Groundwater Hydrology and Management
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Lecture 30
Recharge master plans

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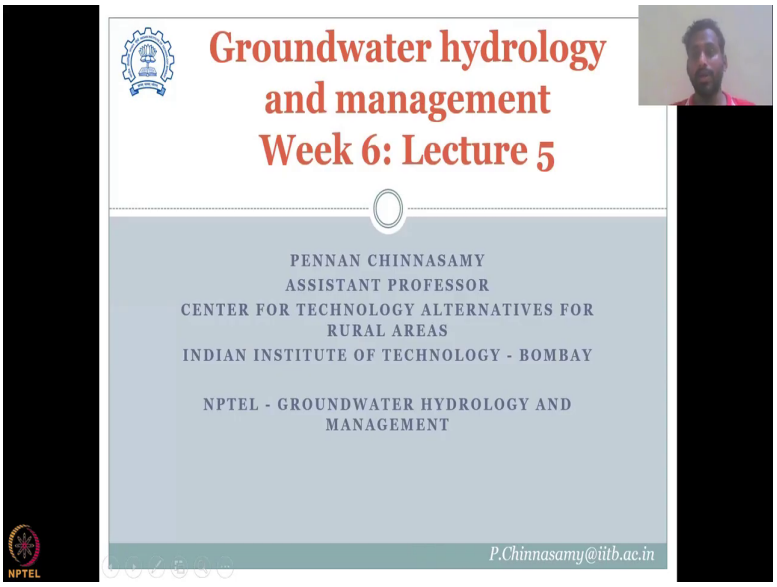

Hello, everyone. Welcome to groundwater hydrology and management NPTEL course, this is week six lecture, week six, we are looking at groundwater recharge and discharge, the multiple methods that are used in understanding the recharge, we looked at multiple methods, and we also looked at some of the benefits and assumptions that are made in these methods the last class for that lecture, let us continue looking at what are the key factors that are use for recharge estimations and how they are used for groundwater artificial recharge.

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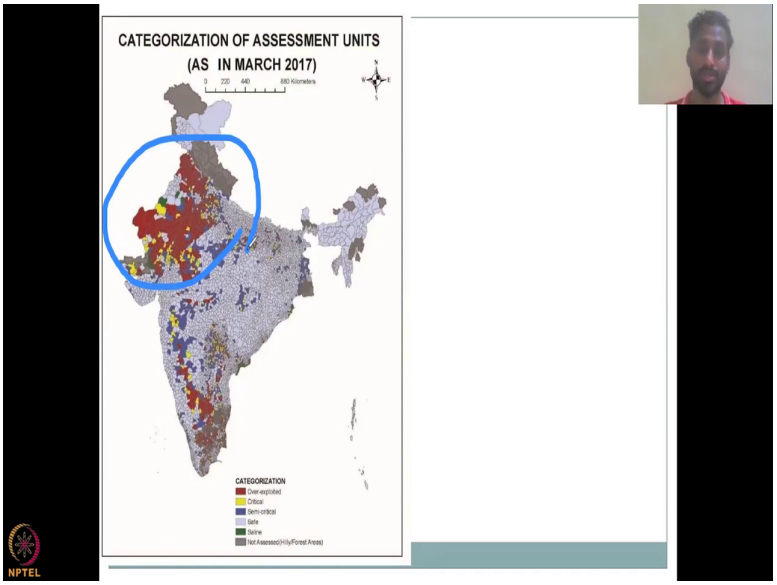

As we ended last lecture, we looked at where the groundwater recharge issues are happening. And since the groundwater recharge is limited, as shown in the central groundwater board, because every time when there is a groundwater recharge, and it recharges back to the initial level, then your blocks are safe, you are using water and it is recharging. But if you are using more than the groundwater recharge, then it becomes a critical or overexploited block.

So, for example, these regions are critical overexploited, red colors, which means you are extracting more than 100 percent of the annual groundwater recharge. Is this sustainable? It is not sustainable. So, what happens is there is a need for augmenting the recharge, because you cannot control the use of groundwater. So, it is better to add more water into the pool so that when you extract it, it is sustainable, at least for some reasons.

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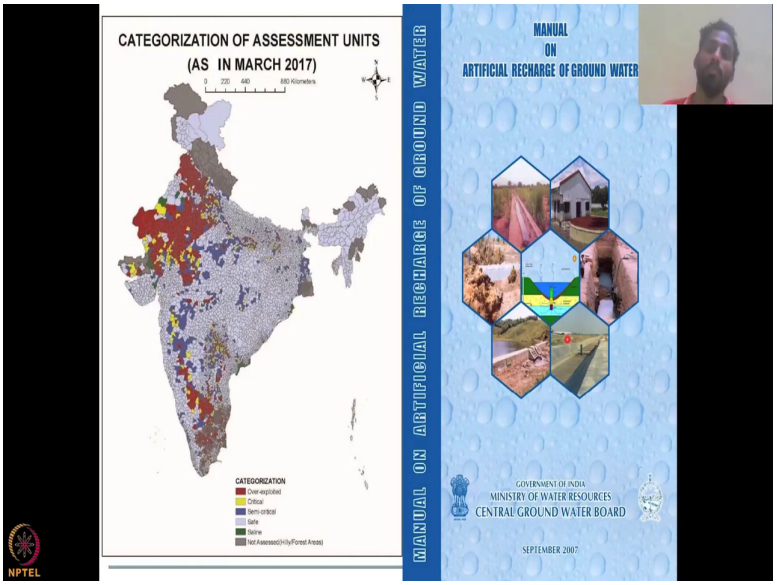

So, let us look at what that means, as per the central groundwater boards reports. So, because there are these groundwater issues across India, the central groundwater boards in 2007 came up to this manual on artificial recharge of groundwater, it is a free open source book, anyone can find it online and download it. Just type in manual on artificial recharge of groundwater, you will get this book.

Here, what happens is in this book, they describe the process of recharge, they will cover most of the things that we covered in class of water level fluctuation method, water balance method, rainfall runoff method, and also specific yield method all those things. And they will also look at past groundwater data per state and within the city and districts. So, they look at state wise groundwater issues and they propose groundwater recharge methods.

Some other methods are given in this image, you could see that. You have canals which are bringing groundwater recharge, you have your lift irrigation, your recharge pits and ponds recharge wells, check dams, irrigation dams, etc, all these are augmenting groundwater recharge. The central image that shows us they have a shaft which pushes water into the groundwater, you can see that the water arrow marks are going.

So, these help tremendously in increasing the artificial groundwater recharge rate through artificial means, the artificial comes because it is not nature based solutions. At some points, we have to take non nature groundwater recharge solutions, because the extraction is not at nature rates, it is much-much faster and we are over exploiting the groundwater. So, it is very

important to put groundwater back into the system every year during the monsoon or good rainfall of the rain months and then use your groundwater for irrigation, domestic use or other uses.

So, this artificial recharge is going across the world, there is something called Manage Aquifer Recharge MAR which is developed by these international organizations, there are books which is also free Open Source from IAHS. So, please go ahead and look into these resources but because this course is on Indian groundwater recharge and systems, I am teaching from this groundwater book.

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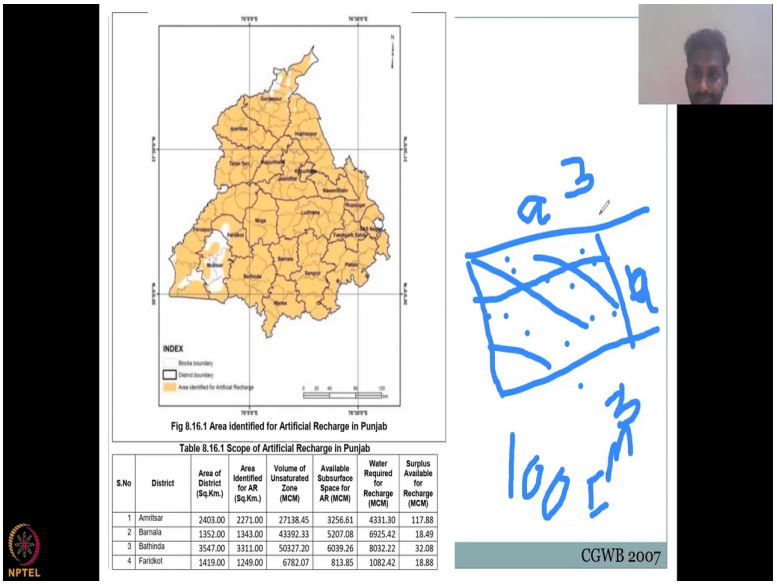

Moving on, let us take a look at some case study examples as per the book. So, you would notice that from your previous figure, this place where Rajasthan, Punjab region is highly depleted by groundwater. So, I went into the book, I selected those states to look at what kind of recharge work they are doing. So, what they do is, they have this area and in that area you have area identified for artificial recharge, they take multiple parameters for estimating the area for recharge.

So, they put the focus on the groundwater aquifer type, the specific yield, the groundwater use, which is a groundwater draft and also how much water is available. As I said in my previous classes, you can have the best system to recharge groundwater, but if there is no water, there is not going to be any recharge. So, make sure that when you plan these

groundwater recharge activities, there is enough water to push into the ground otherwise, it is just an exercise of building structures without any impact on the society.

So, let us see what their results show. So, their study shows that Punjab region is one of the most predominantly groundwater abstracted region and they had the block boundary, district boundary, etc. As I said it is done by state and then they break it into districts. So, in each district, they have identified area of the district, area identified for artificial recharge. And you could see that almost all of this area of Punjab is identified except very few.

So, there will be given take some portions which are not suitable for groundwater recharge like hillslopes and other things, they have neglected. So, in Amritsar for example, you have 200403 square kilometers of total area of which 2271 square kilometers is identified for IR volume of unsaturated zone. So, then what they do is, they divide it into the aquifer layers. So, they have the top layer the unconfined aquifer or unsaturated zone and then your saturated zone in the confined layer.

So, we have available volume in unsaturated zone is million cubic meters is 27 million cubic meters of water available surface sub-surface space for artificial recharge is 3025, water required for recharge is 4331 and surplus available for recharges 1178. So, here what you see is available space in the groundwater aquifer, so, that aquifers should have space which means the pore spaces and also the volume of the aquifer should be enough to store water, so that is how they do.

So, for example, if you have if you have an aquifer this thick b, let us say b is the thickness of the aquifer. And your the entire thickness cannot be given as volume of water, because your specific heat or you have porous space, how much porous space is present etc. So, suppose you have 50 percent of your solid material is solid and 50 percent is porous space where you have air or water, then what happens is 50 percent of b, thickness of b can only be used as your volume for unsaturated artificial recharge.

So, let us say a, let us keep all same. Let us say a a and then thicknesses is also a, so this volume of this cube of soil metrics is a cube. Let us say a cube 100 cubic meters. So, these 100 cubic meters is your this 100 cubic meters is your full volume of your subsurface or

unsaturated zone in this in this particular case. And I am saying that there is no water, so it is unsaturated, but there is solid particles.

So, you have to remove that and as I said the porous porous space of the porosity is 50 percent and if I remove the porosity, what would happen is, I get around only 50 cubic meters for volume of unsaturated zone. And within the volume how much is available for subsurface? Subsurface is very small on top. So, this could be your subsurface that is easily infiltrated and you can store some water.

So, this is how they estimate further thickness the soil type and then they also look at is there water currently there or not. And then they continue the experiments on looking for groundwater recharge zones. So, this is how they would actually monitor groundwater levels monitor because they already have the levels, then they find which areas are more depleting and identify key priority areas for groundwater recharge, here it is the book would be listed in alphabetical order.

So, do not think Amritsar is the key district for groundwater recharge it is just ABCD. So, you just go down and see which area is big or which needs more water. And then the area and divide for artificial recharge is based on the physical conditions, the climatic conditions and then based on those conditions, they assess the volume of unsaturated zone and then available for subsurface space etc. etc.

So, once you have all these details, you can propose the type of groundwater recharge. So, remember all the recharge methods that we showed here, you can pick and choose based on your specific in the porosity and the climate, how much is there. For example, there is very less rainfall or it happens only in one two months, so it is better to capture all the rainfall in a form pond, check dam kind of thing and from there recharge the groundwater rather than distributing the recharge and then losing it in this way.

So, here if you disable too much, you lose all the water because in between they just lost plants are taking it, evaporation is losing. Whereas check dams and deep deep shallow wells in the aquifer shallow aquifer you can put a deep well and then recharge it shaft all these things can be used.

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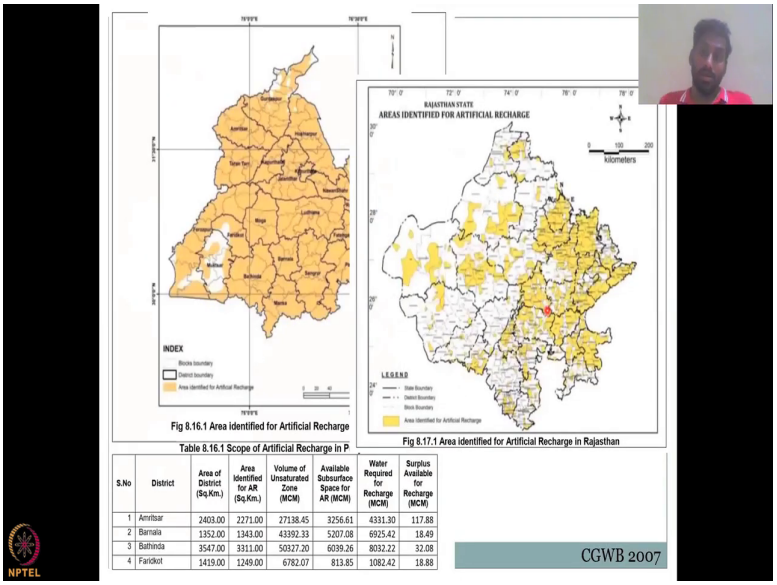

Let us take another state which is also red in color, Rajasthan. Rajasthan state also has a lot of its locations in the red, meaning it is also using more groundwater than the annual recharge, it is not sustainable. So, there is a need for augmented recharge, especially in the regions where the climatic conditions are not favorable. So, if you look at here, the area identified for artificial recharge is much less compared to Punjab. Why?

Is because there is less rainfall, even though you have good non water use, even though you have groundwater, which has been extracted a lot. So, you need to recharge it the need is that, but the possibility is very less because of the rainfall and the arid temperatures, is very hot desert like conditions and the the rock material itself is not conducive for recharge, that is why they are removing the water that is different, that is why groundwater extraction is happening.

But that does not means we can easily recharge, it is going to be a loss of money. Not all areas can be artificially recharged, so, they pick and choose. Here look at it, they are picked mostly along the sides of the neighboring states. And they have recommended a lot of different programs for groundwater recharge. I recommend you to read the book and then find which is more suitable.

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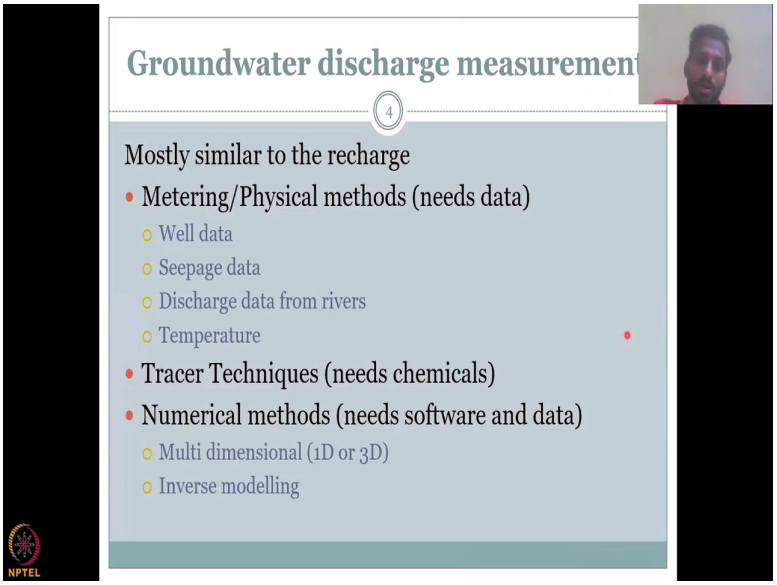

Moving on, we have discussed only about recharge. So how do you do discharge measurements? I will not be spending more slides on this, because it is very similar to recharge, only sign changes and most of the time it is human induced discharge. So, you need to know pumping. So, groundwater discharge is measured or estimated by metering and physical methods, it needs a lot of data. It includes a well data where you record the well and then after you pump you record the well, so you get discharged curve.

Then you have Seepage data, similar to recharge you can have discharge also through seepage, which means groundwater is losing to the river through seepage in your this week's homework, you will see a good correlation between gaining stream and the losing stream. And the gaining stream, the stream is getting water from groundwater, so, groundwater discharge is happening. In a losing stream, the stream is giving water to the groundwater, so it is a groundwater recharge.

So, here seepage data also is needed to understand discharge of river increase in water because of groundwater discharge. Then we have temperature, temperature data is also used for measuring the seepage, because normally groundwater is much cooler than surface water depending on where you are, but in most tropical countries like where we are, etc, the groundwater is more cooler conditions.

So, when it comes in mixes with the river and ocean, other interface you can find where the temperature is changing and that gives an idea of how much volume of water is coming. If

you take other examples, for example, you have in a cold country, you have river frozen underneath the water would come very warm.

So, the ground water is always at a different temperature than the ambient temperature and depends on the cooling conditions inside or the warm conditions inside relative to the outside air temperature. These temperature differences are used to understand how much water volume is actually taken by your flux conditions and also your recharge and discharge conditions.

Then as explained earlier, you do have your tracer techniques where chemicals are needed, traces are needed, it has to be environmentally clear those kinds of things. Moving on there are numerical methods and numerical methods include your software and data, is very similar to your recharge estimations, they are multi-dimensional, 1D, 2D, 3D and inverse modeling is available. Please make sure that of all this data, the pumping data is the most important well data, which is mentioned here for groundwater discharge.

It is very, very hard to get no farmer would readily share that data because they think you are going to bill them. It is not it is not correct on both parts, because we need data to manage the groundwater, but however, their concern is also valid, they are not clear why the government is taking that data. So, there is a need for better estimation of groundwater pumping and that can be done in multiple ways.

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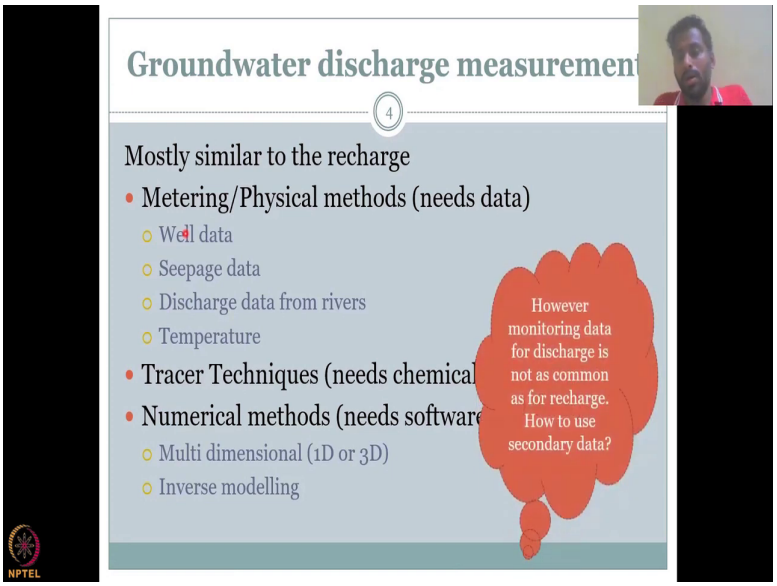

Let us look at some as I said, monitoring data for discharges is not as common as for recharge, because see CGWP wells when I talked about the 50,000 wells in India, they are placed in locations mostly which is not connected to the pumping or not the pumping well, it is a monitoring well. What is a monitoring well? It should not be disturbed, you cannot put in water you cannot take out water.

So, it kind of captures the natural recharge which is slow, but will pumping and all it will capture, because it may be linked to a pumping well, but most probably the wells are not linked you do not get the signal, you do not get the pumping volume in your discharge measurements. So, you just see a falling water, but it could be because of other reasons also, the pump volume is not actually captured by these wells. So, you would need to use secondary data.

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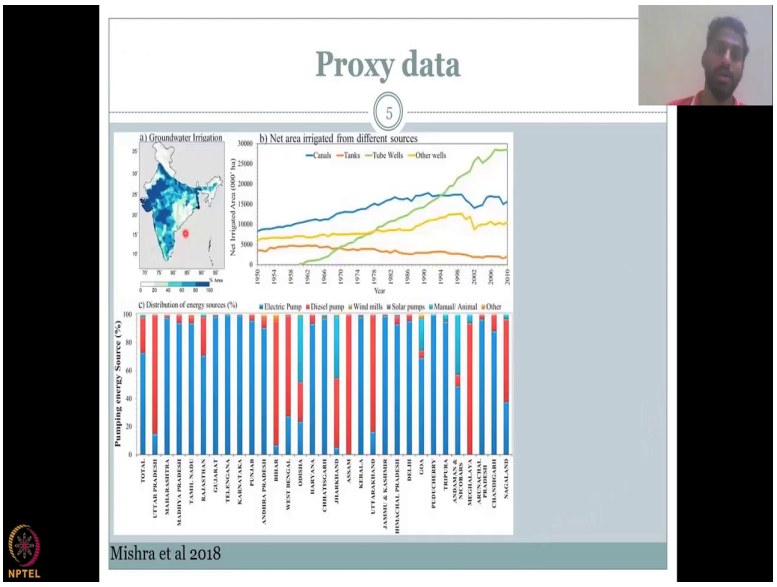

What kind of secondary data is the question? Let us look at some secondary data. Secondary data is defined as not the primary data or not the original data which is being collected for your research for that purpose. For example, census data is about population that is the primary data, but if you use census data to understand the division of people in males and females, and also education wise, are they educated or not, then that is kind of secondary, because you are not going to schools and taking the education data, you are taking it through surveys and secondary method.

Here secondary is, so, in this in this example, primary means your well and pump how much water is estimated or extracted. If you say secondary data, then that means how much energy is given and then the pump or how much acreage of crop is done, then you estimate the water volume that is secondary, you are not directly measuring you are measuring through other means. So, most of the time, we use proxy data or data that reflects what you want.

For here, let us say in the first image, you have a groundwater irrigation you see where normal irrigation has happened and it is area percentage, how much percentage of area is included in the groundwater irrigation. You could see how many canal irrigation have stopped, tanks irrigation has almost plummeted, but tube wells and other wells groundwater resources have increased.

And in the down figure, finger C, you have distribution of sources state wise, where it shows you where what type of energy source they use for groundwater extraction and mostly it is blue in color. What is blue it is electric pump and then you have the diesel pump red. So, these are the two colors which are very-very prevalent. Windmills, very little, Assam has it, Kerela has it and then Solar Pumps again very-very little.

Haryana has little and then manual animal is a lot. So, animals and man you know human lift irrigation schemes or their petals and etc. and others. But most importantly your electric pumps and diesel pumps are prevalent and they consume fuel as electricity they consume and electric power or they can take a generator and from generator this electricity and the diesel pumps use diesel. Here you can kind of estimate how much volume of petrol or diesel they buy for their diesel motors.

And then using the motor efficiency, you can calculate the pumped volume per day and then estimate how much water is taken. Same thing can be useful for electric pumps, electric pumps, there is a time period, there is a meter which shows how much electricity consumption is happening, these are not house electric connections, these are different connections.

So, you can clearly define how much electricity is used and then from the electricity and the pump type you can estimate the volume used based on how much how long the meter was turned on. Now, here comes the question, the efficiency may not be the same. So, how you

operate your cycle is different than how they can operate the cycle. So, and then the efficiency rates, maintenance, all these things, but still is some data which is in a place we do not have any other data.

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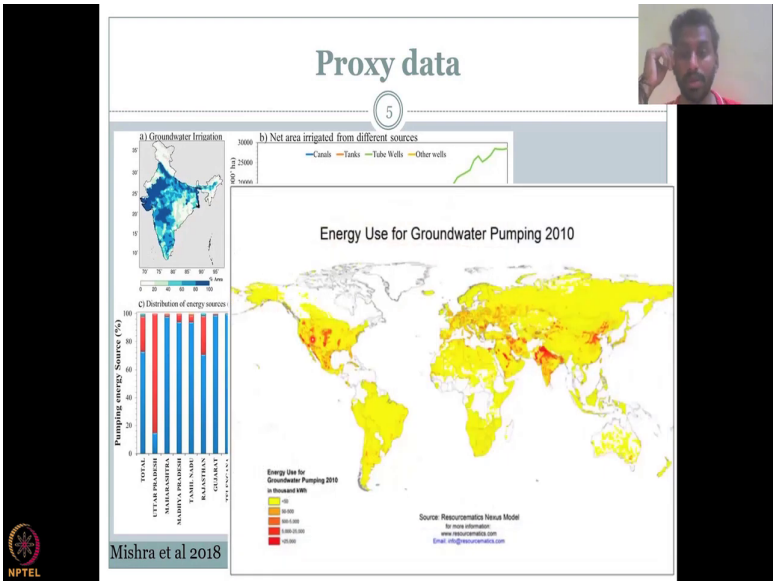

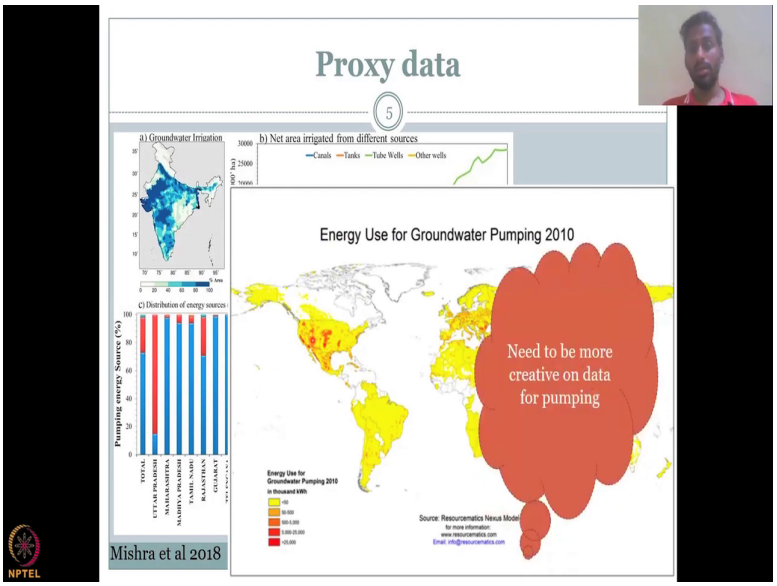

Energy use for groundwater pumping is huge and you can look at India is always the orange and red color which shows tremendous kilowatt hours used for groundwater pumping. So, this data is available, you can indirectly estimate the volume of groundwater pumping.

Even look at US also most regions along the coast where they do grow, California almonds and pistachios, you see all these groundwater being exploited, this can be used as a secondary data for estimating discharge. Need to be more creative and date on data for pumping, because this data is good, but then does not tie correctly because the pumps, the efficiency, the losses etc. etc.

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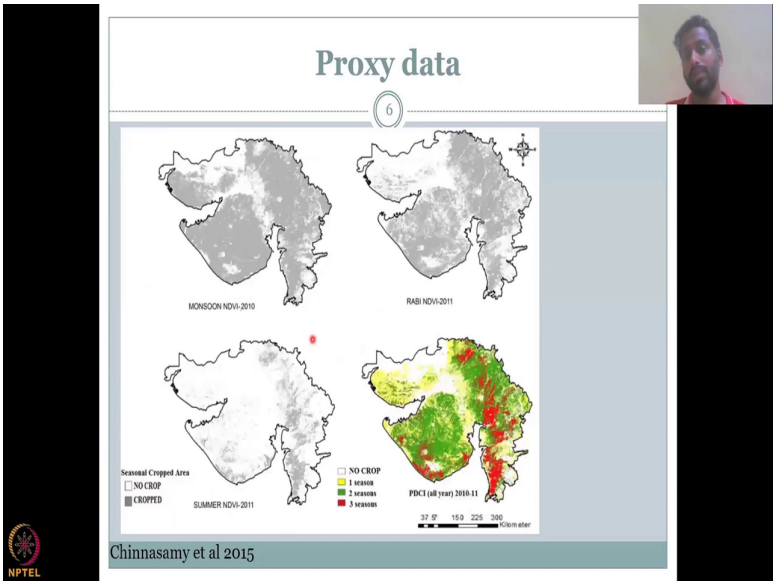

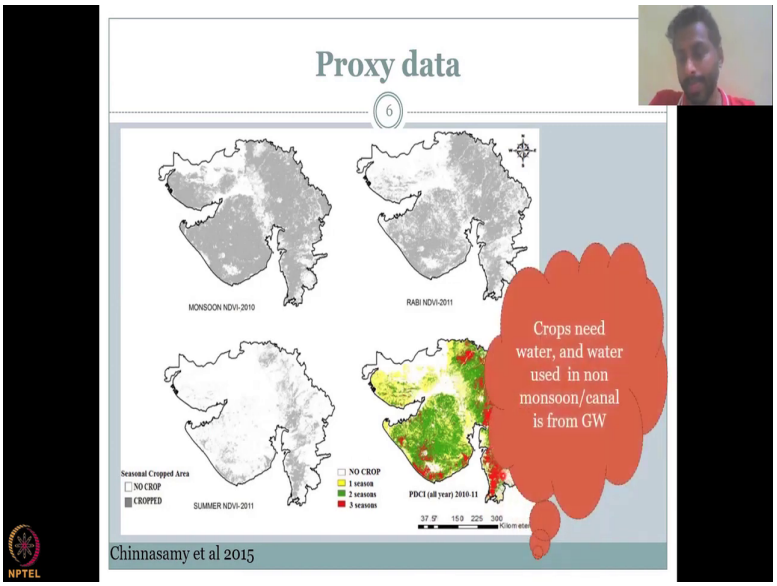

Then there are studies like this like Chinnaswamy et al in 2015, they use satellite imagery for Gujarat and estimated the Rabi crops. And then you can see here, this is the monsoon crop so let us leave a monsoon because that is going to be taken from rainfall, no groundwater irrigation. Then you have Rabi crops which is lesser than the monsoon crops, so, it has been covered most of the areas and then your summer crop also is the extended Rabi crop, it is a non-monsoon crop and also uses groundwater.

So, all the Rabi crops would use some secondary water resource same your summer crop would use a secondary water resource and it is mostly canal irrigation and groundwater

irrigation. So, what you see as a composite of all these images is no crop is only on the top where the Kutch region is there, it is not good for growing crops.

Then you have big water bodies, so, you cannot grow crops inside a water body, but then you have one season crops yellow, which is very little on the north, two seasons are mostly in this big big Saurashtra region and other regions, three seasons is where the canal irrigation is good and groundwater access is there.

So, now, if I know how much the water is released from the dam, which is easier to get, I can get at what is the remaining water needed for this acreage. So, this is an area with the pixels and the size of the pixel, I can calculate the area of crops and if I know the crops, which is not difficult to find it because most of these are mono crops, they grow only single type of crops in in the Rabi season, you can quickly estimate for a particular crop.

There is a particular evapo-transpiration rate and take that evapo-transpiration rate which is in millimeters, multiply it with your area you get a volume and that volume is the groundwater volume extracted after accounting for groundwater, irrigation and water irrigation through canals. So, the somewhat you can get close to water balance using the area of n-type of crop, this has been done in the study cleverly, please go ahead and look at it all these papers are online, you can even get it and read these papers.

So, crops need water and water using non-monsoon or or canal is from groundwater, which is not from monsoon or not from canal irrigation is groundwater resource. So, understand that by either way if the crop is growing as per the satellite imagery, there has to be some data on on what crop it is, or satellite data can provide you with what crop it is, and acreage and then you can quickly estimate the volume used.

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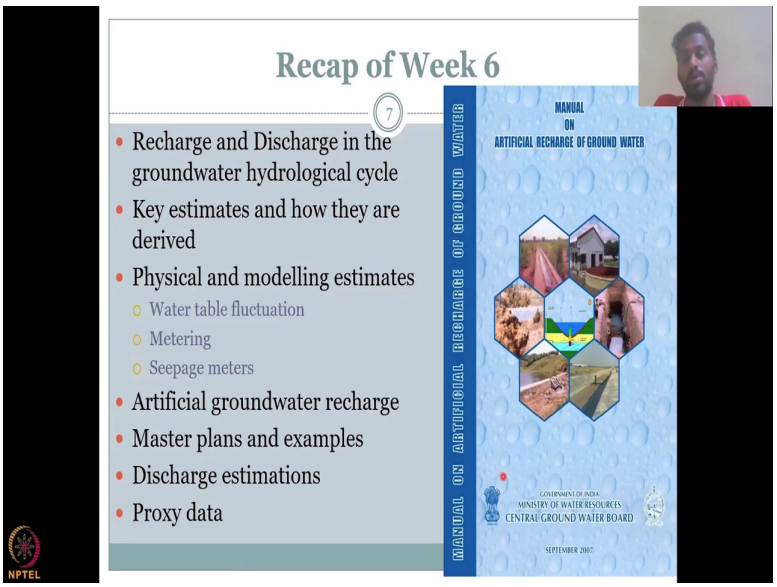

So, with this, I will recap. Week Six, we discussed about recharge and discharge in the groundwater hydrological cycle. We looked at how important these two phenomena are in the overall cycle. If there is no recharge, then there is no water going into the ground. If the groundwater does not seep out or discharge into oceans and lakes and rivers, then the cycle is not fully complete, water goes in and is stored.

And in plants and trees and etc. use a lot of these groundwater resources and so, it contributes evapo-transpiration. Key estimates were looked at and discuss and how they are derived. For example, we looked at the water table fluctuation method and how it was derived using a case study we looked at the graph etc. Then there are a lot of estimates and assumptions made using your water balance, we looked at it and we discussed how some are correct some are not correct.

Then we look at physical and modeling estimates. I said water table fluctuation, metering we looked at a couple of meters, seepage meters etc. And then we jumped into given all this the recharge is not enough that is what the data is showing from CGWB and then we looked at what are the different artificial groundwater recharge areas that have been identified, the exact artificial type we will look at in other classes and we will also look at modeling in one week's class.

Then masterplans and examples were taken from the Rajasthan case and Punjab case. And we did some discharge estimations in the last slides, where we looked at either you take your groundwater level data, or you take it from the pump data or you take crop area data and then

understand the crop type, understand the volume taken, you can get away with groundwater use, which is your proxy data.

So, do refer this book, it is a useful book by central groundwater board and it does not change much because the methods are same, it does not change much even though it is 2007 I find it very-very useful for understanding the key concepts, because you can be very demanding on the data. But as I said earlier, if the data is costly, time consuming, not relevant, in some cases, representative, then you will have to resort to other methods.

And even if you do not have data, you still need groundwater for sustaining livelihoods, so it is better to just start with groundwater recharge, assuming they do not notice going down. So, especially India, because of the volume that we extract. With this, I would like to conclude Week Six lecture. I will see you in week seven lecture. Thank you.