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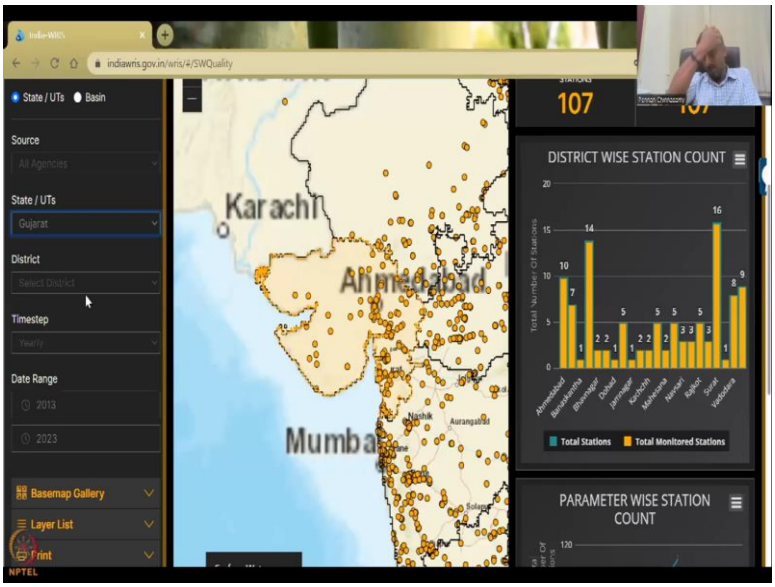

So, now, you can see it is launching. So, Gujarat and Rajasthan are very very important to be monitored for water quality. Why? Because there is lot of water quality issues in these two regions, arsenic you see in the Ganges belt but here you see a lot of iron, chloride, a lot of factory pollutants leaching into the water.

So, it is very very important for monitoring these data cells. And for sure this cannot be true; it cannot have a station outside of India. So, this is sometimes an issue with the data set. We can just quickly see what data services. If you click it, you will have it here coming up, but let me see how Gujarat is coming.

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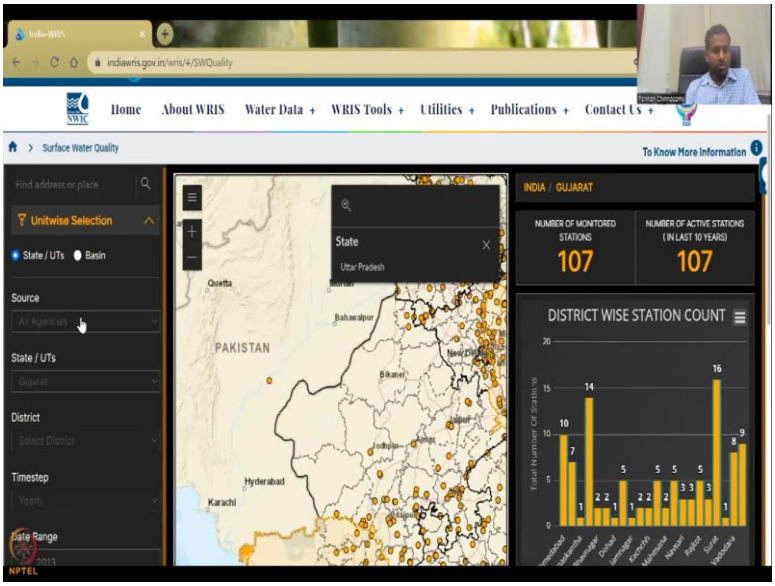

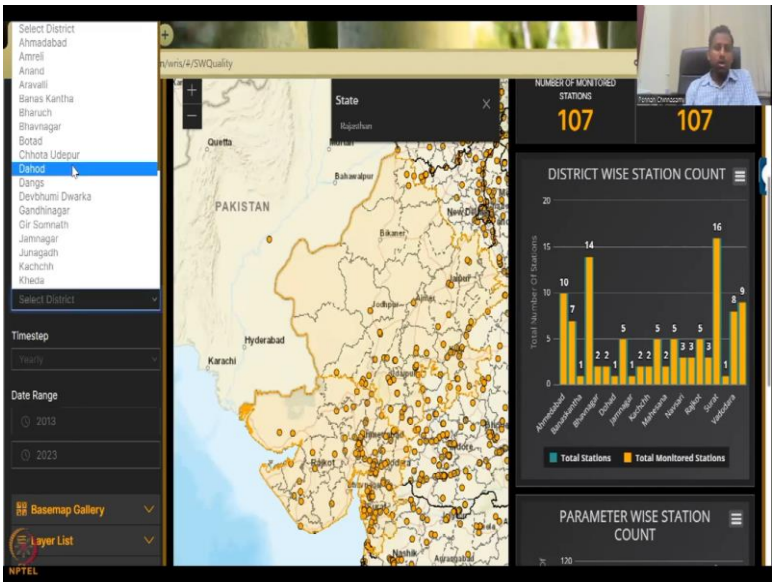

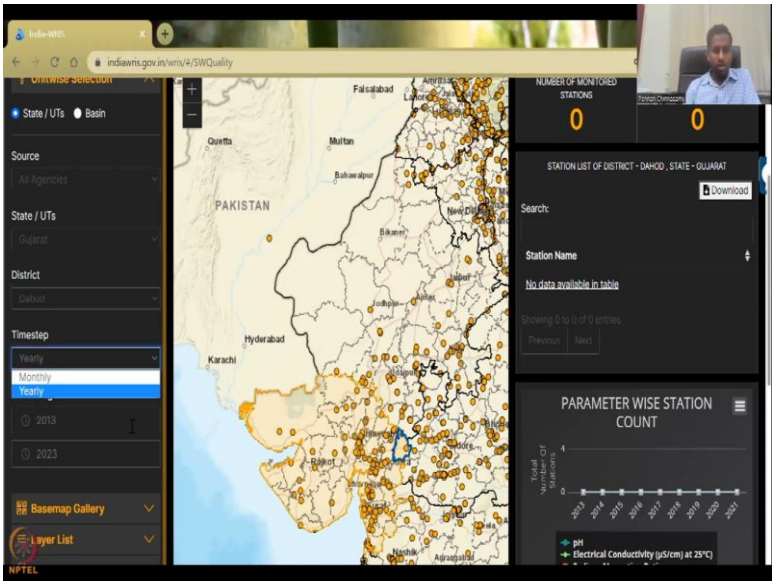

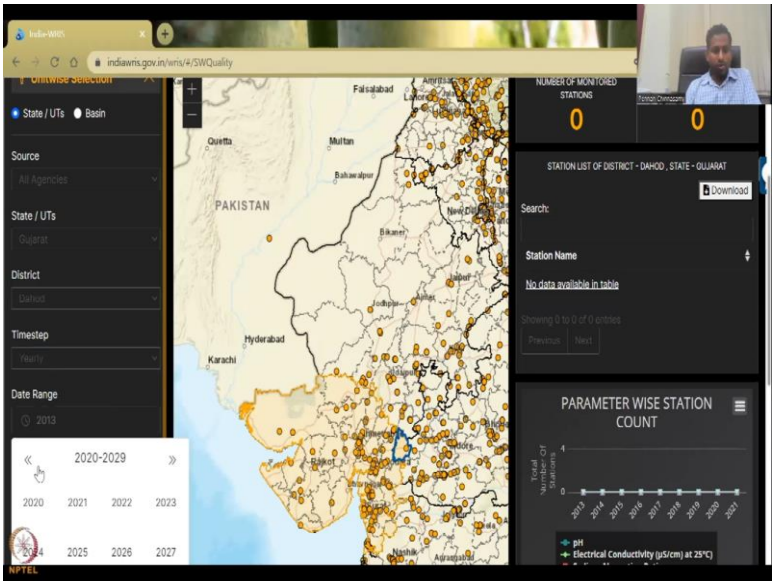

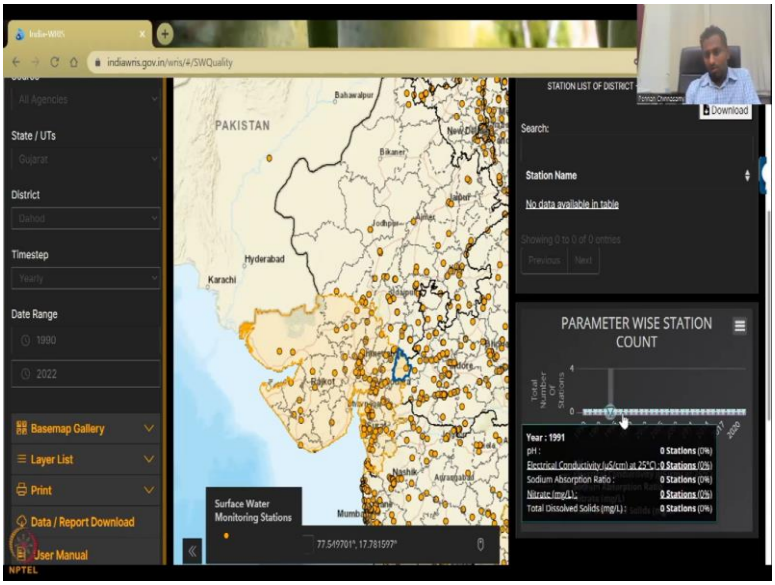

So, Gujarat is coming up the data set. And while the Gujarat is getting populated, we can say like which district you want. Let us keep all districts. I am going to Dahod, anyway and you can click Dahod. So, this data was used actually for the paper. So, that is why I am going to go and show you and then you can see yearly and you can say which date to which date.

If you click on this button, it will move on the number of days. You will see that the date goes to 1939, it just keeps on going, no, we did not have such long data. It is just enough there. So, I think it is 1980s, 1990s is a good number and then you can keep it 2022, yearly. Because 2023 is still going on. So, you have 1990, yes, for sure but number of stations is almost zero zero zero zero zero and some sessions are populating up.

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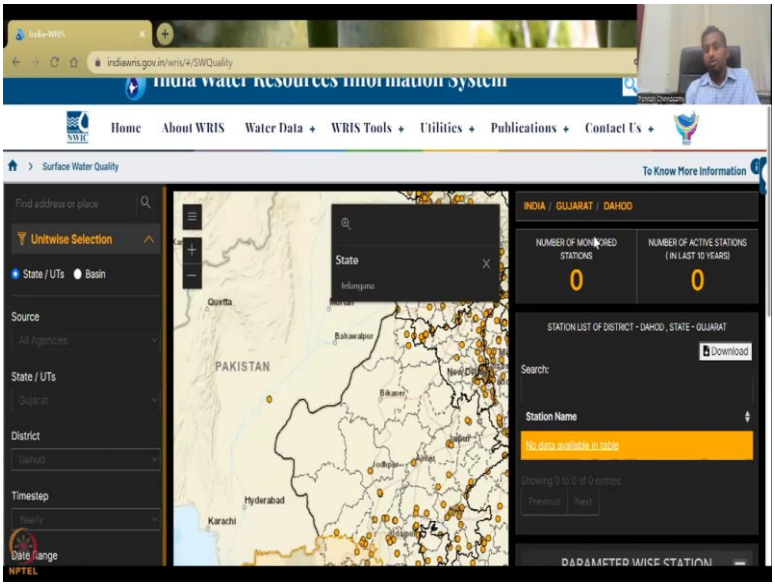

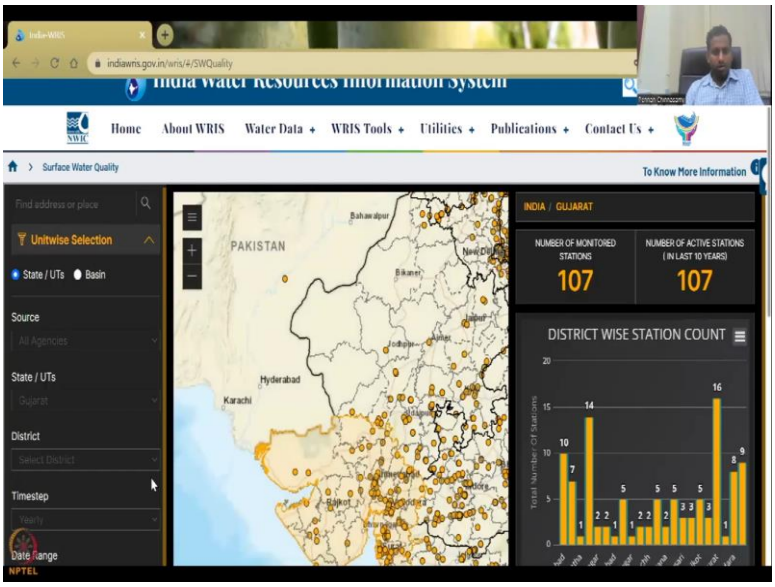

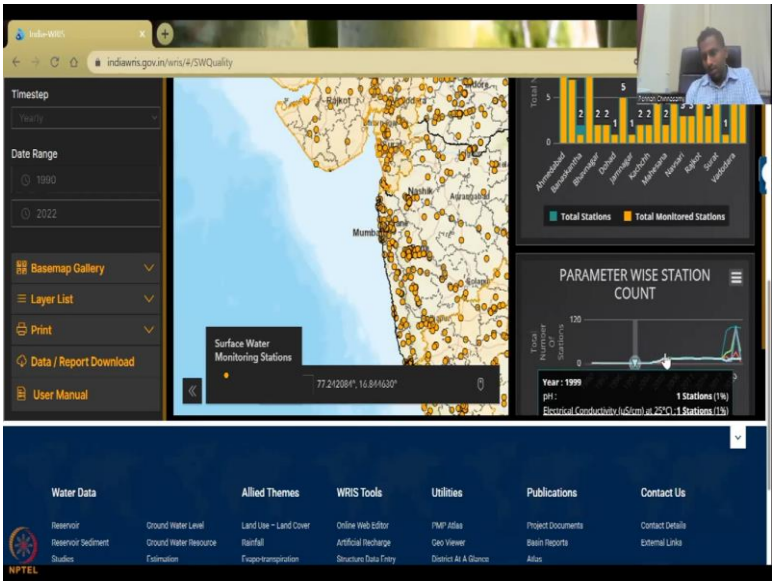

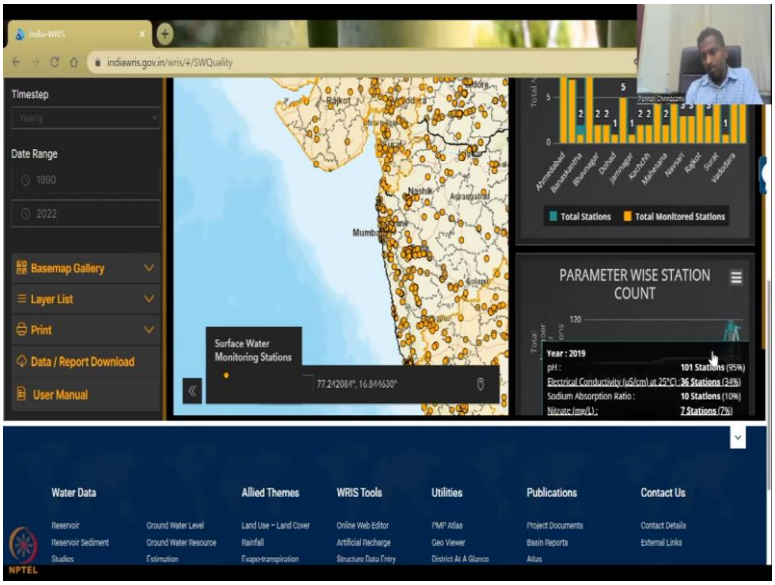

So, the number of stations monitored in Dahod is zero. So, please, note this point in Dahod, there is zero stations monitored which is where I said a lot of lift irrigation and projects are done. But we can keep Gujarat, you can just click on Gujarat, it will go back to Gujarat or all or we can just update this as all districts.

So, all the districts are coming up and I am just going to do the same thing here, 1990, 2022 and it will auto populate. There is no submit button, it will auto populate. And you can see that the zero zero zero station one station and then 15 stations are growing up and then we have a good number of stations around 2017 onwards. So, the last four or five years they are monitoring a lot and you could see that which districts are having more stations are mapped here and for sure we do not have stations in Dahod but the 107 stations are there which is pretty good.

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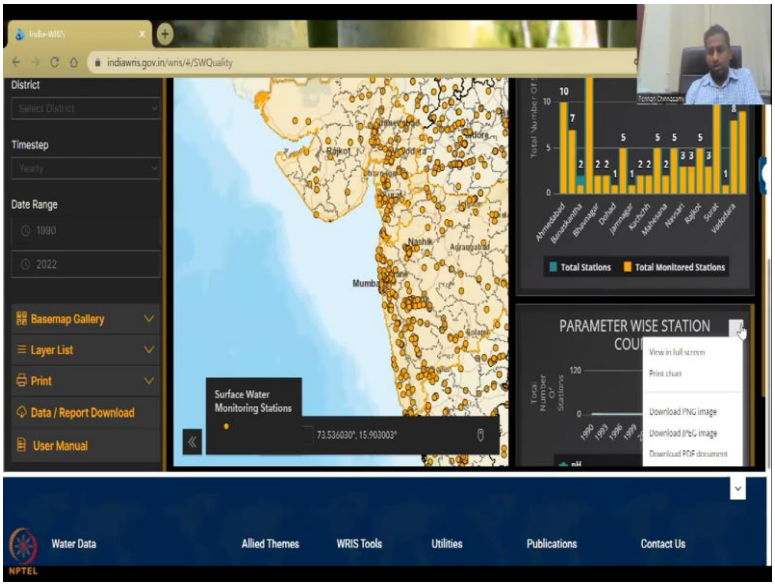

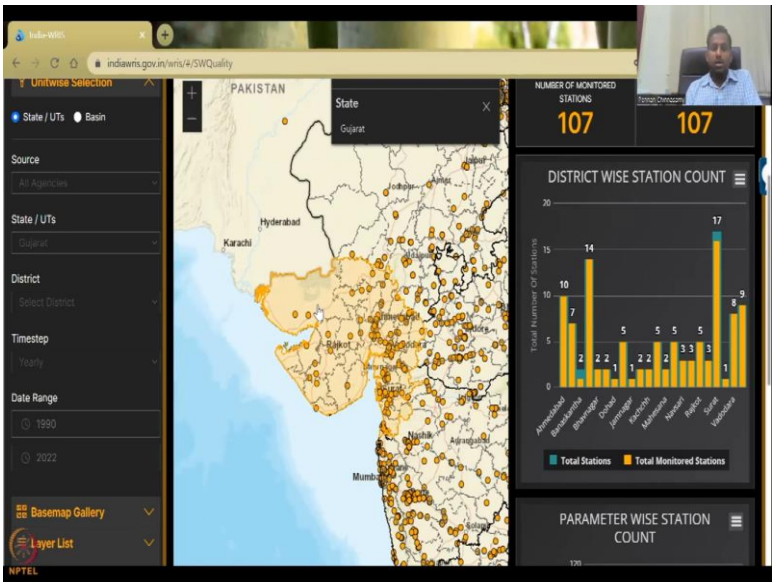

And you can click this to see the full chart and other things and what are the parameters. So, the parameters are not full here. You will need to click on a particular data set to look at it. So, we know that this region Kutchh region has a lot of salt content which is coming up and out of solid precipitation happens. So, we can leave this and not much agriculture happens but we can just take something in the center. I am randomly selecting and then we will pick it up. We will come back here when we do the paper analysis.

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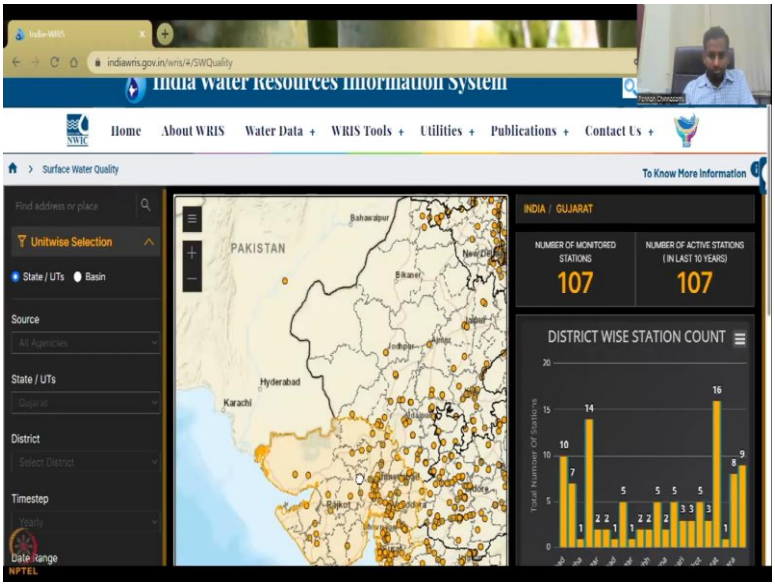
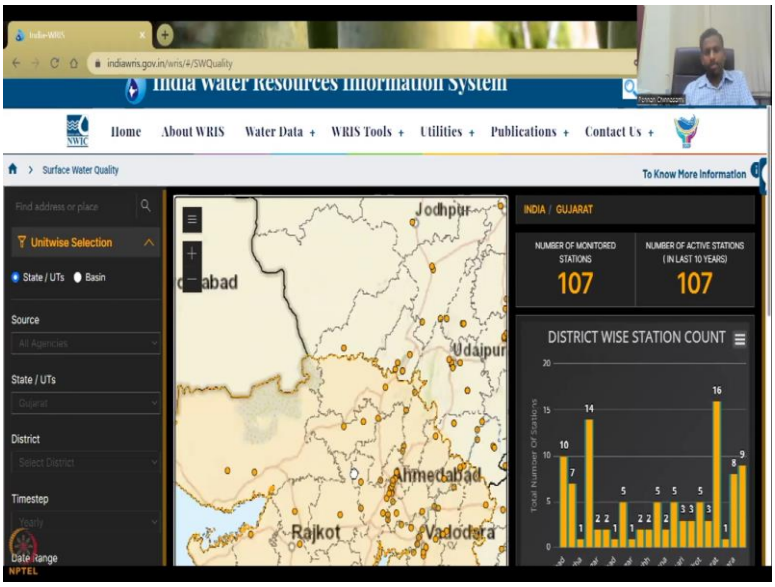
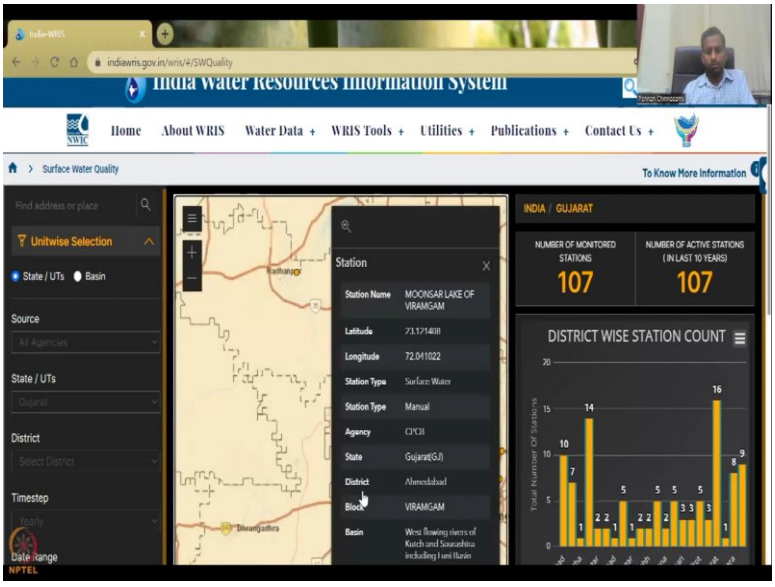
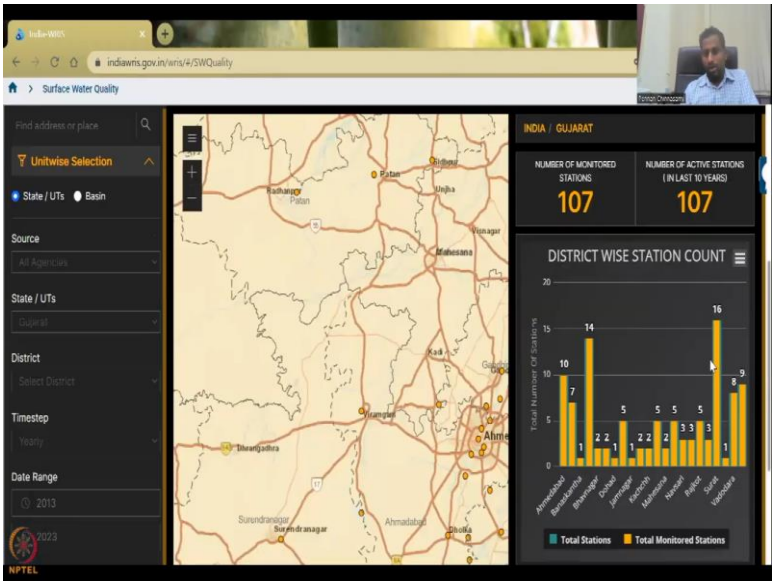
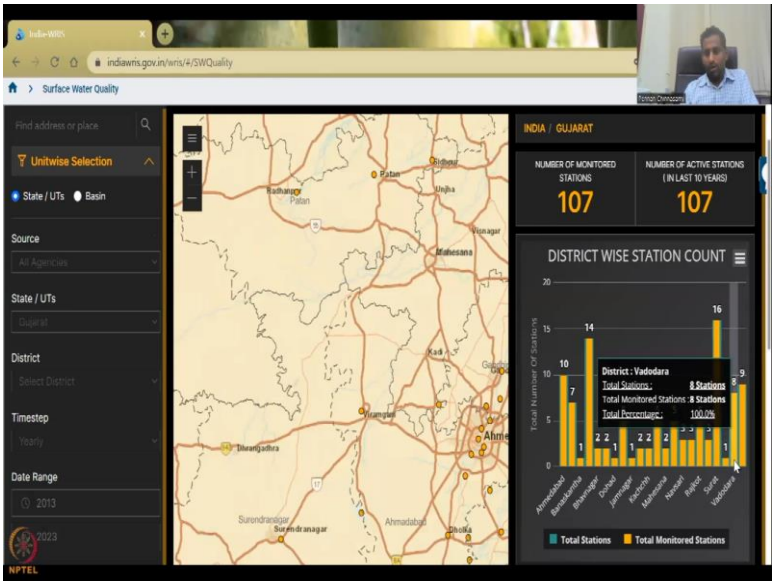
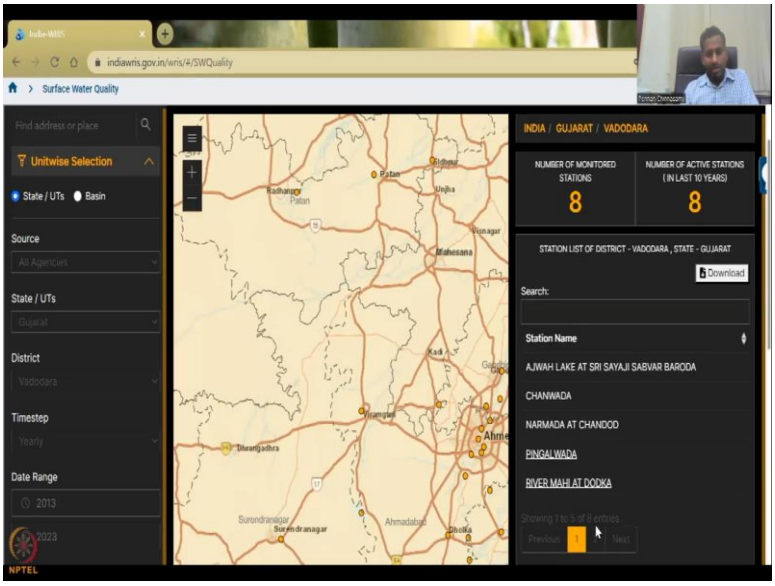


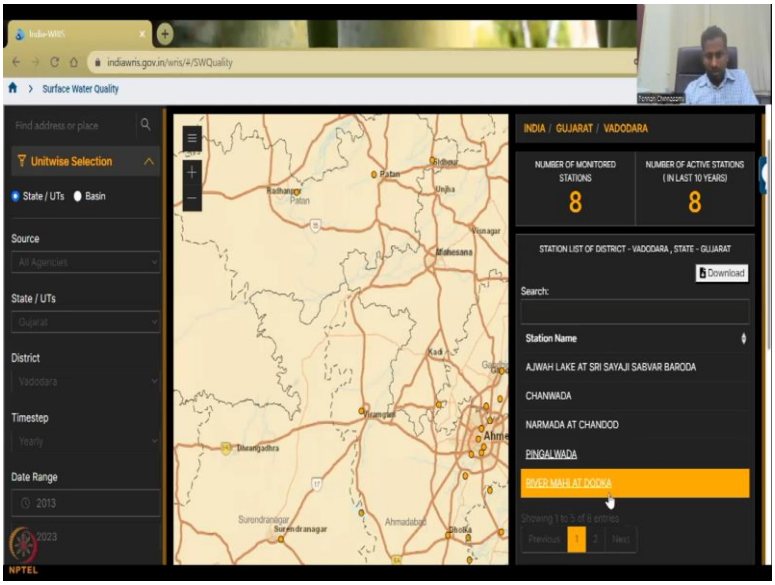





India-WRIS
indiawris.gov.in/wris/#/SWQuality
Surface Water Quality
Find address or place
Unitwise Selection
State / UTs
Basin
Source
All Agencies
State / UTs
Gujarat
District
Select District
Timestep
Yearly
Date Range
2013
2023
NPTEL
INDIA / GUJARAT
NUMBER OF MONITORED STATIONS
107
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
107
DISTRICT WISE STATION COUNT
Total Number Of Stations
Ahmedabad
Banaskantha
Bharuch
Dohad
Jamnagar
Kachchh
Mahesana
Narmad
Rajkot
Surat
Vadodara
Total Stations
Total Monitored Stations


India-WRIS
indiawris.gov.in/wris/#/SWQuality
Surface Water Quality
Unitwise Selection
State / UTs
Basin
Source
State / UTs
District
Timestep
Date Range
2013
2023
NPTEL
INDIA / GUJARAT
NUMBER OF MONITORED STATIONS
107
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
107
DISTRICT WISE STATION COUNT
District : Vadodara
Total Stations : 8 Stations
Total Monitored Stations : 8 Stations
Total Percentage : 100.0%
Total Stations
Total Monitored Stations


India-WRIS
indiawris.gov.in/wris/#/SWQuality
Surface Water Quality
Unitwise Selection
State / UTs
Basin
Source
State / UTs
District
Vadodara
Timestep
Date Range
2013
2023
NPTEL
INDIA / GUJARAT / VADODARA
NUMBER OF MONITORED STATIONS
8
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
8
STATION LIST OF DISTRICT - VADODARA , STATE - GUJARAT
Download
Search:
Station Name
AJWAH LAKE AT SRI SAYAJI SABVAR BARODA
CHANWADA
NARMADA AT CHANDOD
PINGALWADA
RIVER MAHI AT DODKA
Previous
1
Next



So, you can see here, these are the wells in this particular; we can just zoom in a bit and click on a particular well, yeah. So, here we have Moonsar Lake of Virmangam and it is a lake data you can see that lake data. And then you can see if you want to see the station data, you can click on the station itself and it will start to populate. We can actually look into the number of data products and in each station you can look at.

So, now, what I would do is we will go into the paper to see why and how many data sets we have, let us say Vadodara, we can click on Vadodara, now, eight stations are coming up and in these eight stations where do you want to look at. So, let us say River Mahi at Dodka or Chanwada, we can say Chanwada we want to see.

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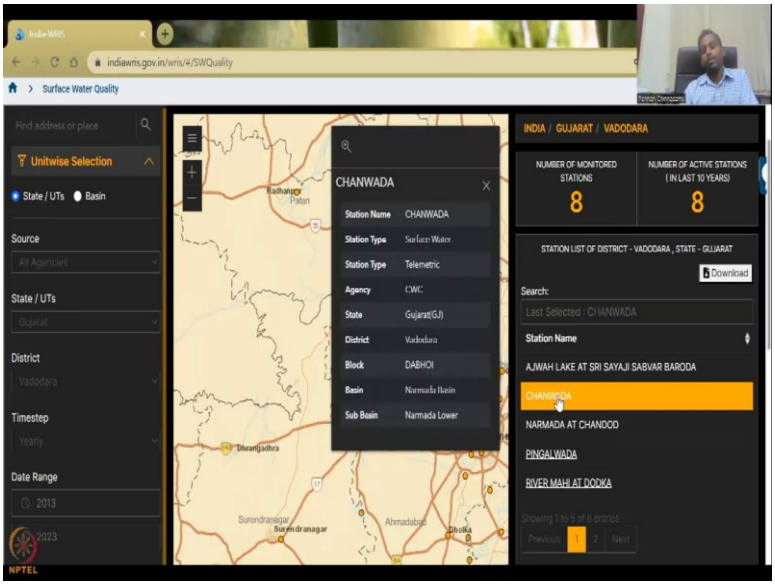
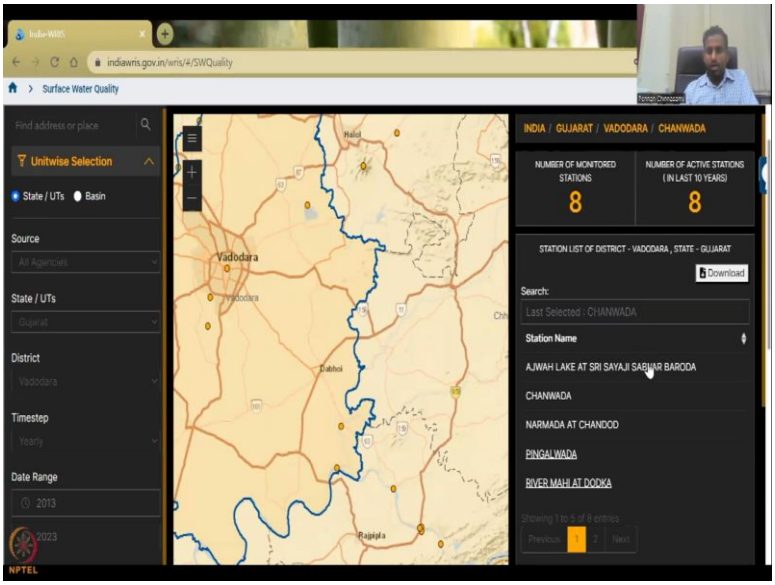
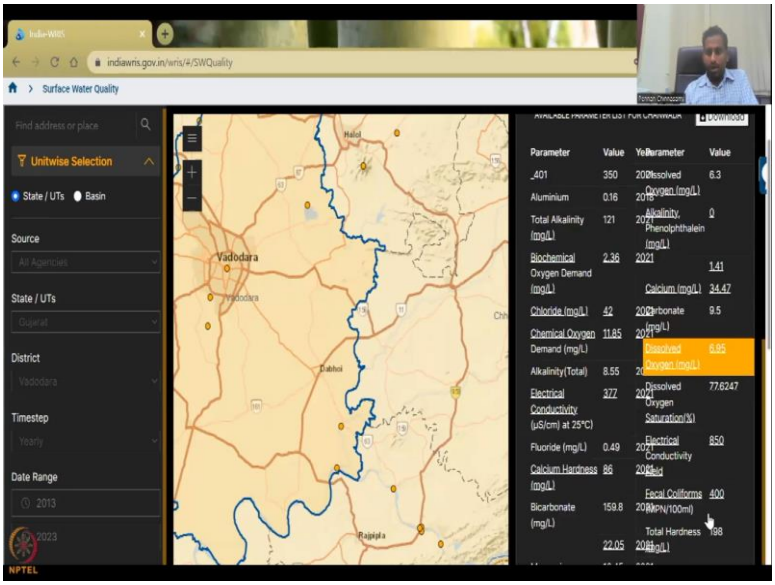
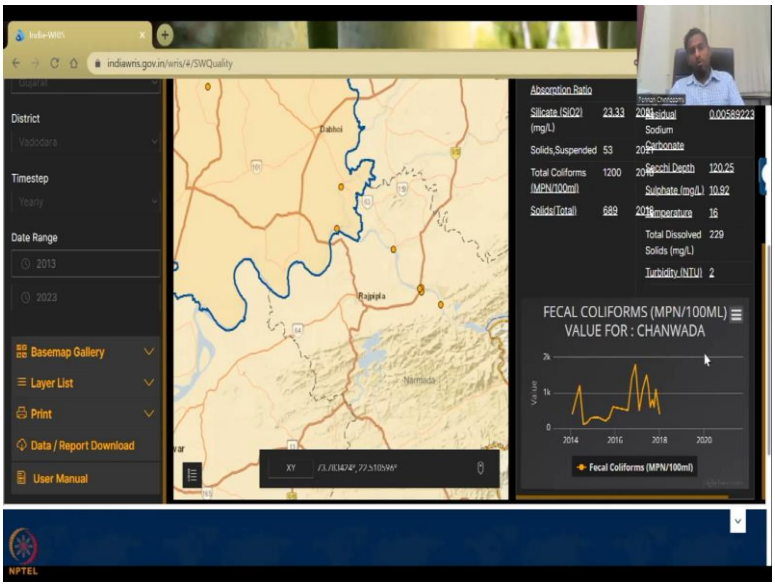



India-WRIS
indiawris.gov.in/wris/#/SWQuality
Surface Water Quality
Find address or place
Unitwise Selection
State / UTs
Basin
Source
All Agencies
State / UTs
Gujarat
District
Vadodara
Timestep
Yearly
Date Range
2013
2023
NPTEL
Halol
Vadodara
Dabhoi
Rajpipla
INDIA / GUJARAT / VADODARA / CHANWADA
NUMBER OF MONITORED STATIONS
8
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
8
STATION LIST OF DISTRICT - VADODARA , STATE - GUJARAT
Download
Search:
Last Selected : CHANWADA
Station Name
AJWAH LAKE AT SRI SAYAJI SABHAR BARODA
CHANWADA
NARMADA AT CHANDOD
PINGALWADA
RIVER MAHI AT DODKA
Showing 1 to 5 of 8 entries
Previous
1
2
Next


India-WRIS
indiawris.gov.in/wris/#/SWQuality
Surface Water Quality
Find address or place
Unitwise Selection
State / UTs
Basin
Source
State / UTs
District
Timestep
Date Range
2013
2023
NPTEL
Halol
Vadodara
Dabhoi
Rajpipla
Download
Parameter
Value
Parameter
Value
Aluminium
0.16
Total Alkalinity (mg/L)
121
Biochemical Oxygen Demand (mg/L)
2.36
Chlorides (mg/L)
42
Chemical Oxygen Demand (mg/L)
11.85
Alkalinity(Total)
8.55
Electrical Conductivity (µS/cm) at 25°C
377
Fluoride (mg/L)
0.49
Calcium Hardness (mg/L)
86
Bicarbonate (mg/L)
159.8
22.05
Dissolved Oxygen (mg/L)
6.3
Alkalinity, Phenolphthalein (mg/L)
0
1.41
Calcium (mg/L)
34.47
Carbonate (mg/L)
9.5
Dissolved Oxygen (mg/L)
6.95
Dissolved Oxygen Saturation(%)
77.6247
Electrical Conductivity
850
Fecal Coliforms (MPN/100ml)
400
Total Hardness
198

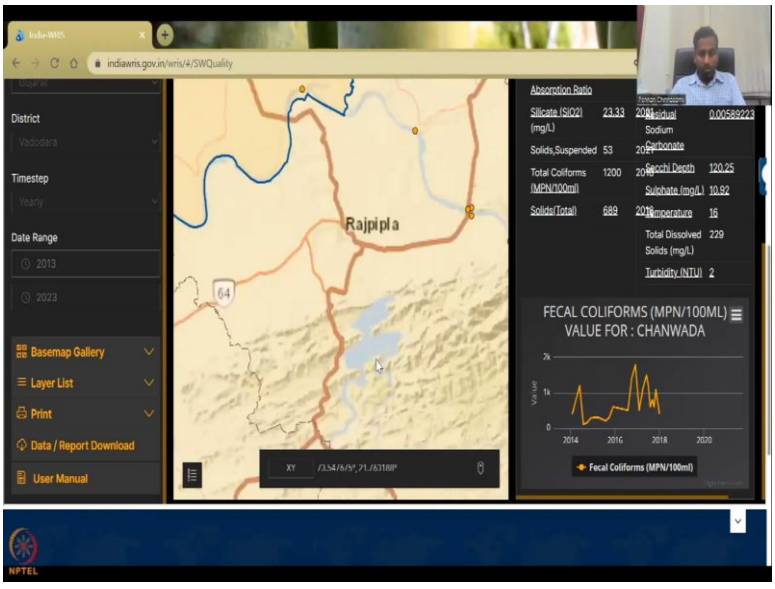

India-WRIS
indiawris.gov.in/wris/#/SWQuality
District
Vadodara
Timestep
Yearly
Date Range
2013
2023
Basemap Gallery
Layer List
Print
Data / Report Download
User Manual
NPTEL
Dabhoi
Rajpipla
Narmada
Absorption Ratio
Silicate (SiO2) (mg/L)
23.33
Solids,Suspended
53
Total Coliforms (MPN/100ml)
1200
Solids(Total)
689
Residual Sodium Carbonate
0.00589223
Secchi Depth
120.25
Sulphate (mg/L)
10.92
Temperature
16
Total Dissolved Solids (mg/L)
229
Turbidity (NTU)
2
FECAL COLIFORMS (MPN/100ML) VALUE FOR : CHANWADA
2k
1k
0
Value
2014
2016
2018
2020
Fecal Coliforms (MPN/100ml)

Just click on it and wait for a bit and then you can see Vadodara is a very industrial area. And here when I click that for Chanwada every time you click an update this link will go. So, India, Gujarat, Vadodara, Chanwada. So, now, you have all these parameters mapped, this is pretty good.

So, all a lot of parameters. It is always important to learn what is the range as WHO standard and ISB standard Indian standards. Please, look at these range before you take a research question because that is how you defend your research. So, it is better to look at it. Let us say one of the alkalinity is pretty important. Important other phenomena as we can see aluminum, magnesium, ammonia, total hard farms and then fecal coliforms which is due to leakage of sewage into the drinking water and water bodies.

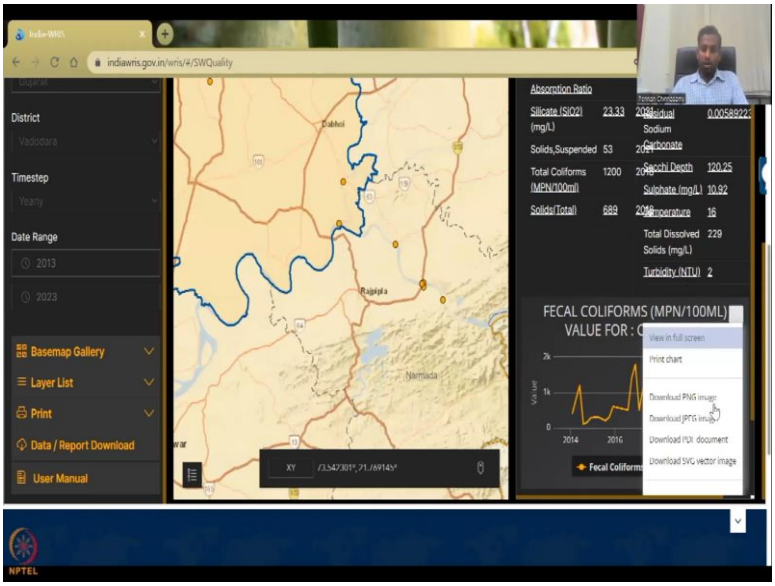
If you can see the data only exists from 2014. So, you have a Jan 2014 and then March and then June. So, one two. So, by monthly, June you have and then July, we do not have, yeah, July and then November, June, July. So, there is some up and down of data but not long-term data which is available and not all parts are marked.

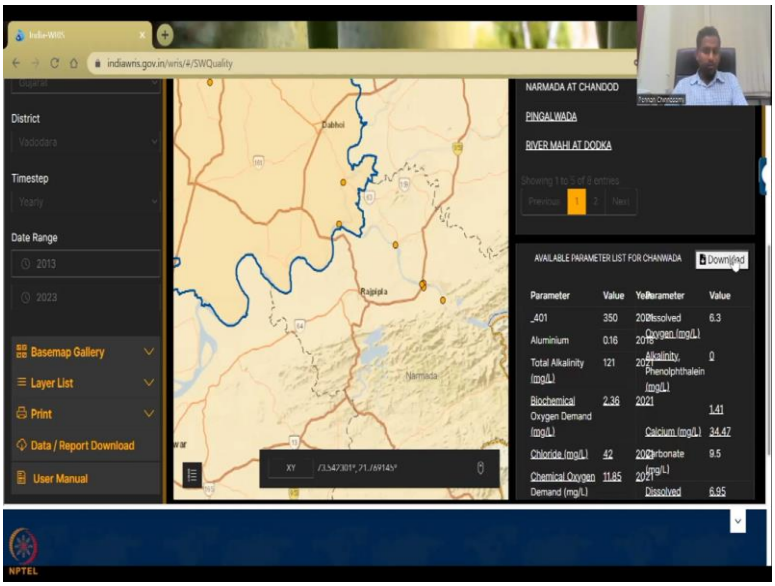
(Refer Slide Time: 12:31)



So, for example, this is a water body but it is not marked. And then we will come back and search for the study areas that are mentioned in the paper.

(Refer Slide Time: 12:40)





So, you can download this data freely, just click here, you can download as image, PDF, vector image, print chart or full screen and log in and get the data, download the data and every year wise, every month wise the data will come. So, more and more entries. So, you can go back to where you want to read the data.

So, in our paper what we have is we do have an analysis of a particular region, especially, in case of Gujarat, we have taken two lakes, one is the Sursagar Lake and then we also have the Nalsarovar Lake. And these two lakes are very important because they have been used widely by people and one is in Ahmedabad and then Vadodara.

So, if you go to Vadodara, you will see that the Sursagar Lake is there and then the Nalsarover Lake is almost on the border of Ahmedabad and Surendra nagar. So, we will just see Vadodara now. So, we do have Vadodara here and as I said Vadodara has multiple say stations and one of the station should be our study area. So, Sursagar Lake is there.

So, let us click on Sursagar Lake and then the data will pop up and you could see that, that is here. So, this is Sursagar Lake. Yes. If you want to see the lake, let us put the base map back in. So, see how this satellite imagery helps because, yeah, it is a particular time period. It is not, it is a stationary image, it is not changing with the time.

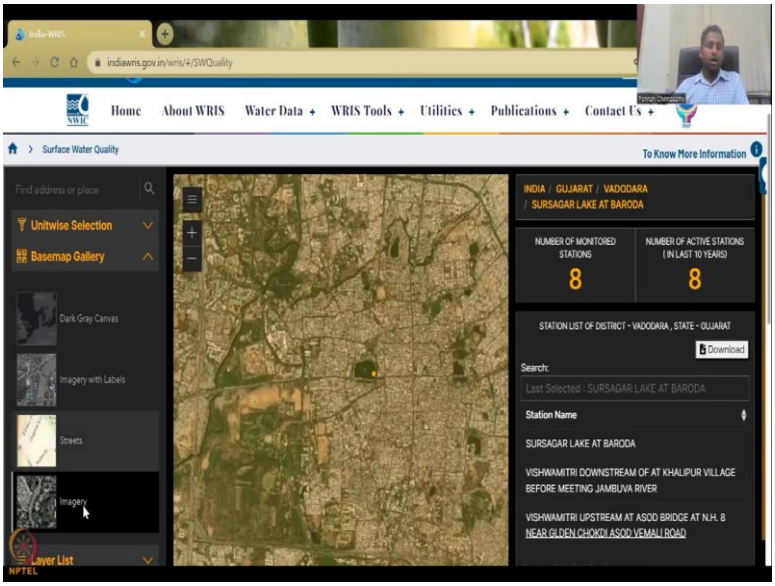
So, as I said the internet does take a hit when you do these things. So, look at the population around and a lot of people depend on this. This is the same scenario for a lake in a rural region because pumps are very low. They have to go to the lake for everything. Initially, in the previous years, it was well maintained for furthers maintained it well but nowadays the generations are not taking care of it. There is a lot of pollution that enters into these lakes.

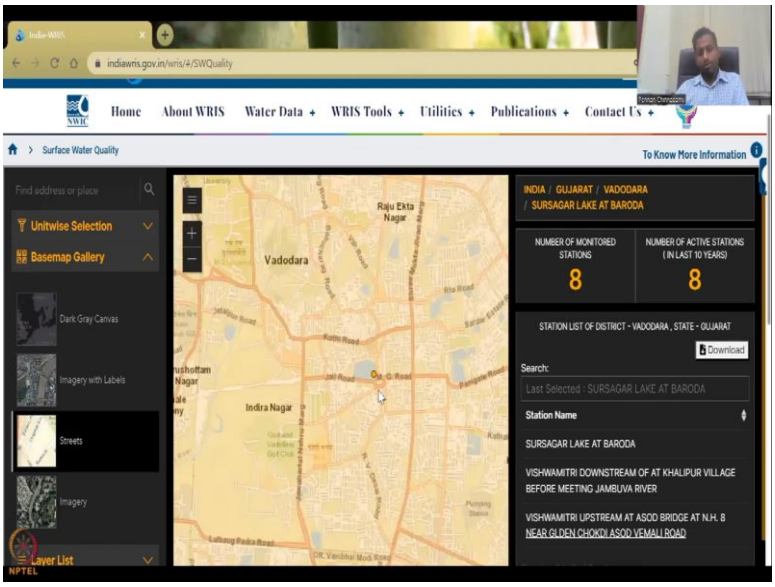
So, it is very very important to monitor and take up these lakes. So, you can download the report, user manual is there if you want to see how to use the data available parameters for the lake are here, you can just click on one of these each one of these. So, fluoride is important and you can see only from 2020 you have these data.

So, what we will be doing is, okay, pH may be a higher value we have, 2018 to 2021 which is good. Ammonia, we do have from 2018. So, and a lot of gaps are there. Again, these are expensive. So, what happens is not every month you will see. So, Jan, April, May, March, April then March, April, May, June and then Sunday as a gap. So, you can see how the gap is there. It disrupts the continuity and the issues maybe there is a big spike of pollution happening that time. So, it is very important to monitor these.

So, let us see how we could get these data. As I said, you can get these as a image or also you can go up here and download the data. You need to have the account for the BRS as usual and then put it for research purposes, student purposes, if you are using it for your studies. So, Now, I am going to go back to the looks like my screen will pop up now.

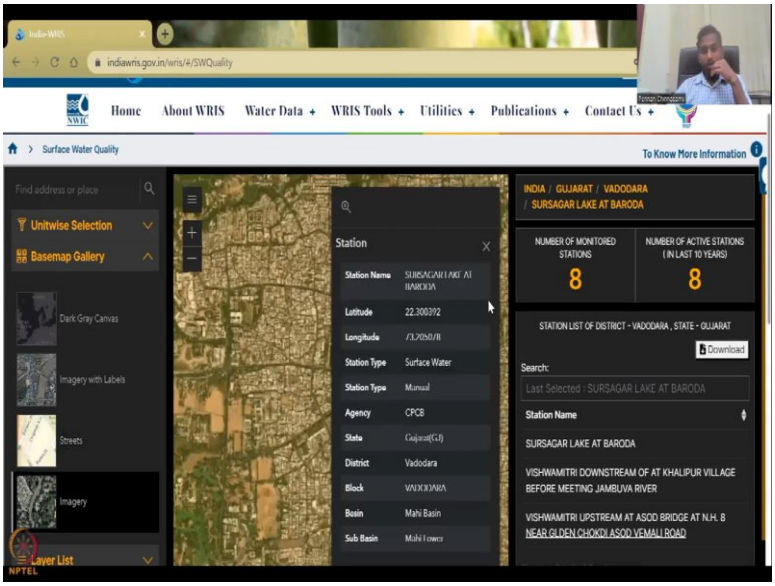
(Refer Slide Time: 16:23)

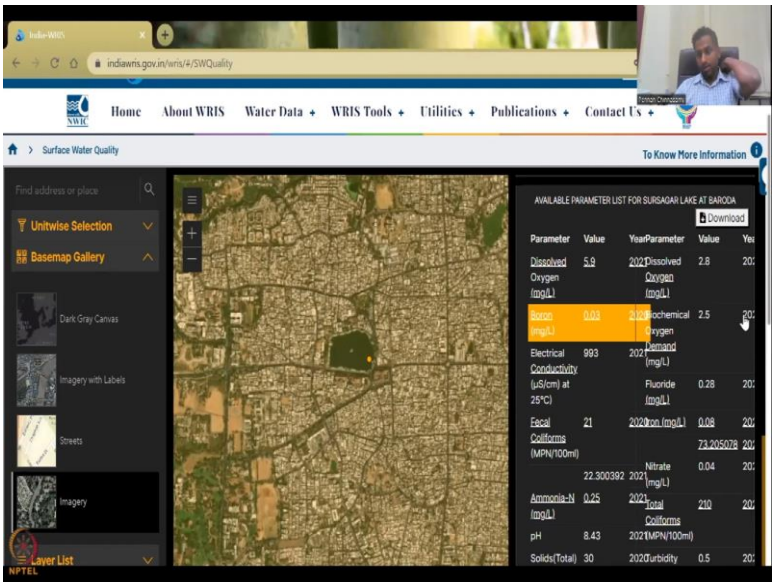


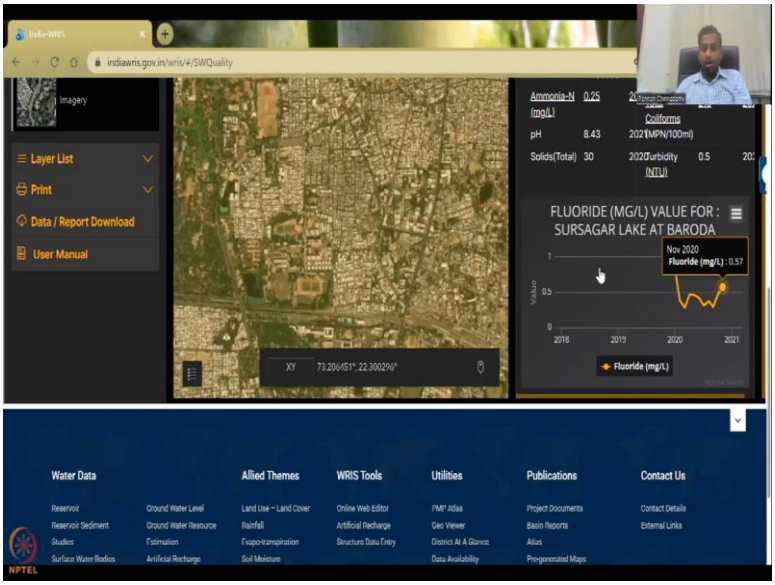


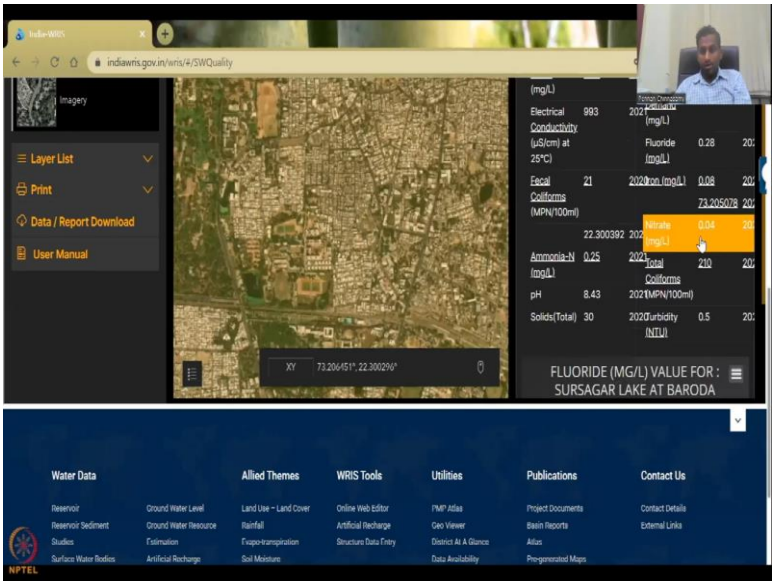
So, what I have done is I have used my base map layers, instead of streets I put imagery and now the imagery does work. So, first it was streets. I zoomed in just the internet took some time. So, just excuse me for that. And what happens here is this is the Vadodara region and the Sursagar Lake. And then I am just going to click on imagery. So, imagery takes more bandwidth.

(Refer Slide Time: 16:47)





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Imagery
Layer List
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Data / Report Download
User Manual
Electrical Conductivity (µS/cm) at 25°C 993
Fecal Coliforms (MPN/100ml) 21
Ammonia-N (mg/L) 0.25
pH 8.43
Solids(Total) 30
Fluoride (mg/L) 0.28
Iron (mg/L) 0.08
Nitrate (mg/L) 0.04
Total Coliforms (MPN/100ml) 210
Turbidity (NTU) 0.5
XY 73.206451°, 22.300296°
FLUORIDE (MG/L) VALUE FOR : SURSAGAR LAKE AT BARODA
Water Data
Reservoir
Reservoir Sediment
Studies
Surface Water Bodies
Ground Water Level
Ground Water Resource
Estimation
Artificial Recharge
Allied Themes
Land Use - Land Cover
Rainfall
Evapo-transpiration
Soil Moisture
WRIS Tools
Online Web Editor
Artificial Recharge
Structure Data Entry
Utilities
FMP Atlas
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Basin Reports
Atlas
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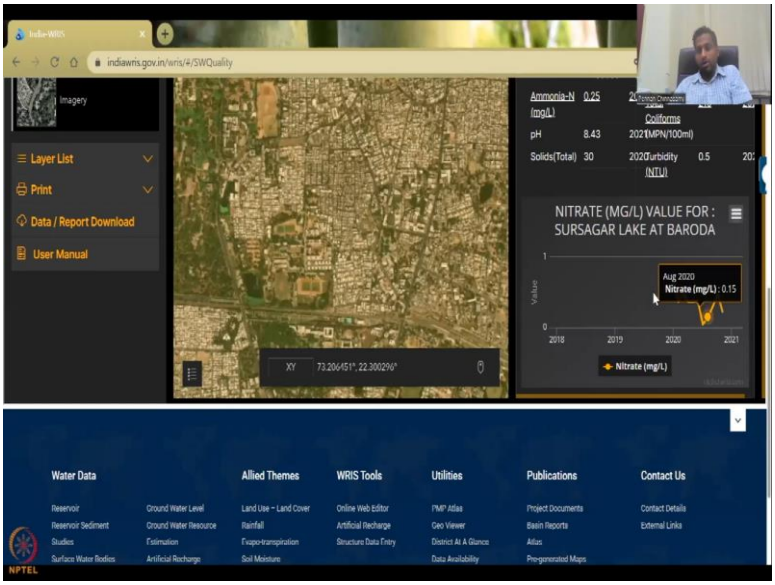
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Imagery
Layer List
Print
Data / Report Download
User Manual
Ammonia-N (mg/L) 0.25
pH 8.43
Solids(Total) 30
Coliforms (MPN/100ml)
Turbidity (NTU) 0.5
XY 73.206451°, 22.300296°
NITRATE (MG/L) VALUE FOR : SURSAGAR LAKE AT BARODA
Aug 2020
Nitrate (mg/L) : 0.15
Value
2018
2019
2020
2021
Nitrate (mg/L)
Water Data
Reservoir
Reservoir Sediment
Studies
Surface Water Bodies
Ground Water Level
Ground Water Resource
Estimation
Artificial Recharge
Allied Themes
Land Use - Land Cover
Rainfall
Evapo-transpiration
Soil Moisture
WRIS Tools
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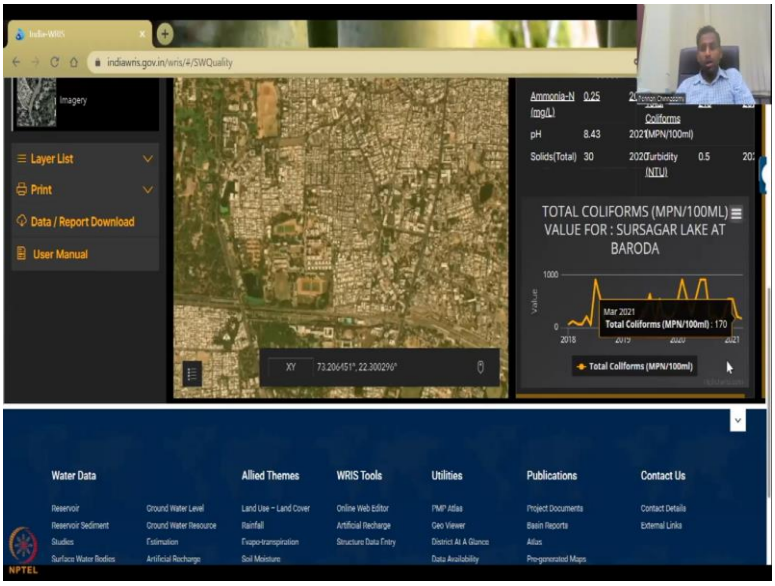
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Imagery
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User Manual
Ammonia-N (mg/L) 0.25
pH 8.43
Solids(Total) 30
Coliforms (MPN/100ml)
Turbidity (NTU) 0.5
XY 73.206451°, 22.300296°
TOTAL COLIFORMS (MPN/100ML) VALUE FOR : SURSAGAR LAKE AT BARODA
1000
0
Value
Mar 2021
Total Coliforms (MPN/100ml) : 170
2018
2021
Total Coliforms (MPN/100ml)
Water Data
Reservoir
Reservoir Sediment
Studies
Surface Water Bodies
Ground Water Level
Ground Water Resource
Estimation
Artificial Recharge
Allied Themes
Land Use - Land Cover
Rainfall
Evapo-transpiration
Soil Moisture
WRIS Tools
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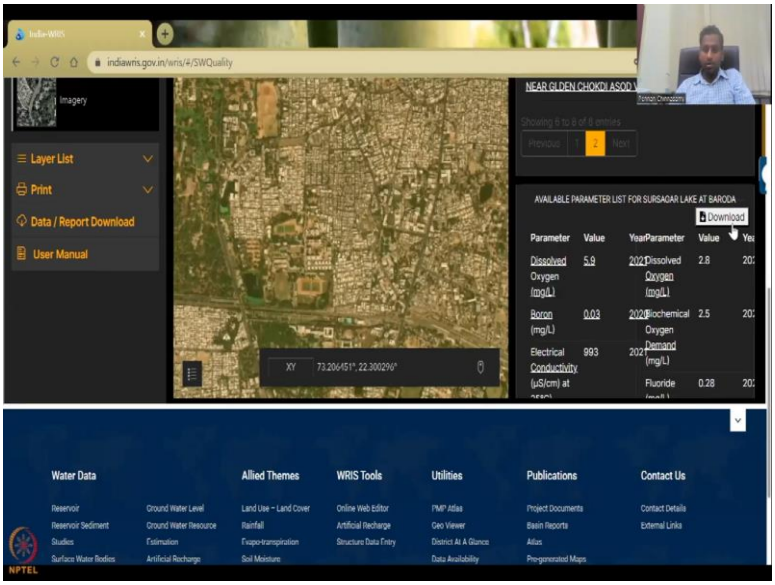
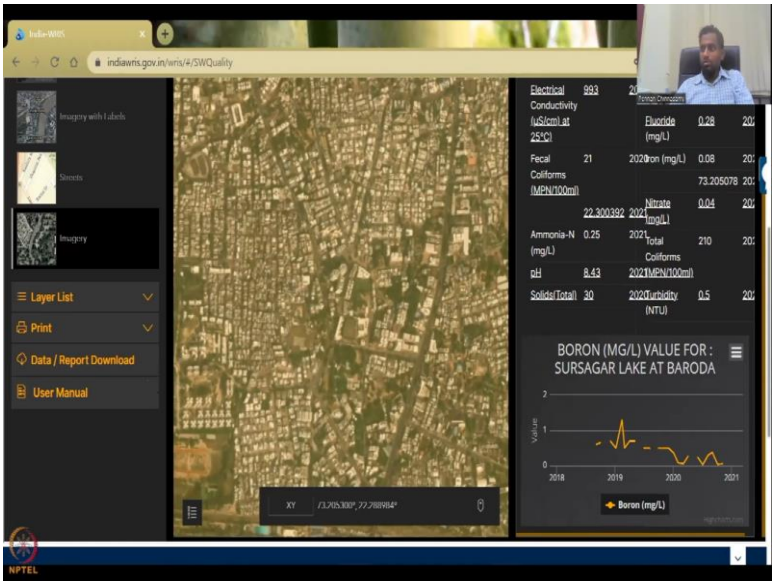




So, what you should be doing is first keep the streets layer which is not a satellite imagery. It is used to from a satellite imagery or not. Then you can go here and then come down and see what are the parameters available. All these are available but if you click on fluoride, for example.

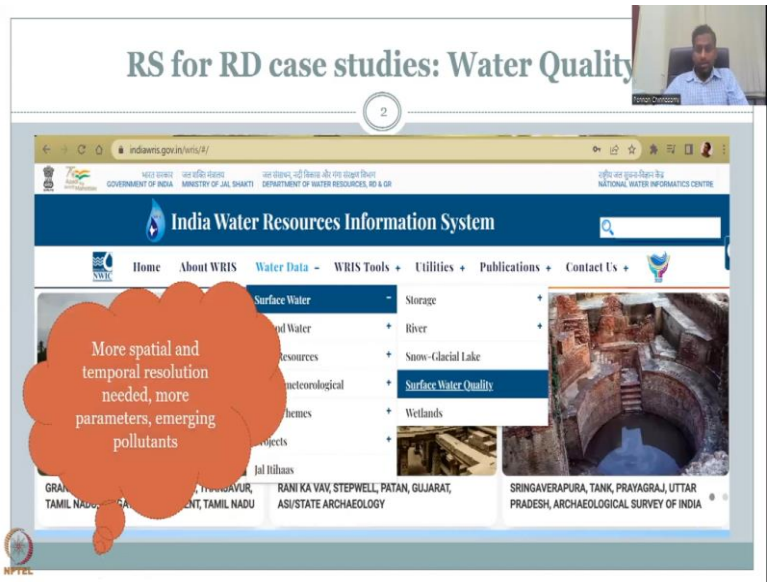
As I said fluoride is only from 2020 to 2021 and fecal coliforms, all these are there. Nitrates are are very bad, you need to monitor it, only very less data as there. Total coliforms, fecal coliforms from 2018 to 2021 and if you need to download the data, just click here you will get all the data or you could bring this click and then take your full image or download their PDF document, SVG, vector image, check that out.

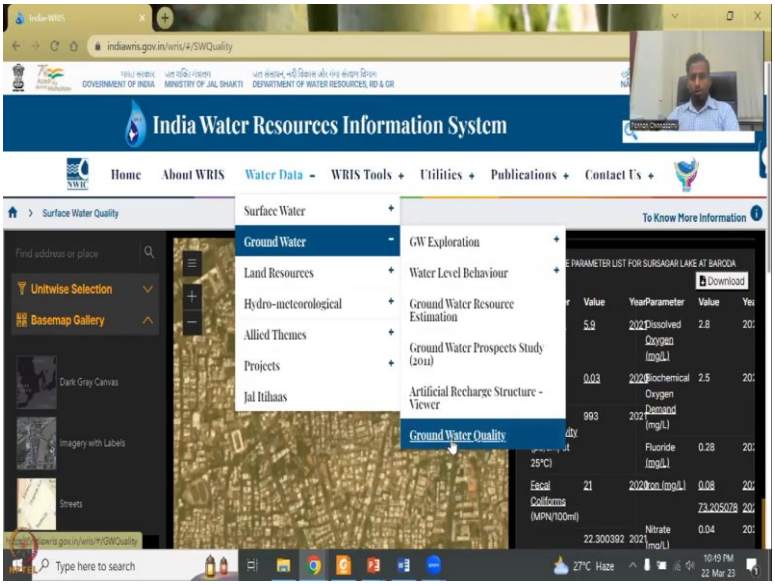
So, now, I am going to show you how we downloaded this data and used it to increase the. So, this is a fecal colifroms the increase the spatial and temporal resolution of this data. Especially, the temporal resolution. For example, Ph, I was saying. It is because pH is more easier to monitor and maintain but nitrates and other things are having issues. There is a lot of gaps.

Fluoride is very important, lot of gaps and then dissolve oxygen water quality parameters etcetera, etcetera. So, please, please, note that everything has to be monitored for a longer term to understand the impacts, otherwise, there could have been a big pollution happening here and if you are not looking at it you are missing the statement.

So, if you see the common ones are there and Boron, for example, a lot of gaps and there could have been a big pollution happening there. So, it is very important to monitor these. So, now, let us go back to see how we did it in our study. So, I am going back to my lecture slides.

(Refer Slide Time: 18:47)





So, we were here. It is come up now in the monitor. So, more spatial temporal resolution are needed as I suggested and I showcase from the data set. More parameters are also needed because by time, you catch these pollutants. You should always read and update yourself on these pollutants and you need to put it into the reports and documents.

So, for example, now COVID. No one knew how this virus was when it came. So, that was emerging because of the new phenomena. Similarly, there could be other issues that can happen suddenly. So, I strongly urge you to take a very careful look at these data sets and then use it wisely for assessing important pollutants and then coming back.

Well, before we go I will also showcase the groundwater part. Let me share my first name. So, there is the data here but also you can go back to the water data groundwater and then

groundwater quality, you can open a new tab just to keep it running. And you would see that it is more, less of the data you will see for groundwater.

And it is a concern because the missions for supplying water for these areas may be using more groundwater. So, because in the summer time, the surface waters are depecting and how do you use other resources is there. So, you have a number of stations is 15800 stations 14492. This is much bigger than the declared by the surface water boards.

So, you can see what agencies are monitoring, if you click here. It is still loading. So, that is when it is not coming up. So, it could be mostly CPCB, Central Groundwater Board and the state agencies are could be there. And then, yeah, just for the internet let me put the base layer as a street map and hopefully let us see if the internet is faster.

(Refer Slide Time: 21:18)


indiawris.gov.in/wris/#/GWQuality
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DEPARTMENT OF WATER RESOURCES, RD & GR
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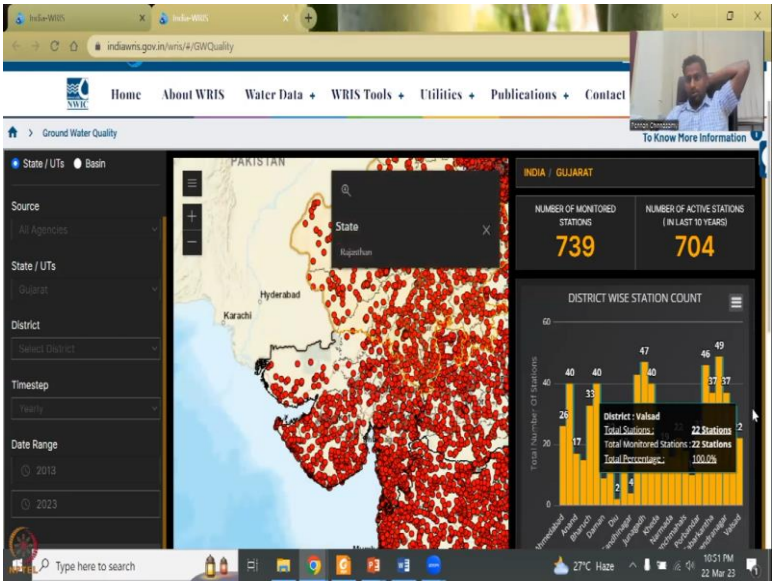
Assam
Bihar
Chhattisgarh
Chandigarh
Daman & Diu
Delhi & NCR
Dadara & Nagar Havelli
Goa
Gujarat
Himachal Pradesh
Haryana
Jharkhand
Jammu & Kashmir
Karnataka
Kerala
Lakshadweep
District
Timestep
Yearly
Date Range
INDIA
NUMBER OF MONITORED STATIONS
15800
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
14492
STATE WISE STATION COUNT
Total Number Of Stations
Type here to search
27°C Haze
10:51 PM
22 Mar 23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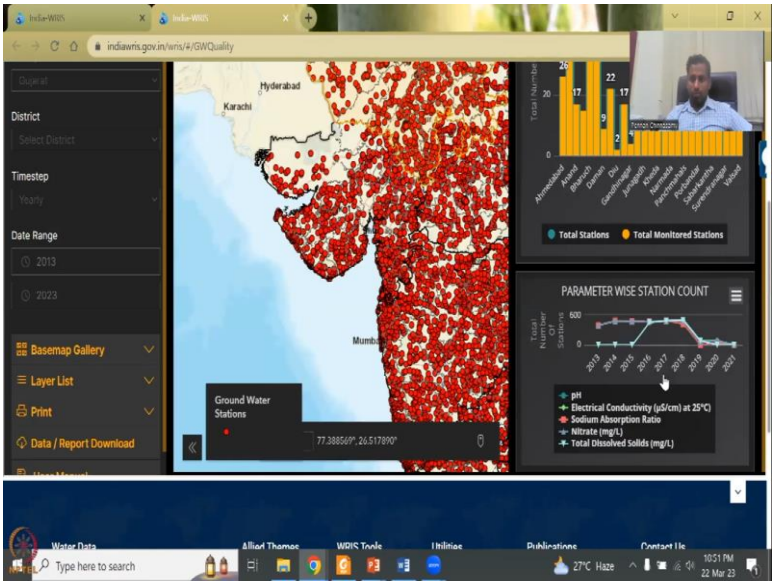
Ground Water Quality
To Know More Information
State / UTs
Basin
Source
State / UTs
District
Timestep
Date Range
2013
2023
INDIA / GUJARAT
NUMBER OF MONITORED STATIONS
739
NUMBER OF ACTIVE STATIONS (IN LAST 10 YEARS)
704
DISTRICT WISE STATION COUNT
District : Valsad
Total Stations : 22 Stations
Total Monitored Stations : 22 Stations
Total Percentage : 100.0%
Type here to search
27°C Haze
10:51 PM
22 Mar 23

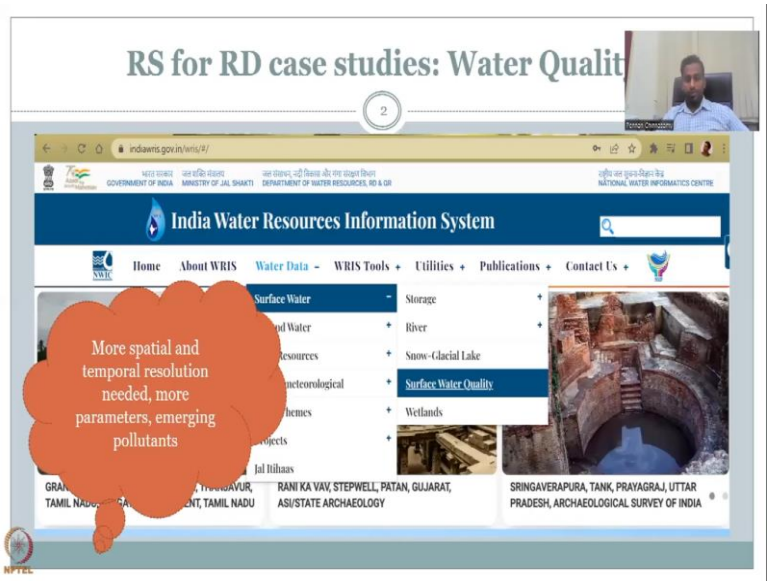

indiawris.gov.in/wris/#/GWQuality
District
Timestep
Date Range
2013
2023
Basemap Gallery
Layer List
Print
Data / Report Download
Ground Water Stations
Total Stations
Total Monitored Stations
PARAMETER WISE STATION COUNT
pH
Electrical Conductivity (µS/cm) at 25°C
Sodium Absorption Ratio
Nitrate (mg/L)
Total Dissolved Solids (mg/L)
Water Data
Allied Themes
WRIS Tools
Utilities
Publications
Contact Us
Type here to search
27°C Haze
10:51 PM
22 Mar 23

So, now, you can see the agency CPC, CPCB, Center Pollution Control Board, Central Groundwater Board as I said and only then Telangana government has put the data up, all the others are not. So, you can still keep all all of them. And then if you save Gujarat, again, you can see a lot of more wells that are coming up. And then select districts almost every district can be there which is fine.

And then we could see here it will come down what are the parameters how long are they been taking all these things are here. There is multiple sliders. So, make sure the yellow and gray ones are different and then how they are monitoring etcetera, etcetera. So, like same way you could do it but as I said a lot of surface water quality is more important to assess. Because groundwater they mostly use it for drinking and agriculture.

They are kind of, no, they will just not use it and ask the government to supply and most of the government supply may come from surface water policies. So, it is important to go back to this area. But again I have just told you how to download the data set; it is the same way that you could download it from the groundwater board. So, let us go back to my slide which is coming up.

(Refer Slide Time: 22:26)



So, we have the paper that we will be discussing today for the next 10 minutes is the Potential of Open Source Remote Sensing Data for Improved Spatial Temporal Mapping and Monitoring of Inland Water Quality in India: Case Study of Gujarat. We did Gujarat because of, because we found out that how many data sets that we could quickly assess and the students also went there to do some fieldwork. It was led by the PHD student Singh Neetu.

So, Neetu is the first name, Singh is the second and all my team members were there including Shivanand, Amita and me. So, what happens here is this paper actually uses open source data. So, which means it is free open source, anyone can use it. As is supported in this course I have only used open source software and open source data.

I have given links to data that is paid version and really expensive, just for those who really want that data for a particular use. But till late I have been happy to use open source data. It has been doing the work that I needed and very very successfully the things are results are coming out. So, we do not have to spend more money on a proprietary data or costly data, unlike the other things.

(Refer Slide Time: 23:52)

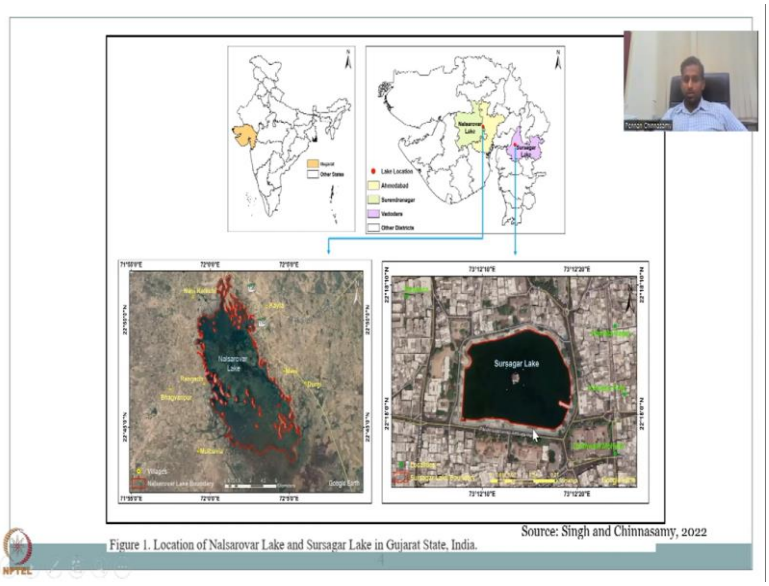


Figure 1. Location of Nalsarovar Lake and Sursagar Lake in Gujarat State, India.

So, what was the base idea here is we have these two lakes and we have limited observation data. How can we use satellite data to capture the impact of water pollutants on water? So, basically visually we know that when we go to the rivers in certain parts of Mumbai or near the airport, you will see there is pitch black in color.

Even Chennai, the river kuvam, aadeyar, aadeyar river sometimes is okay, but Chennai river kuvam, it will be pitch black. So, for sure that really it is not drinkable, it is not portable, but one day it was. It was a really beautiful waterways, people use it for travel, people use it for drinking but now it is purely polluted.

So, this color can give you an inference of the water quality. The same aspect has been used by multiple studies for using satellites for assessing the quality. So, how you have satellites for assessing the plant growth and plant healthiness using the green color, same, the color of the blue, the multiple band colors or the blue can be associated with a particular water quality issue.

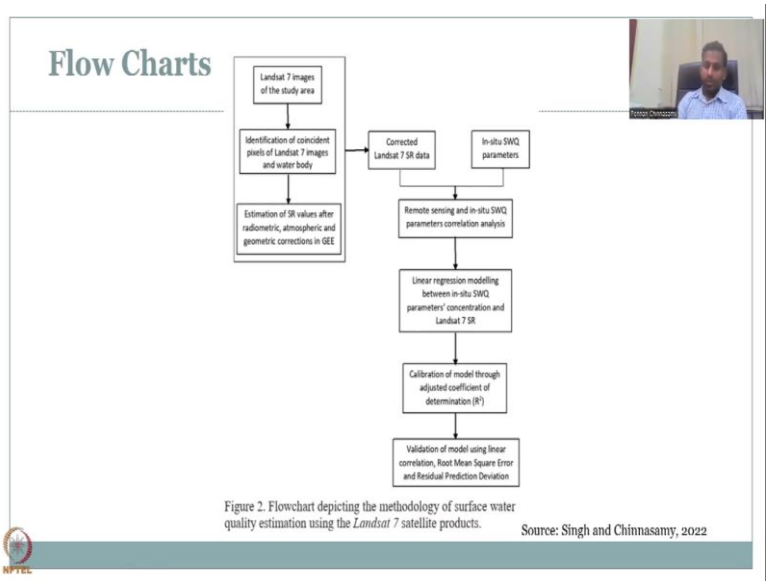
However, this is a correlation kind of work. So, how is the color correlated to the water quality? There is a causality. It is because of mainly sewage dumping, maybe industries dumping, maybe medical waste from another state being put into Tamil Nadu's water bodies. So, what happens is there is a lot of these water quality impacts that can happen. I will just pick up the news and check and see how many issues are happening.

You know how many illegal dumpings happen on the borders of states. Because they this the rules are very strict in a particular state. So, they will go out and put or dump and stuff. So, this is very sad but because they are not given an option to clean the water or they just do not want to do it and let others suffer.

So, this satellite data can actually pick it up. So, this is what we did. We did some correlation analysis between the color of the water and the pollutant level and then trend a model, trend a model with high accuracy to predict the water qualities for longer time. So, let us see how we did.

First these are study areas in Gujarat State the Nalsarovar Lake which is next to Ahmedabad and Surenda Nagar and then the Sursagar Lake in Vadodara. We have taken it these are the two lakes. You can see how the lake is surrounded by both rural and urban entities whereas this is more an urban entity.

(Refer Slide Time: 26:37)



And then the flowchart. Always flowcharts are good for studies. So, a kind of a recommendation for all students is whenever you are working with satellite data, remote sensing data, please, draw it as a flowchart. When I introduce GIS, I had mentioned the schematic of the works which is very important to understand. The same thing you can do here by having images of a flow of the work.

So, let us see here what with the study starts by doing is analyzing landsat images for the study area. So, just collecting landsat images and these images can be collected from the

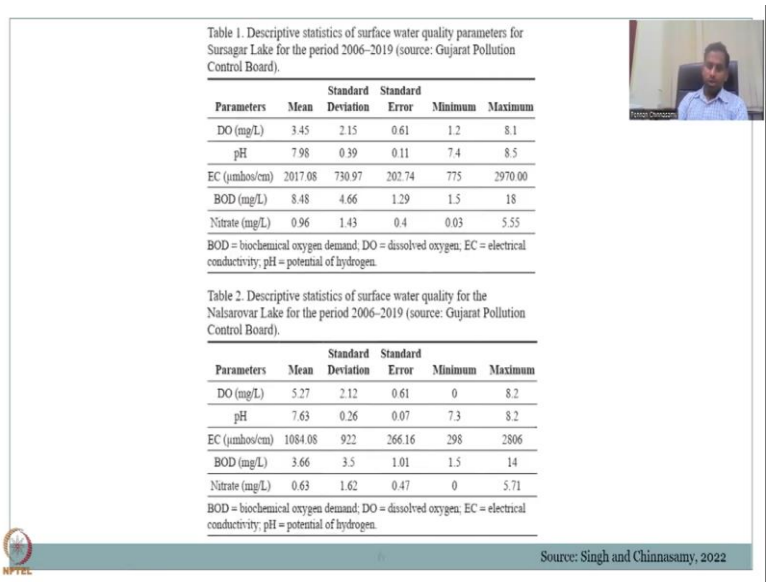
NASA or the ESA Sentinel portals. I have shown you how to do it. And then identification of coincidence of pixels and the water body.

So, just masking out the pixels that can come out and then estimation of some more quality concern values. So, you get a corrected landsat value. Just leave the how they corrected; maybe they have a better correction for cloud cover and then reflectance, etcetera, etcetera. So, there is some post processing needed before running into this.

And then what we do is, so let us say we have a corrected landsat image which nowadays you do get from different portals. Then you have the in situ water quality parameters. What is in situ? In situ means observed, monitored physically. So, you take a sample that is in situ monitoring, you take it to your labs, analyze the water quality and bring out the results. So, the remote sensing in situ surface water quality parameters pollution analysis is happening.

So, both on two axis and then say, oaky, what colors can capture these water pollutant levels and then linear regression modeling is being done between in situ and as a surface water quality parameters and concentration and landsat 7 S R and then calibration of model, adjusted coefficient determination. So, these are the processes at the bottom, are the processes for evaluating the model. So, the model is basically kind of a linear regression model. A regression correlation model between the bands and the water quality.

(Refer Slide Time: 28:50)



So, what you could see is these are the first descriptive statistics of the surface water quality from the period 2006 to 2019 and you can see that Gujarat Pollution Control Board is the data

set that we use. And they have beautiful data for bio-chemical oxygen demand BOD, DO, dissolved oxygen, EC, Electrical Conductivity, then pH. Then you have the same thing for another Nalsarovar Lake. You could see that there is a mean, standard deviation, very very basic statistics we have done.

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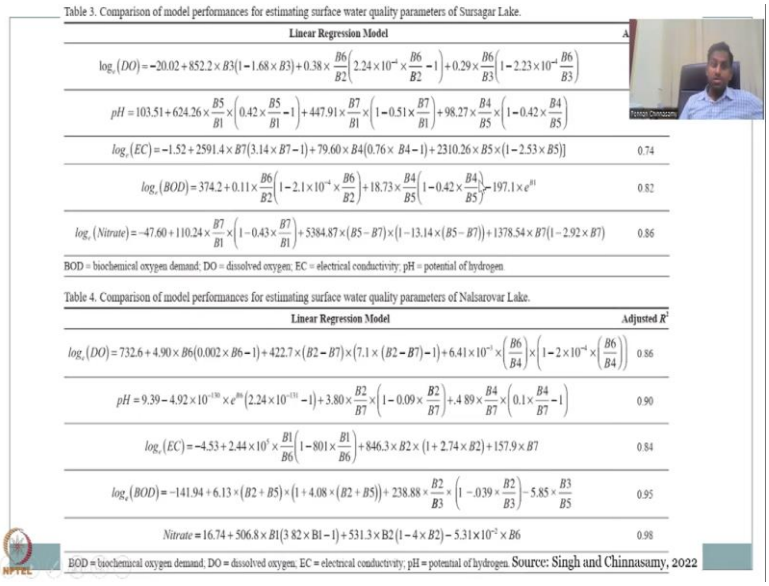
Table 3. Comparison of model performances for estimating surface water quality parameters of Sursagar Lake.

Linear Regression Model	A
$\log_e(DO) = -20.02 + 852.2 \times B3(1 - 1.68 \times B3) + 0.38 \times \frac{B6}{B2}\left(2.24 \times 10^{-4} \times \frac{B6}{B2} - 1\right) + 0.29 \times \frac{B6}{B3}\left(1 - 2.23 \times 10^{-4} \times \frac{B6}{B3}\right)$	
$pH = 103.51 + 624.26 \times \frac{B5}{B1}\left(0.42 \times \frac{B5}{B1} - 1\right) + 447.91 \times \frac{B7}{B1} \times \left(1 - 0.51 \times \frac{B7}{B1}\right) + 98.27 \times \frac{B4}{B5} \times \left(1 - 0.42 \times \frac{B4}{B5}\right)$	
$\log_e(EC) = -1.52 + 2591.4 \times B7(3.14 \times B7 - 1) + 79.60 \times B4(0.76 \times B4 - 1) + 2310.26 \times B5 \times (1 - 2.53 \times B5)]$	0.74
$\log_e(BOD) = 374.2 + 0.11 \times \frac{B6}{B2}\left(1 - 2.1 \times 10^{-4} \times \frac{B6}{B2}\right) + 18.73 \times \frac{B4}{B5}\left(1 - 0.42 \times \frac{B4}{B5}\right) - 197.1 \times e^{B1}$	0.82
$\log_e(Nitrate) = -47.60 + 110.24 \times \frac{B7}{B1} \times \left(1 - 0.43 \times \frac{B7}{B1}\right) + 5384.87 \times (B5 - B7) \times (1 - 13.14 \times (B5 - B7)) + 1378.54 \times B7(1 - 2.92 \times B7)$	0.86

BOD = biochemical oxygen demand; DO = dissolved oxygen; EC = electrical conductivity; pH = potential of hydrogen.

Table 4. Comparison of model performances for estimating surface water quality parameters of Nalsarovar Lake.

Linear Regression Model	Adjusted R^2
$\log_e(DO) = 732.6 + 4.90 \times B6(0.002 \times B6 - 1) + 422.7 \times (B2 - B7) \times (7.1 \times (B2 - B7) - 1) + 6.41 \times 10^{-3} \times \left(\frac{B6}{B4}\right) \times \left(1 - 2 \times 10^{-4} \times \left(\frac{B6}{B4}\right)\right)$	0.86
$pH = 9.39 - 4.92 \times 10^{-130} \times e^{B6}\left(2.24 \times 10^{-131} - 1\right) + 3.80 \times \frac{B2}{B7} \times \left(1 - 0.09 \times \frac{B2}{B7}\right) + 4.89 \times \frac{B4}{B7} \times \left(0.1 \times \frac{B4}{B7} - 1\right)$	0.90
$\log_e(EC) = -4.53 + 2.44 \times 10^{5} \times \frac{B1}{B6}\left(1 - 801 \times \frac{B1}{B6}\right) + 846.3 \times B2 \times (1 + 2.74 \times B2) + 157.9 \times B7$	0.84
$\log_e(BOD) = -141.94 + 6.13 \times (B2 + B5) \times (1 + 4.08 \times (B2 + B5)) + 238.88 \times \frac{B2}{B3} \times \left(1 - .039 \times \frac{B2}{B3}\right) - 5.85 \times \frac{B3}{B5}$	0.95
$Nitrate = 16.74 + 506.8 \times B1(3.82 \times B1 - 1) + 531.3 \times B2(1 - 4 \times B2) - 5.31 \times 10^{-5} \times B6$	0.98

BOD = biochemical oxygen demand; DO = dissolved oxygen; EC = electrical conductivity; pH = potential of hydrogen. Source: Singh and Chinnasamy, 2022

And then the linear regression models. So, we have on the left side the parameters. The parameter can be absolute or log values depending on the model. So, which is better fit. So, here you could see the pH is a function of your B5 B1 and B7 B1 B4 B5 B4 B5. So, these kind of estimates can be quickly obtained by literature review. So, which models have worked?

And the same models you could try for your area and if you are happy with the error estimates, probability distributions, etcetera, R-squares then you can continue the model or you should be using different bands. So, this is the idea of using remote sensing data. So, for example, let us say pH study in U S would have used B3 and B1 and it did not work well for our study.

So, we had to keep on looking at different colors. Because the pollutant color could be slightly different, or the pollutant color impact on the water body could be different than what we have in India. So, that is where we have to mix and match and play. Google Earth engine helps you for it. But then once you get it with a couple of iterations. Because if it is just as simple as this.

You cannot get it into a good journal. This is a very very good journal that we had published. And because of the novelty that the bands are used to predict water quality when observation quality is low. So, you have these two models, one for the Nalsarovar Lake and then the other for the other Lake and what do you have here is the adjusted R-square which is kind of giving you the closest to the fit of the model between observed and in situ.

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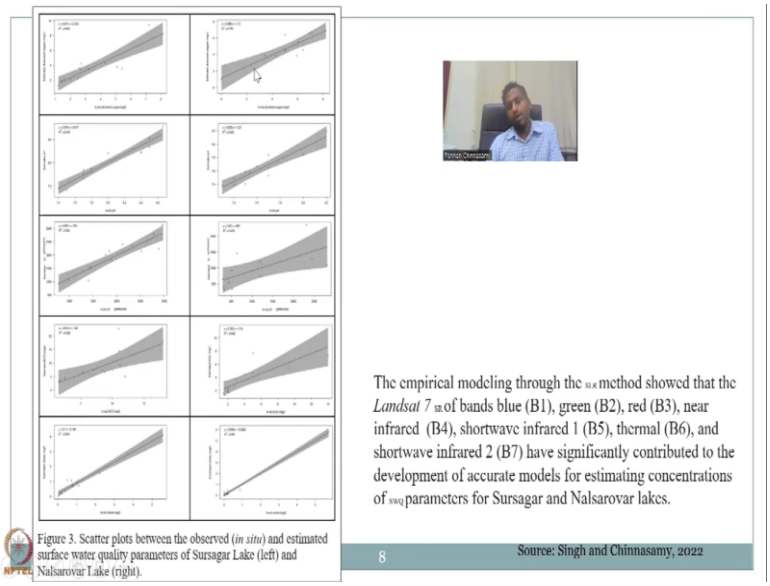
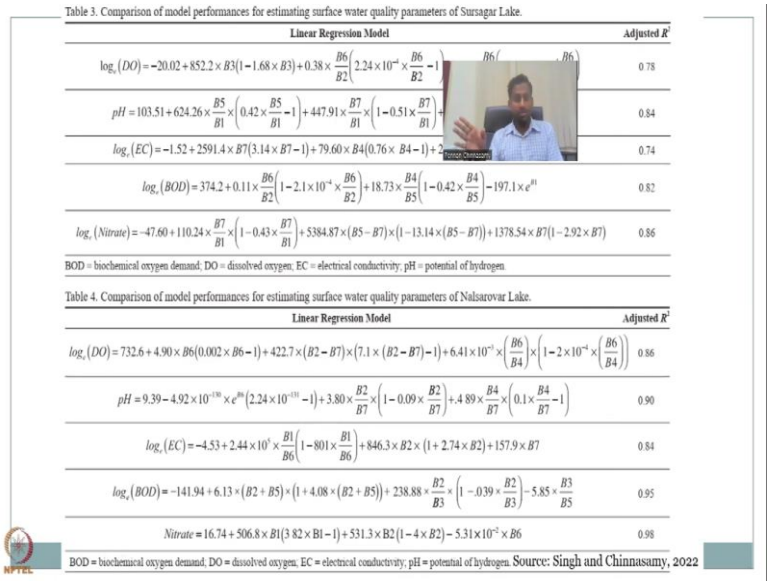


Figure 3. Scatter plots between the observed (*in situ*) and estimated surface water quality parameters of Sursagar Lake (left) and Nalsarovar Lake (right).



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$pH = 103.51 + 624.26 \times \frac{B5}{B1} \times \left(0.42 \times \frac{B5}{B1} - 1\right) + 447.91 \times \frac{B7}{B1} \times \left(1 - 0.51 \times \frac{B7}{B1}\right) +$	0.84
$\log_e(EC) = -1.52 + 2591.4 \times B7(3.14 \times B7 - 1) + 79.60 \times B4(0.76 \times B4 - 1) + 2$	0.74
$\log_e(BOD) = 374.2 + 0.11 \times \frac{B6}{B2}\left(1 - 2.1 \times 10^{-4} \times \frac{B6}{B2}\right) + 18.73 \times \frac{B4}{B5}\left(1 - 0.42 \times \frac{B4}{B5}\right) - 197.1 \times e^{B1}$	0.82
$\log_e(Nitrate) = -47.60 + 110.24 \times \frac{B7}{B1} \times \left(1 - 0.43 \times \frac{B7}{B1}\right) + 5384.87 \times (B5 - B7) \times (1 - 13.14 \times (B5 - B7)) + 1378.54 \times B7(1 - 2.92 \times B7)$	0.86

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$\log_e(EC) = -4.53 + 2.44 \times 10^5 \times \frac{B1}{B6}\left(1 - 801 \times \frac{B1}{B6}\right) + 846.3 \times B2 \times (1 + 2.74 \times B2) + 157.9 \times B7$	0.84
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$Nitrate = 16.74 + 506.8 \times B1(3.82 \times B1 - 1) + 531.3 \times B2(1 - 4 \times B2) - 5.31 \times 10^{-2} \times B6$	0.98

BOD = biochemical oxygen demand; DO = dissolved oxygen; EC = electrical conductivity; pH = potential of hydrogen. Source: Singh and Chinnasamy, 2022

It is also necessary to see the scattered plots between the observed and the monitored. You could see that we are capturing all of that with a particular confidence band interval and there are some outliers or some some of them are going above and beyond the confidence interval and the most, the empirical model, these are empirical models. What is an empirical model?

An empirical model is based on statistics. Here the band color could be done by a physical parameter but it is a reflection. So, we are using that as a proxy data. So, it is kind of an empirical model and then you could, we showed you that the landsat bands of blue, green, red, near infrared and IR, shortwave.

So, these are the B1 B2 that we saw in the earlier slide and then shortwave infrared, thermal shortwave infrared have significantly contributed to development of accurate models for estimating surface water quality parameters for us, Sursagar and Nalsarovar Lake. So, this is the conclusion that we had that between the observed and the models we had good correlation, good accuracy.

And once the accuracy is set then what do you do? You either, you see because here you do not see any observation data. So, the idea is you find the correlation between an observed water quality parameter and its impact on the bands. And this is the impact. So, it is not a straight A plus B plus C. It is just a very complex linear regression model but again and we are using computers and the data sets we can definitely do this quickly on computers.

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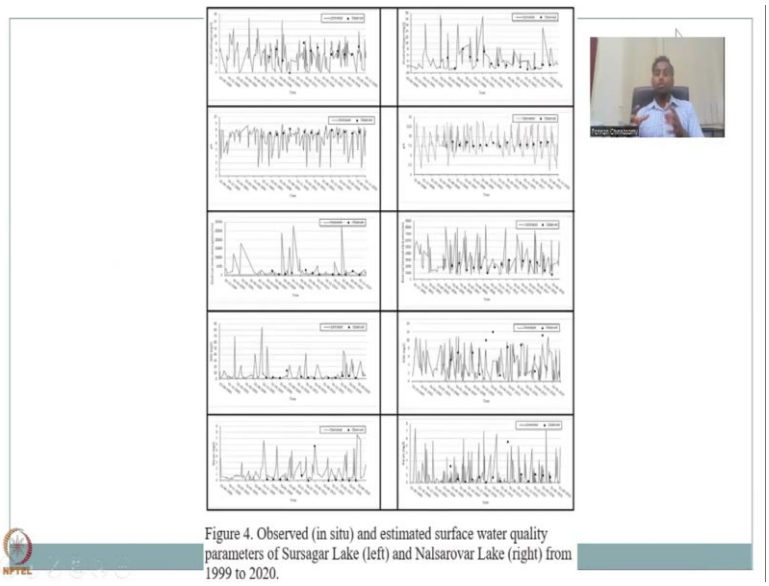

And then what happens is you run the model and then you plot your observed data on it to see the accuracy effect. So, here if you could see, let me zoom in to some of them. So, you can see that the observed part is the dots and then the estimator is the using satellites, estimated is the line.

So, you can see that the estimated for pH. Let us take the Ph. pH goes up and up and on. Why do we have higher number of lines is because satellite data has higher spatial and temporal resolution. So, this particular data set at least would be let us say bi-weekly or monthly, whereas the the observation data you could see comes in weekly or once in two months, once in three months.

And there is a lot of data gaps. Whereas satellite data did not have any data gaps and it is kind of continuous. Because every 15 days the data was coming in. So, you could see that the estimates fell correctly and whenever the quality was okay, the Ph went down and more acidic depending, on the model. But we are concerned more on when the data captures the errors well. So, that is one part.

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ure 4. Observed (in situ) and estimated surface water quality
ameters of Sursagar Lake (left) and Nalsarovar Lake (right) from

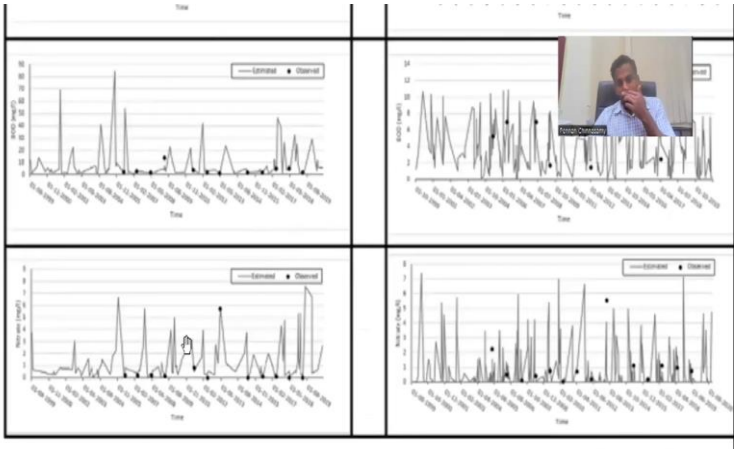

Figure 4. Observed (in situ) and estimated surface water quality parameters of Sursagar Lake (left) and Nalsarovar Lake (right) from 1999 to 2020.

And then you can also see these are the two lakes and dissolved oxygen and then we have BOD and then nitrates. So, if you see here, you could see that the model predicts the up and down also not only the bottom ones. Whereas the observed data is only capturing the bottom once.

So, maybe the observed data was smart enough to take only the low points when the data was available but beautifully the model captures this aspect. It is a sinusoidal because rainfall comes water comes and then stops then rainfall comes. So, there is a sinusoidal movement happening and you can see that the peaks are also being caught. Here the peak one peak is not being caught but other peaks are being caught. This could be an outlier or our data did not catch it.

Again, you cannot expect perfect fit like this is a good fit, you can see up and down is being capturing the data. Here also you can see it. But the point here is it is not observed data. So, always as a model data, you should be using it very carefully. However, if I find such high correlations and such high estimation power using remote sensing, we should use it, at least as a warning.

So, if suddenly my remote sensing satellite captures the water quality turning slight brown which is not visible to the eye, these bands are not visible to the eye, so, once these these satellite data can show a warning then we can send the person to go collect the water quality and measure it, rather than ignoring those warning sessions.

Because if you just say every three months I collect, rainfall happens or not, pollution happens or not, I have a fixed three months, then it is not going to help. Whereas these kind of episodals where the remote sensing captures a sudden blackening of water and then you go, oh, you will send the person in and then take it. I will share you some experience from the field from Singapore also.

You would see that suddenly in the night the water levels started to increase even with over and there is no rainfall. This happens also in some cities in the South where I did some fieldwork. In the night there is a lot of discharge. So, some sewage treatment plant or some illegal dumping will happen in the night because people will not see it.

But in the morning when they walk around that area, they will say, oh, no, it is smelling is really bad and the water quality is bad. For example, not now, but like 10 years ago during the water dying industries where the clothes dying industry is using water dyes and very high chemicals in Tripur region, they would dump all these into the rivers.

And because of that the rural people having a lot of breathing trouble, there is a lot of papers on it, there is a lot of studies, the government cracked down and then said stop. So, there is a ban on these kind of illegal dying units in Tripur, it was known as the Manchester of India because a lot of clothes were dyed and sent abroad and now, these clothes are being died in Bangladesh. I do not know what is the environmental pollution there but in the South it was really banned.

All the rural regions around these industries are still facing the effects because the water quality is bad the land turned is infertile and all those things. So, these things can be captured by satellites because in the night if you do it still there is some data that has been collected as soon as the daybreak happens and then the light is there and if a sample is being taken beautifully you can take it.

And as I said some colors are not visible by the eye but the bands will be caught. So, we should be using these with observed data, whatever limited observed data we have, we should mix these two data and then make sure that we use them for prediction of water quality parameters.

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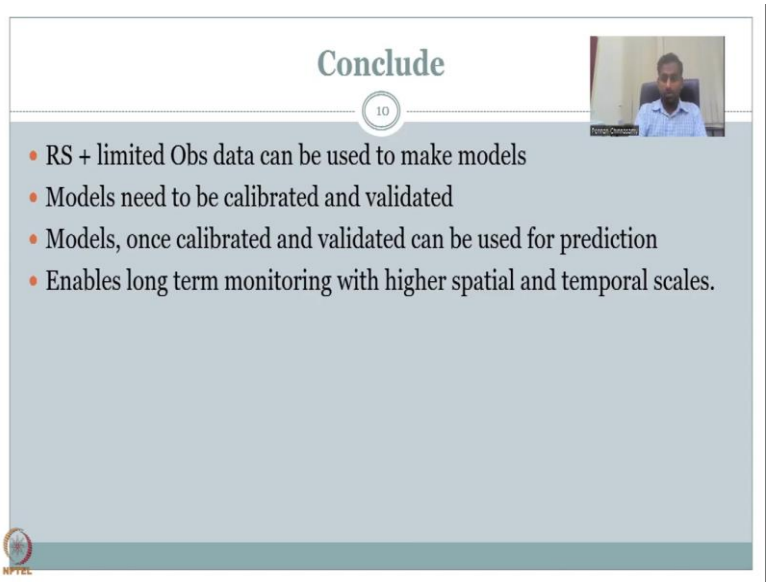

So, RS is going to help with limited observation data. Plus. I use the sign plus, not just RS or not just observation data. We should be using them together and to make models or the models needed to be calibrated and validated, just not simply using it. And periodically. So, if I calibrate the model now, and I am using it for two years. I should still think about calibrating the model because some new water quality parameter would have come up, some bands would have been increased in the satellite, etcetera.

Models once calibrated, validated can be used for prediction. So, you can predict automatically the water quality issues and this enables long-term monitoring with higher spatial and temporal resolutions because that is what is needed for effective sustainable rural development and mapping. Thanks with this. I would like to conclude today's lecture. I will see you in week 12 lecture 4. Thank you.