Introduction to Remote Sensing
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Lecture 19

Hello everyone and welcome to the 19th lecture of this introduction to remote sensing course. So far we have covered all theoretical aspects of basics of remote sensing and this is we are going to discuss in this one one particular application which is related with groundwater and some applications of GIS we will discuss. Say integrated application of remote sensing in GIS in groundwater studies. As you know that groundwater is very important resource for drinking, irrigation and other purposes and therefore it will it remains a very important aspect for exploration and management.

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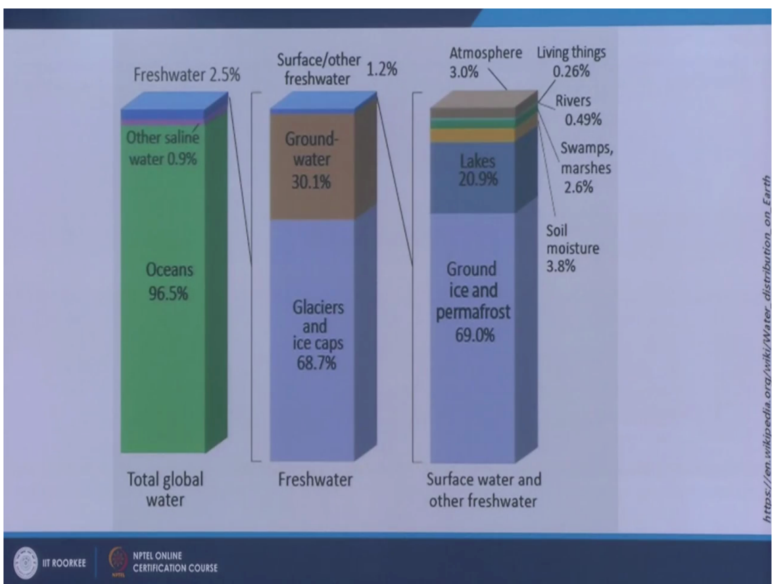

If you see that out of the total global water which is available, the freshwater resources are just 2.5, rest goes in oceans or saline water and within this (shref) fresh water, you see the glaciers and icecaps which occupies about 69% of the water and groundwater is just roughly 31 30.1% and other water which is on the surface is 1.2. So if we go for this then this is very tiny amount of out of what you see here, out of 2.5%, only this much of 30% of 2.5% is a our groundwater.

So replenishment of groundwater, management of groundwater is very very important and from that point of view, we are going to discuss this particular application.

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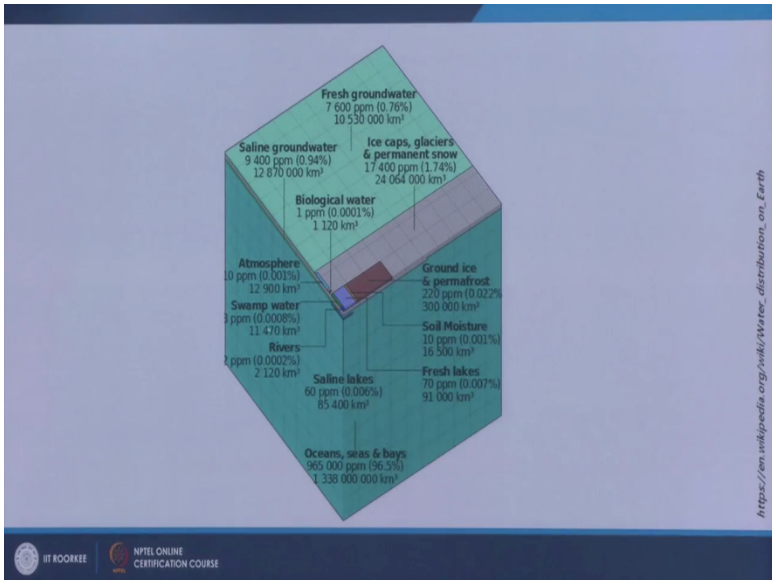

You can also see as a total thing that groundwater, river waters and other are very very tiny in as compared to the seawater or saline water.

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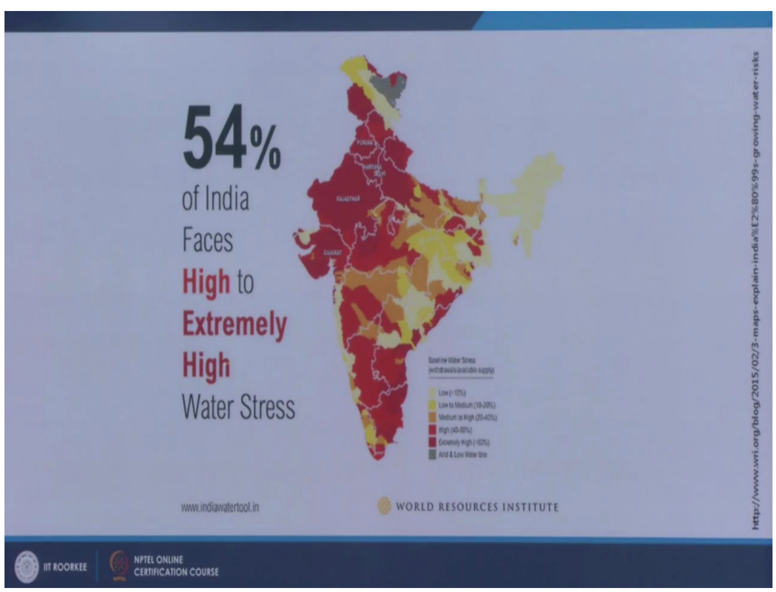

If we see in in Indians for Indian terms what we find that 54% of India faces high to extremely high water stresses especially during 3-4 months of summer and except may be in the northeast India, somewhat little in J&K and rest of the places we really see a lot of problem about the water so therefore (re) replenishment that means in simple words, we can say recharge of groundwater is very much required and also one can notice that 54% of India's total groundwater wells are decreasing that means the the water table is going down in almost in all parts of India so that is another concern.

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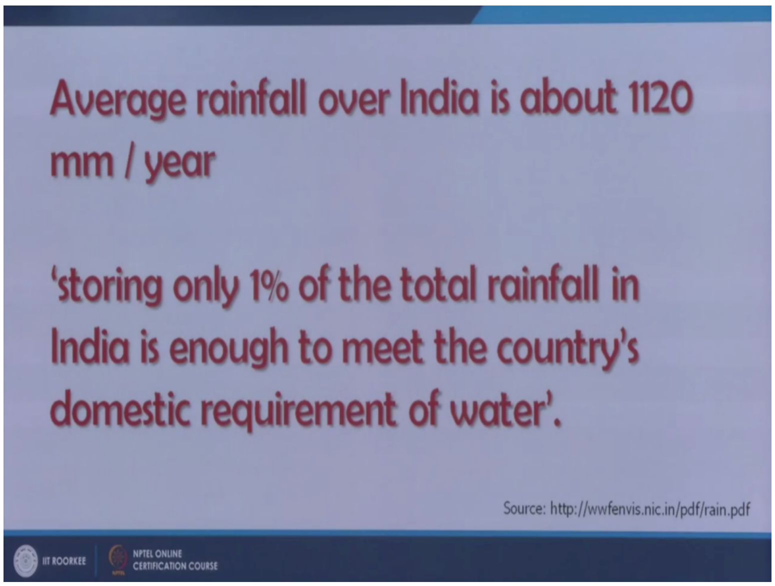

Can remote sensing and GIS play a major role, can we do something employing these technologies? Especially remote sensing so this discussion is mainly on this. Also if you see that the average rainfall over India is (la) about 1120 millimeter per year so from rainfall point of view, in someway, it is quite sufficient and only very tiny percentage of this rainfall that is roughly 1% of total rainfall is sufficient for India to meet country's domestic requirement of water so we require a very amount of water to (re) to store in groundwater if possible out of this 1120 millimeter to have sufficient water for the country.

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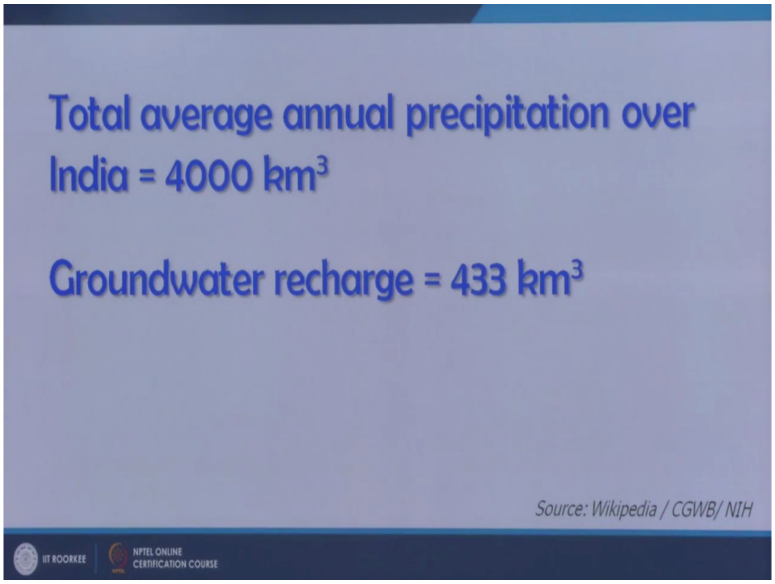

So therefore the groundwater recharge is perhaps the best solution which is available and total average of annual precipitation over India is a if we calculate the total volume of water which is falling over India is 4000 cubic kilometer which is a quite good amount of water available and whereas in case of groundwater recharge, it is just 433 cubic kilometer, that much is the groundwater recharge is happening. If we double this by some means, by groundwater (re) better management, groundwater recharge etc then we can solve this problem very easily. Surface water runoff is major concern which goes large amount of water there.

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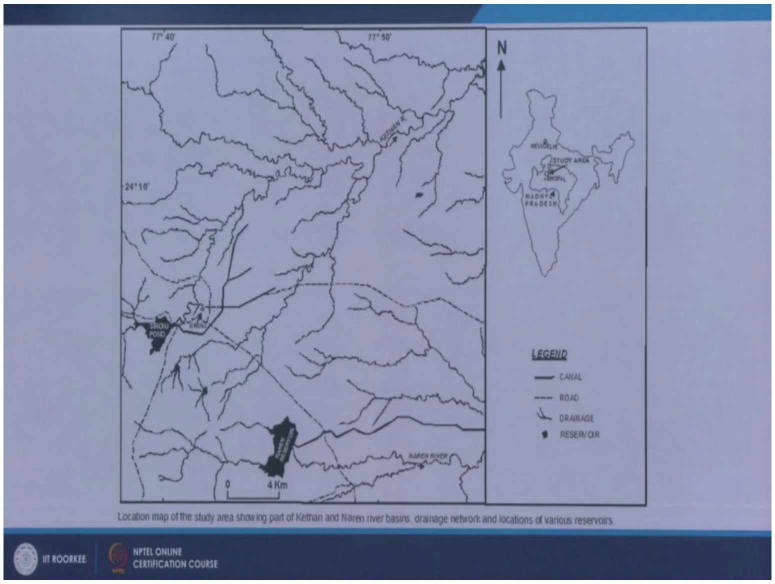

I am going to take a very example from hard rock terrain from central India where mainly 2 types of rocks are there and you are having weathered basalt or in the basement you are having Bundelkhand granite, that is granitic rock and on in some places, you are having the basaltic rock. So in this terrain in this part of the country where water is the big problem and you see that how these small small groundwater recharge structures in form of dams (surf) storing first the surface and then it is going to recharge the groundwater, you will see this is a part of Madhya Pradesh where this study I am going to show you.

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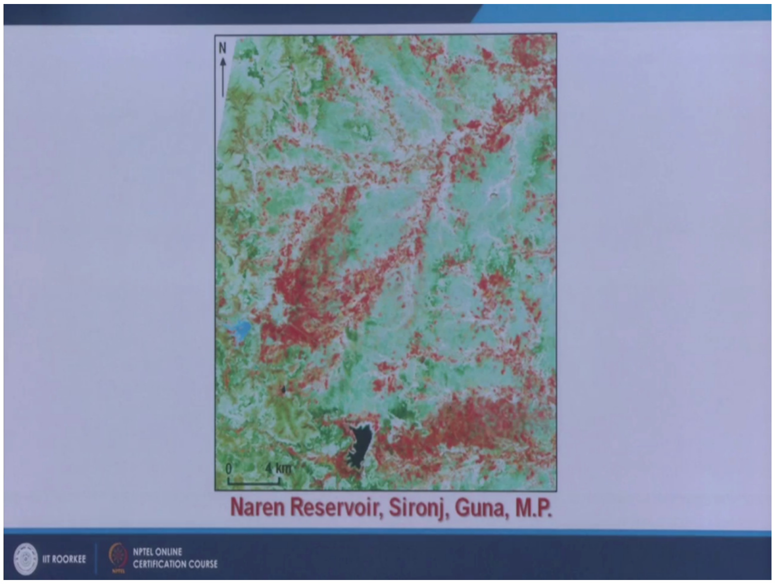

Now what how we (sa) employ a remote sensing, that's the main focus of this discussion today that is that how best we can employ remote sensing to solve this groundwater recharge problem. So what we see here that this is a false color composite of IRS Liss 3 image and you know is that in false color composite, the vegetation will appear as red and water bodies depending on the depth or turbidity and these will appear either black or blue.

In this case there are 3 water bodies one can see, one this one is the black means if I since we have the ground information and know that there is no turbidity in these water bodies therefore I can say that this is having quite a good depth of water in this particular reservoir whereas as compared to this this has a shallow and therefore the bottom of the reservoir is reflecting and instead of getting black in false color composite, we are getting blue color. And there is a third one, very tiny one here also which is another small reservoir.

Now what interesting feature which we are observing that this is the reservoir and downstream of this reservoir, we are seeing the growth of vegetation. Similarly this reservoir and again downstream of this reservoir, we are seeing the growth of vegetation and the even in tiny reservoir is also having in downstream growth of vegetation. So that means wherever you are having reservoirs, in the downstream, you are having growth of vegetation and these are mainly agricultural fields because this image of end of February and in (thi) in this part which where geologically it is almost same as these areas.

And this is the area where you are having unweathered or weathered basalt in the basement you are having granite and here, you are having unweathered basalt and this is little higher ground which I will show you through a digital elevation model as well. So what we observe here that since there are no reservoirs (hen) and hence we are not seeing much growth of vegetation. So wherever there is groundwater recharge structure, in the downstream, we are having vegetation so this is how we start interpreting satellite images for a particular purpose. Here the purpose is to think that how the the such information which we are interpreting or inferences we can make for groundwater recharge.

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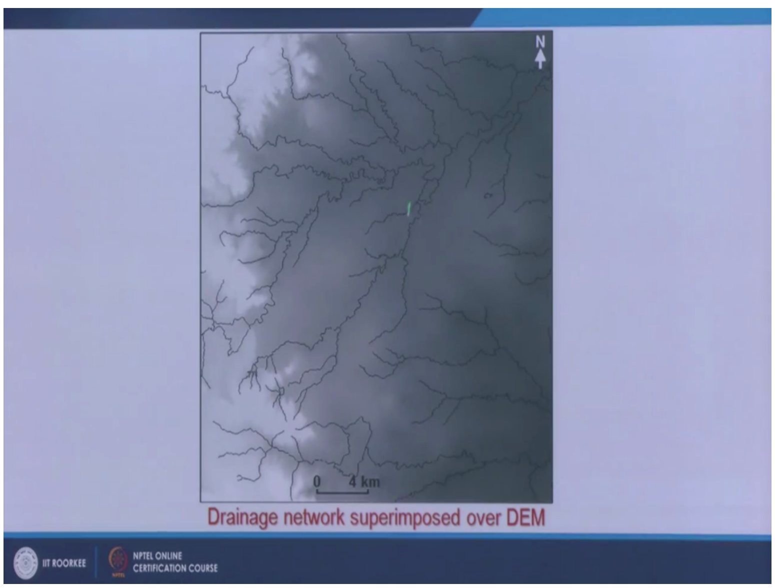

And now in order to confirm all these things, we this is again that area and geology, another part of earth is shown here. So this in order to confirm that we are on the higher ground or lower ground and in background, you are seeing a digital elevation model and brighter the areas, higher the ground, darker the areas, lower the ground and over that we are having a drainage network and what we observe that wherever this reservoir this is on though it is on the lower grounds whereas this reservoir though it is small but on higher grounds so after having this and this is also on the (re) relatively higher grounds as compared to this Sironj reservoir.

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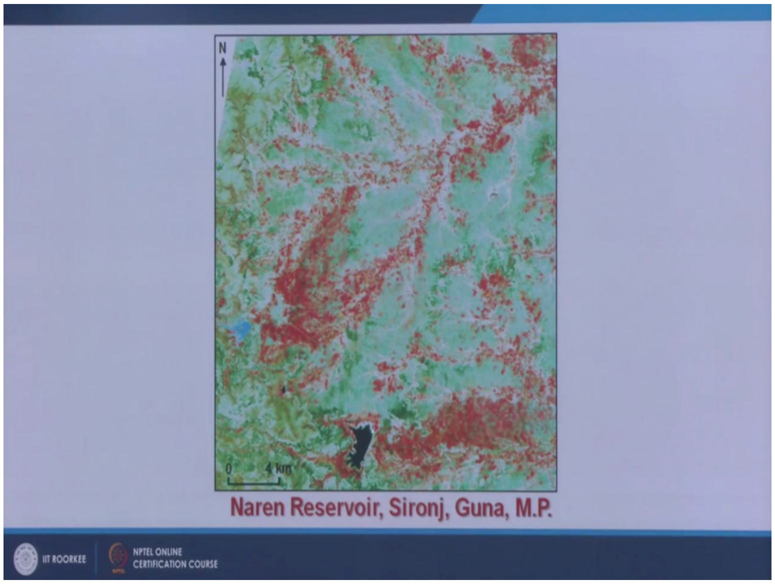

So if I go back to the original image where we started this discussion, what we find that the reservoir which is on the lower (grou) and higher grounds, though it is small but having a high recharge area or high benefit area, large benefit area whereas this reservoir, though it is larger but it is on the lower ground as we have confirmed through digital elevation model and it is having relatively less benefit area as compared to this one. Even the tiny one is also there so what we can think now that this is what we we can say that this is my submerged area and this is the benefit area. Similarly here, the reservoir part is my submerged and this is my benefit area. Since there are no submerged area and hence the recharge is also not much there and we don’t see (sun) such a distinct benefit areas in this part.

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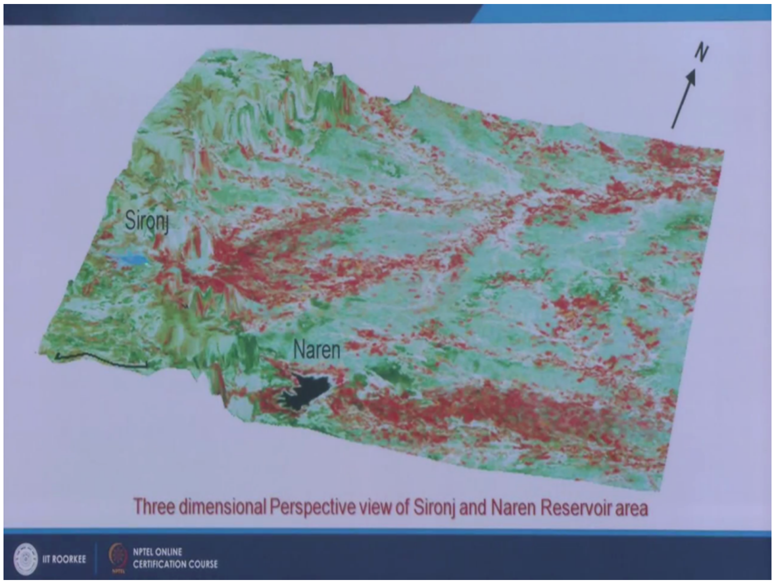

Now this can also be (cov) confirmed employing again digital elevation model and top of that, the satellite image has been dragged so you can see that this reservoir Sironj reservior is on higher ground and having a larger benefit area, Naren reservoir on relatively on lower grounds and having less benefit area and this clearly indicates that though this reservoir is small but because of higher hydraulic gradient, it is providing much better groundwater recharge as compared to Naren reservoir in this terrain.

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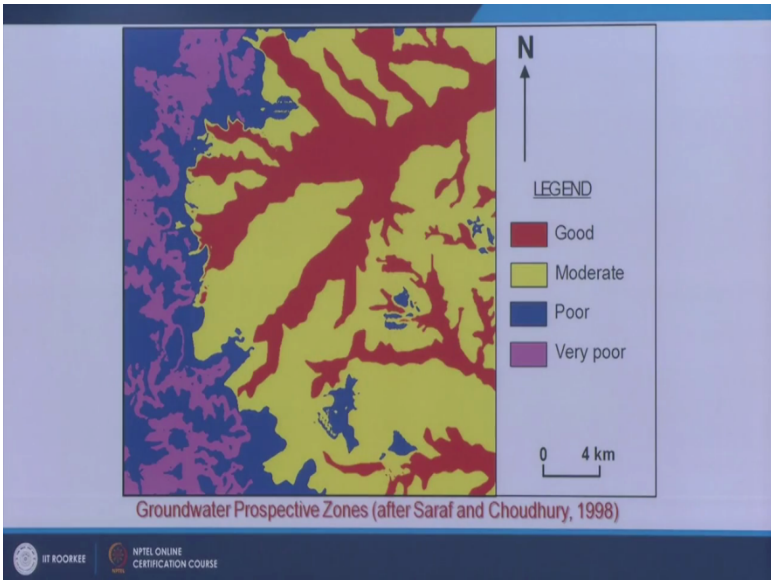

Based on this inferences and incorporating other information like geology, soil, geomorphology and growth of vegetation, we can employing GIS, we can we can have a groundwater prospective zone map like this which we are seeing here and so that we can indicate very clearly that which are the good areas, moderate areas, poor and very poor for finding groundwater. So the valley zones specially and the though they are shown in red colors but they are the good areas and the this violet color one are the very poor area which are very higher grounds as well.

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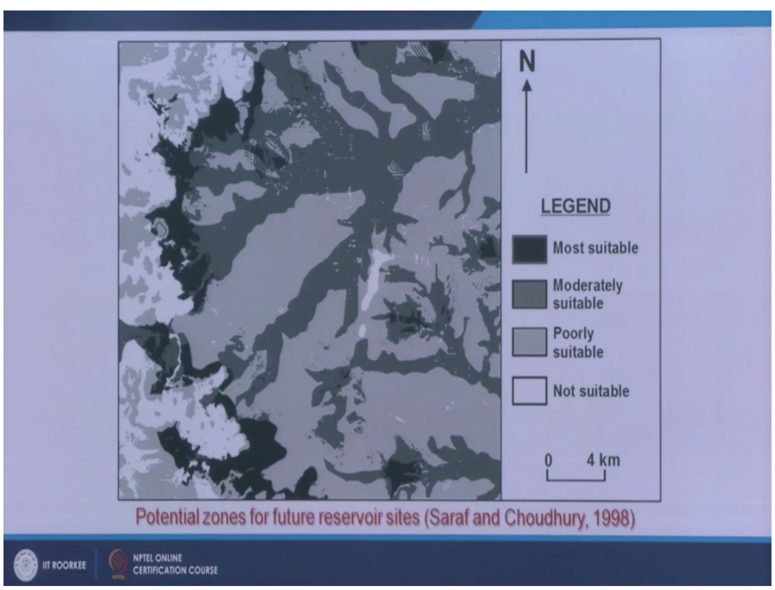

Similarly we can also develop a potential zone for future reservoir sites. That means if I want to learning that a reservoir which is on little higher ground though may be small can have a larger benefit area therefore if we would are looking for some solutions for this entire area then these are the areas which are black areas which are the most suitable to construct reservoir or groundwater recharge structures particularly in this part of the country.

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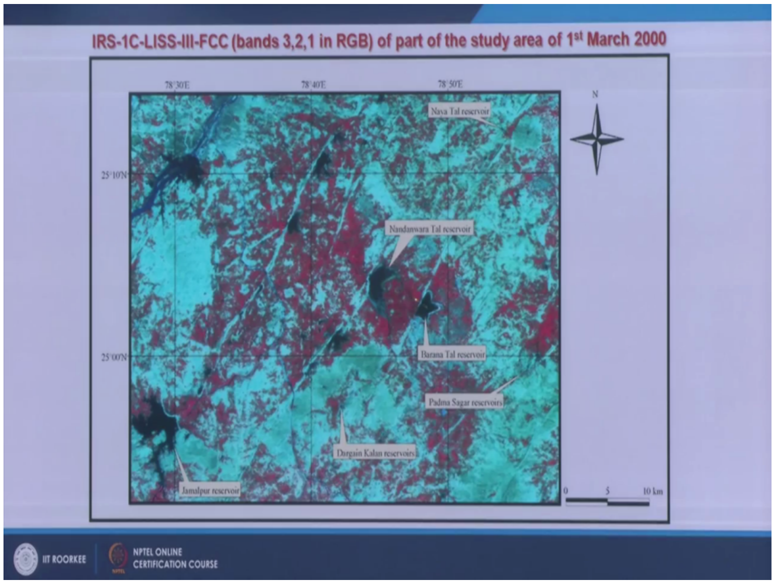

If we remain almost in the same area but in instead of this interface of granite, Bundelkhand granite and Deccan traps or basaltic terrain, if we focus mainly on the granitic terrain what we find here, very interesting features are there which are again natural or geological features which are we are seeing a quartz reefs which are basically because of weathering and erosional processes and these have these are made of quartz and they remain there and whereas the granite which was surrounding has got weathered and got lower ground.

So these these (qa) quartz reefs are serving as a barriers for groundwater flow and a same time also, these quartz reefs have been in past exploited wherever we had some stream which was passing through these quartz reefs so that they blocked these quartz reefs and made certain reservoirs and what you you are observing here that (the) these quartz reefs are serving as a groundwater recharge structures and this is again false color composite so what you are seeing, there is a reservoir because of this is quartz reef is working as a dam natural dam axis.

This was blocked, a stream was blocked so this is the upstream area, this is the downstream area and you are seeing a groundwater recharge and therefore growth of vegetation. Similarly here, again a stream was blocked by this using this quartz reef and this is the benefit and likewise, wherever these streams which were breaching the quartz reefs have been blocked, a groundwater recharge structure have been created and what you are seeing the benefits in form of growth of vegetation and wherever you don't have any groundwater recharge structures like in this area or this area, you don't see much growth of vegetation.

So that clearly indicates that if you recall that 1120 millimeter of rainfall is happening, hardly 1% of rainfall is being stored as a groundwater. Rest is going as a surface run off. By such means or by such structures, a natural dam axis has already been there, existing so if we employ these remote sensing, find out the suitable sites may also employ GIS and we can find out the suitable sites where such a structures can be made and more groundwater recharge can happen.

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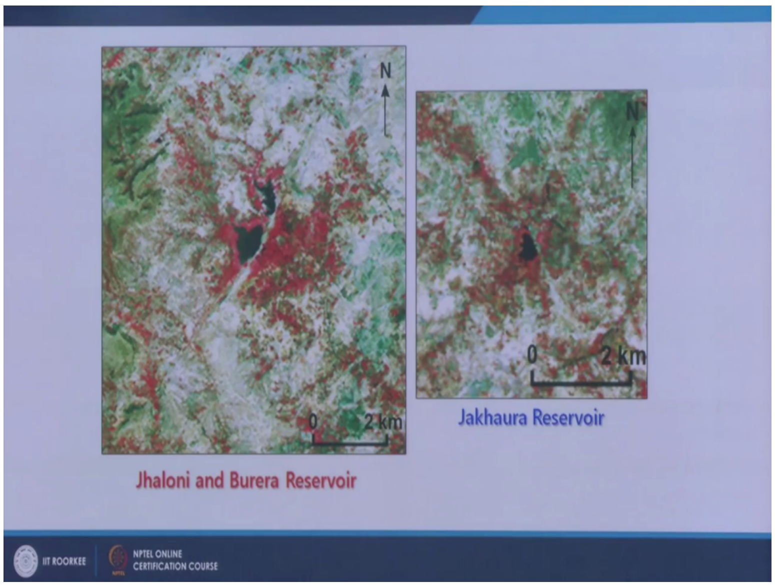

So this we will see in little more detail, there are 2 twin reservoirs, Jhaloni and Burera and again here you are seeing that this is quartz reef, this is the downstream area, this is the upstream areas and there is a submergent area, there is a benefit area. Similarly here and in a Jakhaura reservoir also, sometimes what we (fin) we have found that these quartz reefs are so strong that they do not allow much water to go through. That means they are (wo) working as complete groundwater flow variant, it doesn't matter even then because of rainfall, if by some means if we hold the water for some time, it will recharge laterally or in the surroundings of the reservoir and ultimate aim is to just ground, to recharge groundwater regime whether it is in the surrounding laterally or downstream it doesn't matter much.

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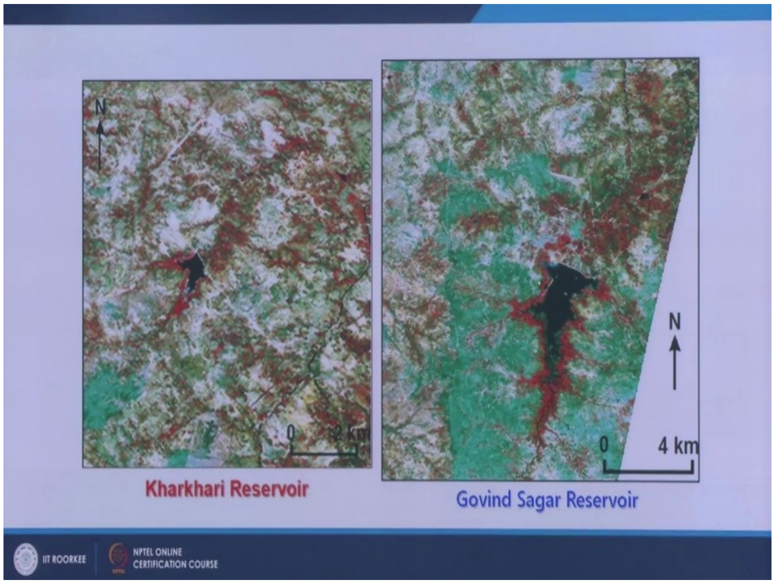

Similarly there are another reservoir and another reservoir is there which is Govind Sagar, little larger one here so this is the reservoir at the downstream you are having Lalitpur town so when when this reservoir is full, you are having a quite growth of, good growth of vegetation in the downstream in the agricultural fields and other, when you don't have much water, he problem comes.

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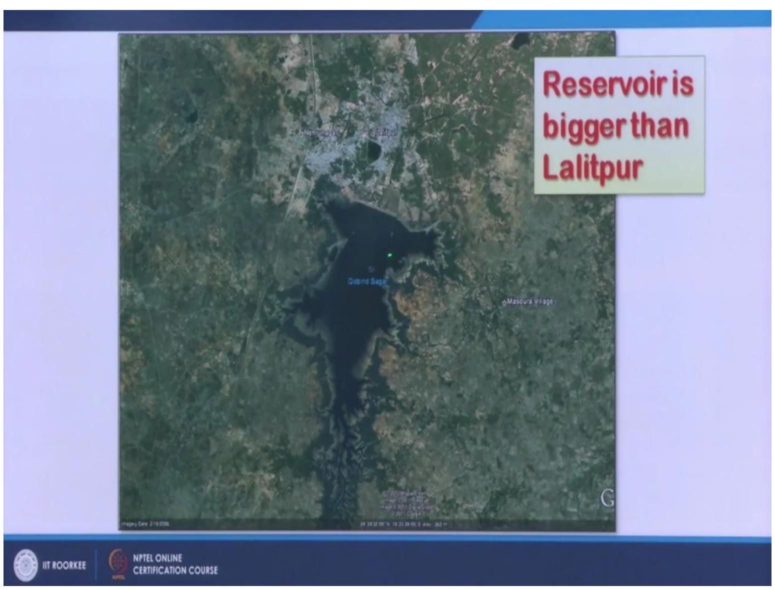

What another important thing in this part of the country, if you see here, this is a from Google Earth, you say natural color, more or less natural color or true color image. What you are seeing the vegetation is appearing as a green and a water body as a black, what you see that this reservoir relative to the town Lalitpur town is very big so if I roughly I say that a you know this is double the size of the town and even then, the entire water supply to town is through this reservoir either directly through pipelines or through groundwater recharge so if in this type of terrain, if 1 (bla) 1 town has to sustain and should get the water throughout the year then at least more than double the size of reservoir is required to (propy) to provide the water for such a town in such terrain.

Why more than double because few months, at least 3 to 2 to 3 months, this town every year also suffers from water (scate) a scarcity during the summer months. So therefore even a larger reservoir, if it would have or the height can raised then probably we can have water supply throughout the year so this is the terrain condition that if we want to provide the water, we have to submerge more than double the size of a town in this part of, in such terrain so that the (wat) water can go as a groundwater recharge or can be supplied through this thing. This is all this reservoir though is also having some canal network as well.

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There are some examples like in around Alava and other places wherever you are seeing the seeing the reservoir in the downstream, you are seeing growth of vegetation, wherever you don't have much reservoir, you don't see such growth of vegetation.

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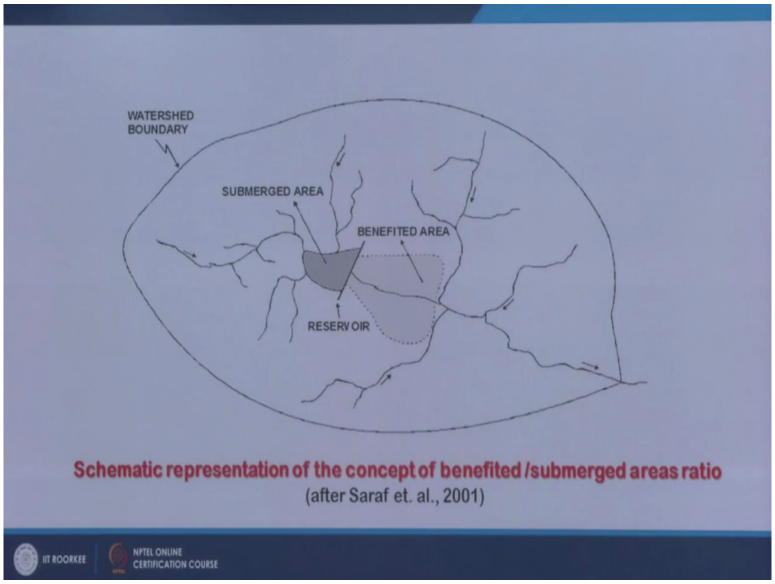

So if we want to quantify this thing and use this in inferences or knowledge which have developed through the interpretation of satellite images then the what we can do that we can through this schematic, we can understand that if it is submerged area which is the reservoir area then this is the benefit area by we we that area we can identify verily easily in false color composite by demarking the growth of vegetation whether it's a natural or manmade means agricultural land, it doesn't matter. So by this we can identify that this is submerged area and this is the benefit area so if we develop a ratio, a index saying that the benefit versus submerged then what scenario we see.

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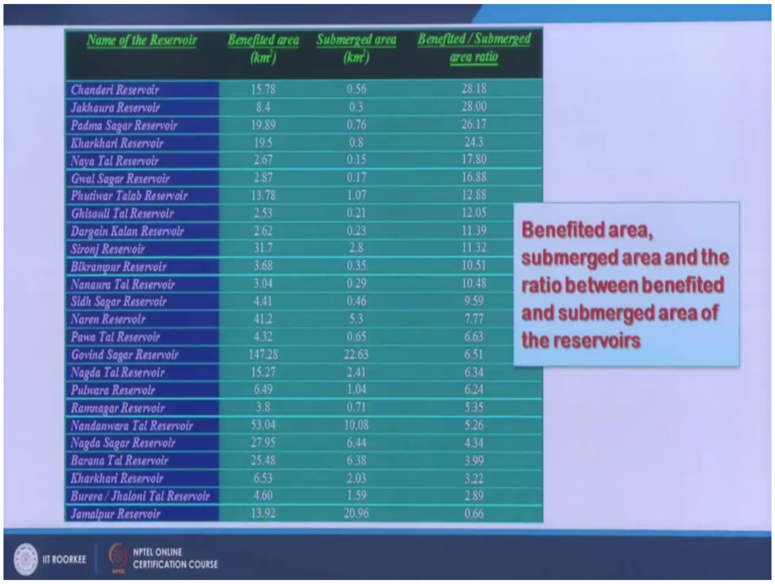

Name of the Reservoir	Benefited area (km^2)	Submerged area (km^2)	Benefited / Submerged area ratio
Chanderi Reservoir	15.78	0.56	28.18
Jakhaura Reservoir	8.4	0.3	28.00
Padma Sagar Reservoir	19.89	0.76	26.17
Kharkhari Reservoir	19.5	0.8	24.3
Naya Tal Reservoir	2.67	0.15	17.80
Gwal Sagar Reservoir	2.87	0.17	16.88
Phutiwar Talab Reservoir	13.78	1.07	12.88
Ghisauli Tal Reservoir	2.53	0.21	12.05
Dargain Kalan Reservoir	2.62	0.23	11.39
Sironj Reservoir	31.7	2.8	11.32
Bikrampur Reservoir	3.68	0.35	10.51
Nanaura Tal Reservoir	3.04	0.29	10.48
Sidh Sagar Reservoir	4.41	0.46	9.59
Naren Reservoir	41.2	5.3	7.77
Pawa Tal Reservoir	4.32	0.65	6.63
Govind Sagar Reservoir	147.28	22.63	6.51
Nagda Tal Reservoir	15.27	2.41	6.34
Pulwara Reservoir	6.49	1.04	6.24
Ramnagar Reservoir	3.8	0.71	5.35
Nandanwara Tal Reservoir	53.04	10.08	5.26
Nagda Sagar Reservoir	27.95	6.44	4.34
Barana Tal Reservoir	25.48	6.38	3.99
Kharkhari Reservoir	6.53	2.03	3.22
Burera / Jhaloni Tal Reservoir	4.60	1.59	2.89
Jamalpur Reservoir	13.92	20.96	0.66

So doing this exercise for this Bundelkhand region, a part of Bundelkhand region, what we have found that there are reservoirs which are having a very large ratio that means the submerged area is very small, benefit area is very large and in the same terrain and there are areas where you are having this ratio is 0.666 whereas this ratio is 28. So what it what basically indicating that in such areas, this is these are the areas which are best suitable initially in the first phase or on a priority basis, these are the areas which are best suitable for groundwater recharge that means if I if I am going to submerge a 1 square kilometer of area then in at least in 28 square kilometer area, especially in the downstream, I am going to have benefit by groundwater recharge and ultimately through growth of vegetation whereas in this area, these are not that means my investment is more and benefit, I am getting less.

Here the my investment is 20 square kilometer, my benefit is only 14 square kilometer so in that way it is not good but if these are the area, say here upto 10 times I am getting benefit so these are the areas where if somebody is really looking for the site to ground for groundwater recharge then wherever these these areas, these reservoirs are existing, these are the benefit areas, these are the best areas where maximum benefit can be taken in specially where this Chanderi, Jakhora, Padma Sagar, all these reservoirs are there. 28 times benefit, you submerge only 1 square kilometer of area, say for example you are going to have 28 square kilometer benefit area.

So by this analysis, we can you know estimate or predict what going to we have what going to happen for benefit area in this part of the country or in such kind of terrain.

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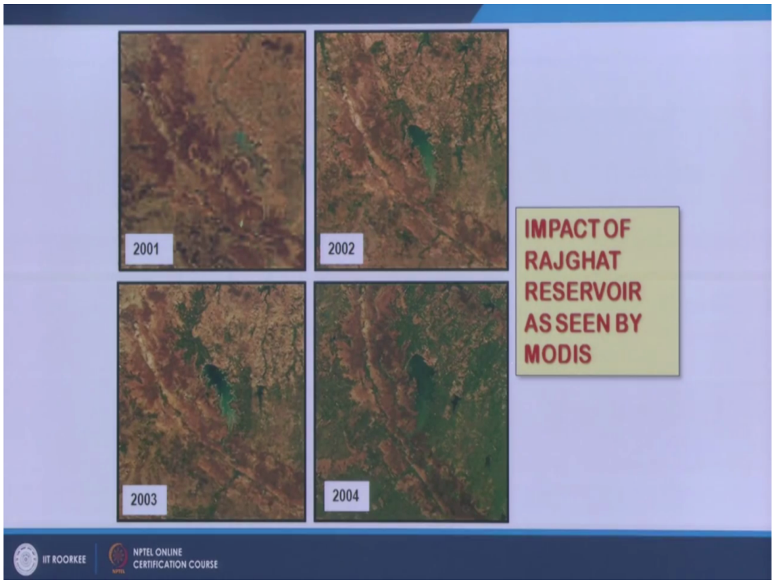

One other how quickly so this is 1 question that what how much area will get benefit, how quickly the area will get benefit and this is a time series data which is very interesting. This is from Modis, it's covering a large area, this is a very large reservoir, multipurpose reservoir, it is it is having hydropower, it is having canal irrigation, it is having lift irrigation but we are not looking from those point of view, we are mainly looking from the (gro) submerged area and benefit area from in from groundwater recharge and growth vegetation growth.

And what we observed here that when this reservoir was under construction or just filling started, you don't see much growth of vegetation, this is true color image and in just after 1 year, what you start seeing growth of vegetation, in that downstream area and in the mainly in the alluvial fill areas where you had the streams or older rivers and so on and this benefit has started coming further, in 2003 a large area got green here and see what happened in 2004. One may think that this might be, the first one might be a pre monsoon image and this might be the post monsoon image but this is not correct.

If we see for the same date of all different years, 2002, 04, 05 and 13 and what we find that se the reservoir has started filling in 2001 and the benefits see start coming in all around because it is having lift irrigation system as well so across the Watersat, also the benefits are coming and entire area got benefit because of this reservoir so (hydro) (pa) apart from hydropower and other things, the groundwater recharge has become the major and because here the irrigation network and other things are there and therefore you compare and there is a a large vegetation growth in form of agriculture land is happening.

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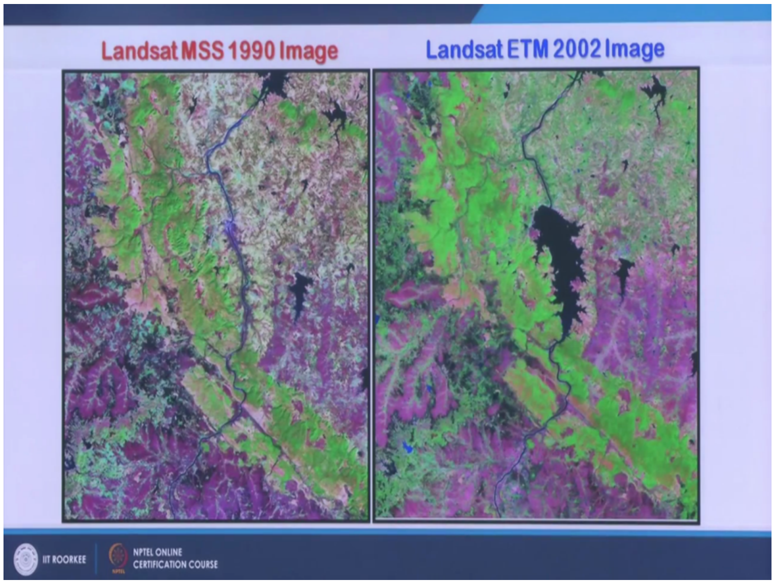

And that you can see here also that in 1990, this was the Landsat MSS image and this is Landsat ETM image, both are in in near true color and see this when there were no reservoir, the greenery was not there. When the reservoir is there, see in the downstream area, you are having these are all agricultural fields, these is of course the forest but these are all agricultural fields so the difference you can see how a reservoir can provide and it is providing a quite good benefit area.

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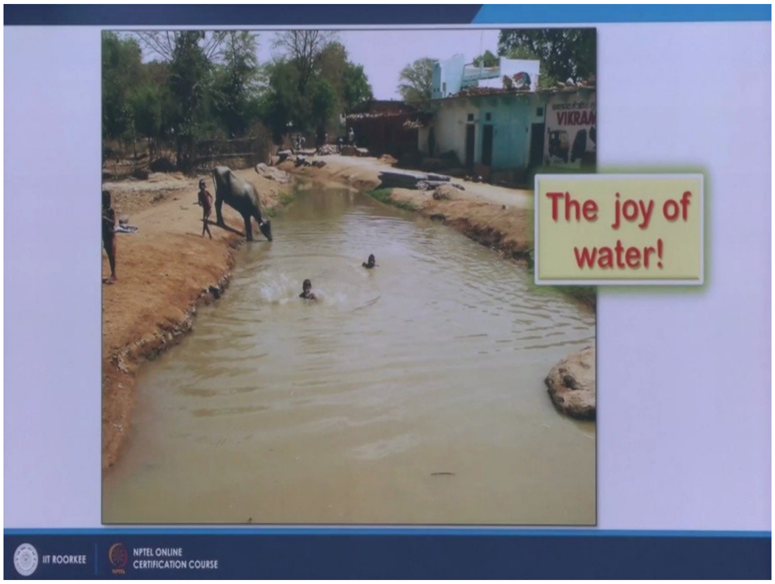

This is the benefit in area where earlier before reservoir, you didn't have the water. Now in front of their house, (the) you are seeing the water, these are the unlined canal network and the advantage of this that they are this water is recharging groundwater regime and therefore you are seeing benefit of a groundwater recharge through growth of vegetation in a large area in the downstream area.

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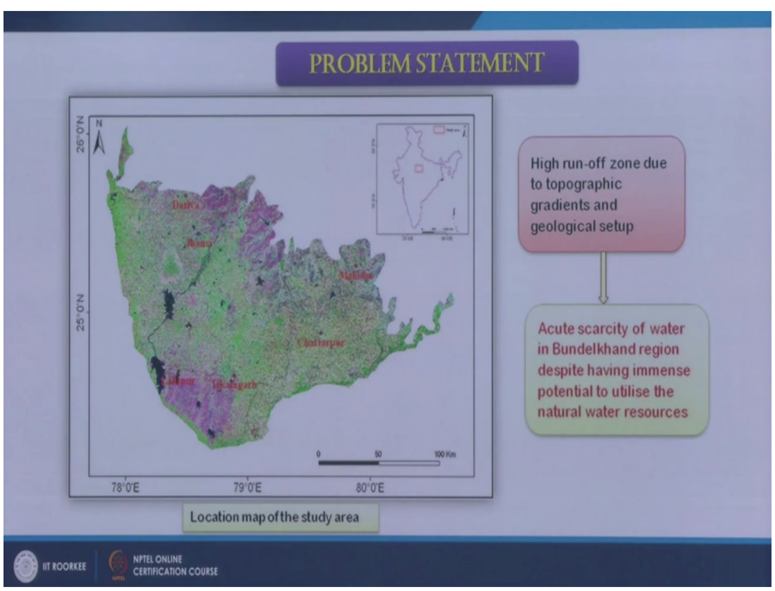

So if we start looking the entire region, this is all entire Bundelkhand region and which is all granitic terrain, there are small and large reservoirs, 2 reservoirs on Betwa Rajghat and Matatila and there are other small reservoirs and what you will observe when you will zoom these images that wherever reservoir in the surrounding or especially in downstream, you will see growth of vegetation otherwise it is implement right except in your so you are having gradients, the geological setup I have already indicated and this area suffers every year for water scarcity so acute water (ac) scarcity but same time, as earlier also mentioned that this area is having (lotch) lot of quartz reefs which are running northeast and southwest.

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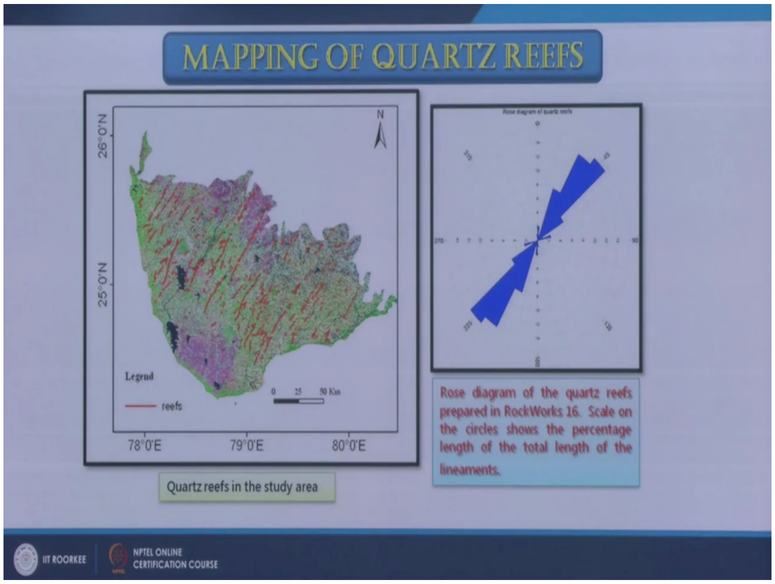

Some of the quartz reefs are running for 10s and 20 or 100s of kilometers and at places they are breaching these quartz or at places the natural drainages breaching these quartz reefs and these are the areas which can be identified based on the remote sensing data and then reservoirs can be constructed, specially for groundwater recharge point of view. This is just rose diagram to indicate that what is the orientation of these quartz reefs.

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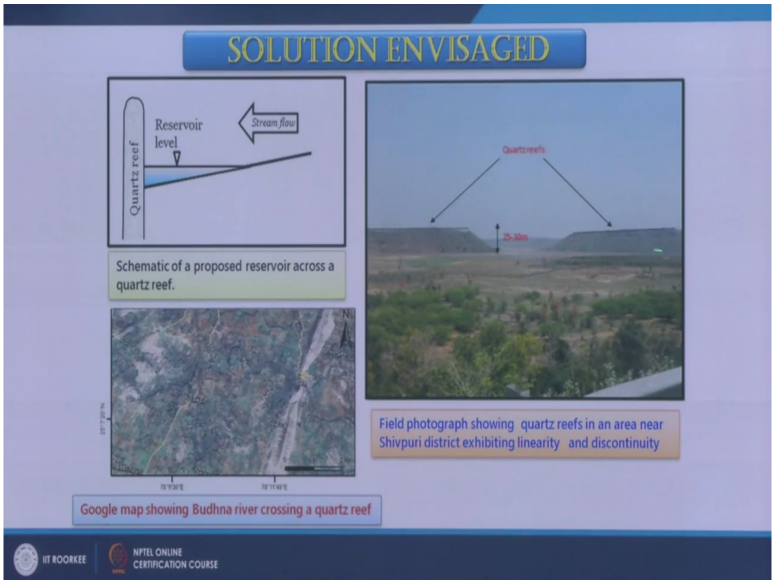

So if it's going the ground (wat) this is what we observed, this quartz are like this, a stream is just passing through so that means these are these (be) these quartz reefs can be treated as a natural dam axis and if we block this this much this much then this can serve as a reservoir or a ground water recharge structure, this is how you see from the top and the Google Earth images these are how you see on the ground and this is this is basically the idea that if the ground is having this kind of thing, the quartz reefs like this which you are seeing on the ground, if you fill with that then it is going to recharge the groundwater regime. If a quartz reef a completely a (())(26:53) and it doesn't allow water to flow through doesn't matter, even in the vicinity or in the surrounding or laterally it will recharge the groundwater regime.

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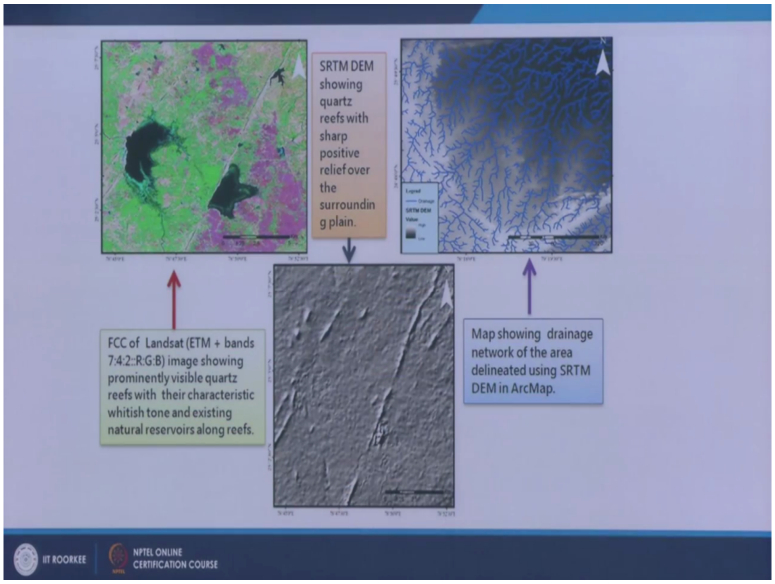

So by identifying these things and and learning from developing knowledge from interpreting satellite images and like digital elevation model or shaded relief model, we and drainage network, we can identify such thing.

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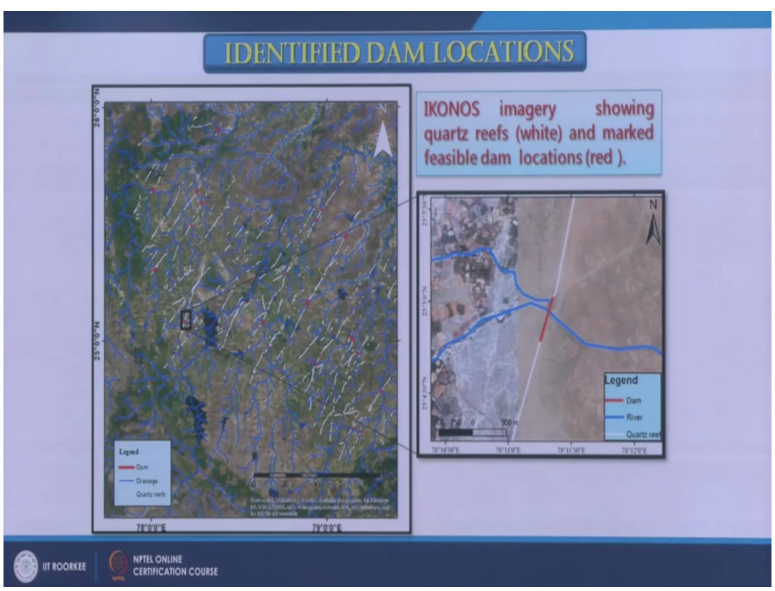

As in this particular example, a quartz reef was identified where a natural drainage was breaching and unchecked so that day, if we go for a reservoir here, what happens and how high, what should be the height of the reservoir and things, these things can be simulated into GIS as I am going to explain.

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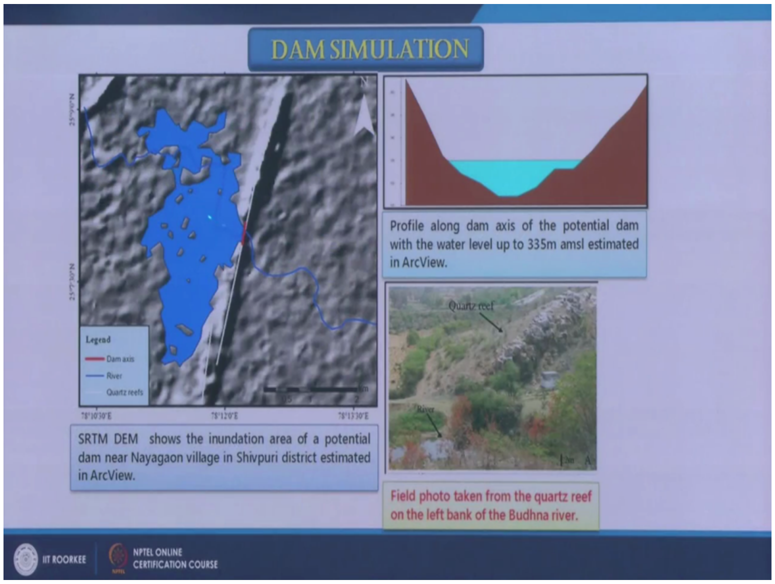

So this quartz relief was identified where natural drainage was breaching it and if we feel this reservoir to the roughly the same height as currently the quartz reefs are there then this is what the submerged area you are going to have. This is purely a modeling and if you recall the definition of GIS when I was discussing the (integra) integration of remote sensing GIS and GPS, in the definition of GIS this says that to model and display according to user defined specification so this is nothing but the modeling.

We are predicting that if the reservoir is created in the upstream, this is the inundated area going to be so you see the plan view, as well as you can (cal) calculate or estimate the volume as well, how much water you will hold and you can simulate, you can do the modeling so that you can raise the you can raise the reservoir height or you can lower the height as per our requirements and this is how in the profile, along the quartz reef, it will look like this and this is the ground, this is how on the ground it looks and the stream which is still unchecked is going through this quartz reefs. So this is how one can exploit all these 2s which are available, remote sensing and GIS specially and can think how to recharge groundwater regime.

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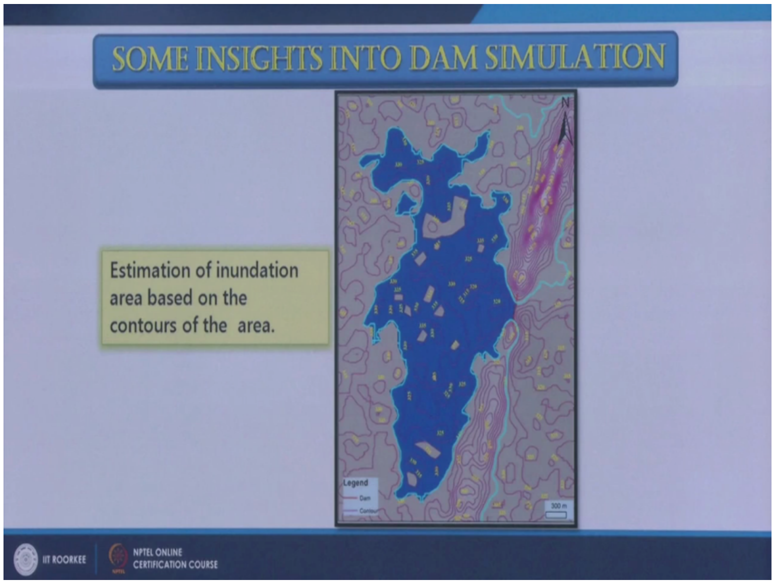

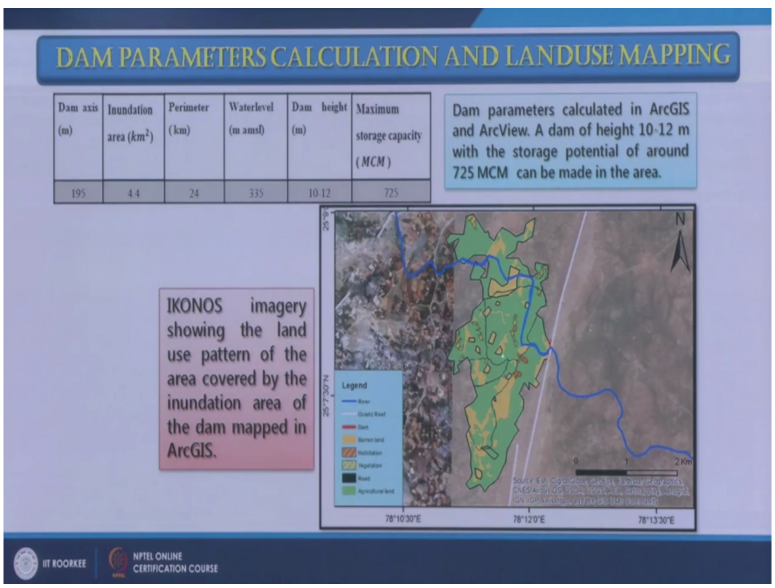

And if we employ further on this then we can also know that what is basically, what kind of land use we are going to going to submerge if we construct a reservoir and that can also be you know though before deciding the height of the reservoir. So in this scenario what what is the analysis saying that if we keep the dam axis, this much this is the inundated area, 4.4 perimeter is going to be like this, water level is going to be like this and dam height is roughly 10 to 12 meter and a storage capacity is going to be in of this much quantity and these are the land use which will submerge.

So if everything is acceptable then one can go and and develop a ground water recharge structure and benefits as you have seen will start coming within 1 or 2 years time in this part of terrain as we have seen through the time series data of a reservoir, Rajghat reservoir in the same part of the country or in a similar terrain conditions.

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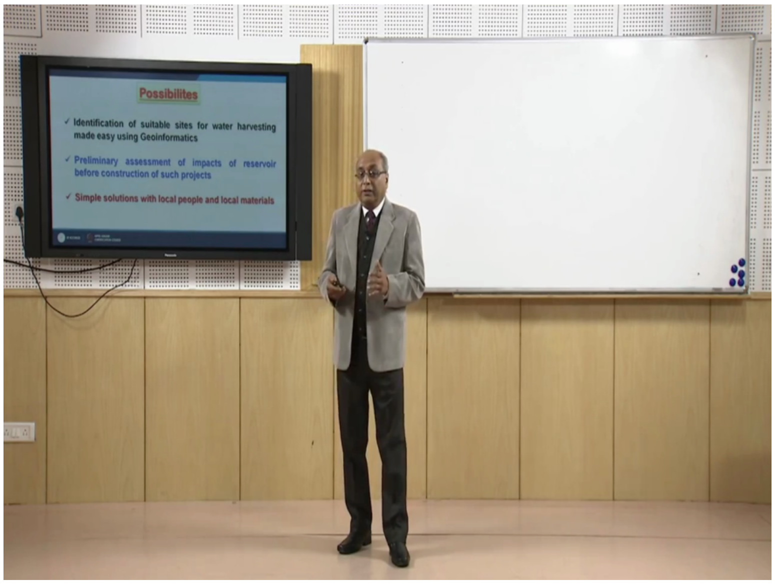

So what are the possibilities of employing remote sensing and GIS for groundwater, especially groundwater recharge and overall groundwater management is that we can identify suitable sites for water harvesting based on our satellite images and (sub) supplementing that through the like digital elevation model and others and then we can make the preliminary assessments of impacts of reservoir even before the construction.

That means we can model that we can we can try to answer those questions like how much will be the submerged area. What will what is going to be the total volume of water available as a surface water and in which area which area we will get benefit and when which we will seeing benefits through the growth of vegetation and how much time it will take to see the benefit so all these answers, all the questions to all these, answers to all questions can be given with such analysis. And simple solutions are possible with the local people and local material to solve this groundwater issue and water supply throughout the year.

So this this is how the remote sensing and GIS can play very important role to not only identify the problem but also the solution, solution and that simple solutions with the help of local people and local material so this basically end to this brief discussion on how remote sensing and GIS specially related with groundwater can be applied. Thank you very much.