Groundwater Hydrology and Management
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Lecture 9
International importance of groundwater and focus groundwater use in India 4

Welcome everyone to the NPTEL course on Groundwater Hydrology and Management. This is week 2, lecture 4. In this week, we are looking at the importance of groundwater resources, both in the international forum and also nationally why it is important.

We involved already looked at and discussed in the previous lectures, where groundwater is mostly occurring, where the aquifers are major and complex in nature, and which countries do take more groundwater for their agriculture industry purposes. We did come across that multiple sources that groundwater was being extracted mostly in Asian countries and that kind of the globe, India has the highest groundwater extraction followed by US and China. Most of the groundwater that is extracted in India is for growing rice, wheat and sugar cane.

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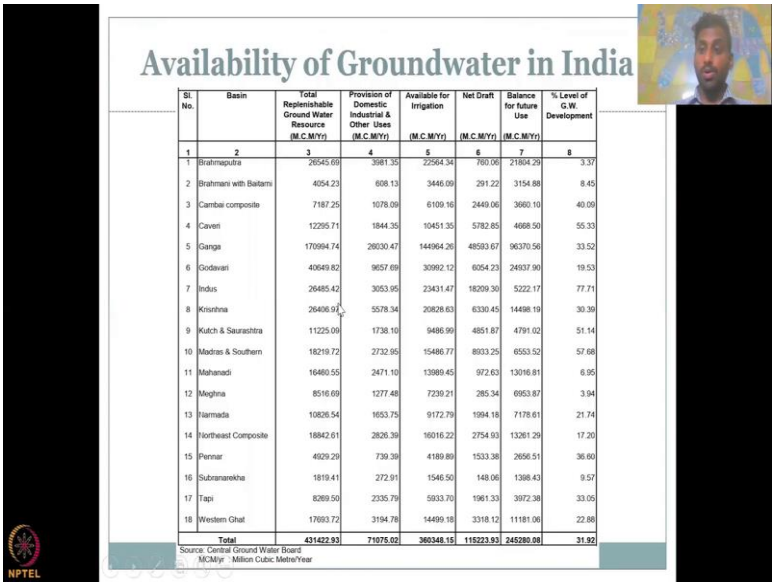

Sl. No.	Basin	Total Replenishable Ground Water Resource (M.C.M/Yr)	Provision of Domestic Industrial & Other Uses (M.C.M/Yr)	Available for Irrigation (M.C.M/Yr)	Net Draft (M.C.M/Yr)	Balance for future Use (M.C.M/Yr)	% Level of G.W. Development
1	2	3	4	5	6	7	8
1	Brahmaputra	26545.69	3981.35	22564.34	760.06	21804.29	3.37
2	Brahmani with Baitarni	4054.23	608.13	3446.09	291.22	3154.88	8.45
3	Cambai composite	7187.25	1078.09	6109.16	2449.06	3660.10	40.09
4	Caveri	12295.71	1844.35	10451.35	5782.85	4668.50	55.33
5	Ganga	170994.74	26030.47	144964.26	48593.67	96370.56	33.52
6	Godavari	40649.82	9657.69	30992.12	6054.23	24937.90	19.53
7	Indus	26485.42	3053.95	23431.47	18209.30	5222.17	77.71
8	Krishna	26406.97	5578.34	20828.63	6330.45	14498.19	30.39
9	Kutch & Saurashtra	11225.09	1738.10	9486.99	4851.87	4791.02	51.14
10	Madras & Southern	18219.72	2732.95	15486.77	8933.25	6553.52	57.68
11	Mahanadi	16460.55	2471.10	13989.45	972.63	13016.81	6.95
12	Meghna	8516.69	1277.48	7239.21	285.34	6953.87	3.94
13	Narmada	10826.54	1653.75	9172.79	1994.18	7178.61	21.74
14	Northeast Composite	18842.61	2826.39	16016.22	2754.93	13261.29	17.20
15	Pennar	4929.29	739.39	4189.89	1533.38	2656.51	36.60
16	Subranarekha	1819.41	272.91	1546.50	148.06	1398.43	9.57
17	Tapi	8269.50	2335.79	5933.70	1961.33	3972.38	33.05
18	Western Ghat	17693.72	3194.78	14499.18	3318.12	11181.06	22.88
	Total	431422.93	71075.02	360348.15	115223.93	245280.08	31.92

Source: Central Ground Water Board
MCM/yr : Million Cubic Metre/Year

On this note, it is also important to look at the groundwater availability in India as per the use and we did discussed that it is first major basis it has been a structure we looked at what percentage stable. And more precisely, we understood that most of the Northern aquifers or groundwater basins are highly stressed anything above 50 is kind of concerning, and we need to take immediate actions to preserve the groundwater resources.

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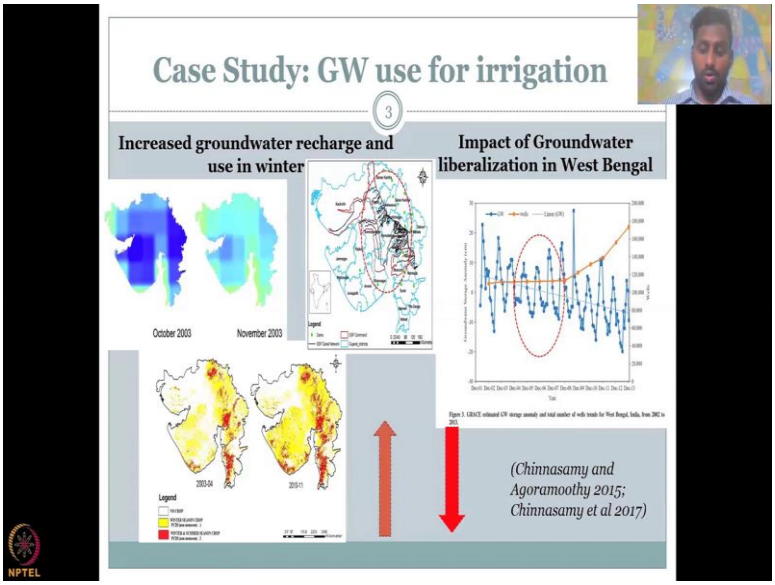

Moving on, let us look at some case studies to see how the data do change or commit common agreement between studies and some of the international studies on groundwater use India. As we know there has been groundwater use mostly for non-monsoon season because this monsoon we have the kharif crops where the crops direct rainfall just by the rainfall in nature. So, in the rabi season groundwater irrigation is important.

So, in this study, the researchers Chinnasamy at all looked at how the groundwater use was in Gujarat region and they found that there is abundant of remote recharge and indirectly due to canal water. Mostly when the dam structures and canal irrigatiin network was around the canal is going there is a lot of features happening was also seen that the groundwater recharge is prolonged in these recharge networks, even though the regions are not having enough groundwater. For example, in November all the basins did not have proper resources comparatively to the central regions where groundwater was more abundant in nature relatively.

And also that also showed the picture at groundwater is being recharged and is available for agriculture. So, now, we will study also looked at how the groundwater based irrigation was happening in 2003 and after seven years. So, the study found more and more crops grown during the rugby season and winter season, where groundwater is used. So, there is more single crop with rugby and double crop also rugby witticism, which leads the same land is now used for more irrigation because of groundwater.

Is this sustainable is a different question but we do understand that water has increased the number of times a land can be cropped. So, during the rainfall season, you will have one drop and during your groundwater irrigation season during rugby and winter, there is a possibility of additional 2 more crops. Short crops, but it is possible using a groundwater recharge in these aquifers.

So, the study also found that during the irrigation scenario using the surface water is the canal commands are there, the red is the canal command region. All the water that has been sent down during using the canals are being indirectly reached in the groundwater. Basically the groundwater was for supply of irrigation for crops. However, because it is not mined, and there is a lot of recharge happening, that recharge water can be used later during the non-surface water irrigation period for groundwater irrigations of one plus one crop and plus two crops.

Also, another study from the same authors at how the introduction of groundwater wells in West Bengal liberalization in 2015 led to a sudden decrease in the net groundwater. So, the study first started out the hypothesis by many authors and studies that the Ganges basin is tremendous in nature is huge. So, there will not be any issues in digging a groundwater because it will be recharging annually.

However, the study clearly found a correlation between the number of wells that started to jump after 2015 because of the liberalization of the wells in West Bengal from 2005 to 2015, and most impacts were seen in 2015. And the groundwater depletion, so, if you could see, the groundwater was already stabilizing during the non-liberalization of the groundwater network. But after 2007 and 2008, when the number of wells start to increase, there was a gradual depletion of the groundwater.

So, the blue line you could see, the linear fit shows that the net groundwater level is declining or volume or thickness around you want to put it here is representative as equal thickness of water in centimeters. So, the water levels or the storage is declining as an along the same pace as the wells are increasing. So, we already looked at in previous studies, at Burwell, it is approximately around 11,000 meter cube per year extraction and 20 billion wells in India.

So, this graph can also give you the number of wells in West Bengal that were introduced and how much the water levels were declining. So, there is a net decline in groundwater reserves wherever there is groundwater radiation happen, it is not bouncing back. So, if the well level

are coming back up to the normal levels, then we will say you are using the water that is recharging. So, there is no issues for groundwater in India. However, that is not the case.

We will see in 2005, 2006 when it was introduced, a stable groundwater level was all fluctuating because of a seasonal pattern, summer, winter, rainfall etcetera, it will come back to the same levels hovered around zero average, but then it starts to decrease.

In 2005, 2006 when the groundwater market was starting. So, the recharge and discharge we have seen here due to the irrigation lands, so one is where you saw recharge because of the irrigation plants, and also another groundwater depletion because of rain groundwater market open for agriculture.

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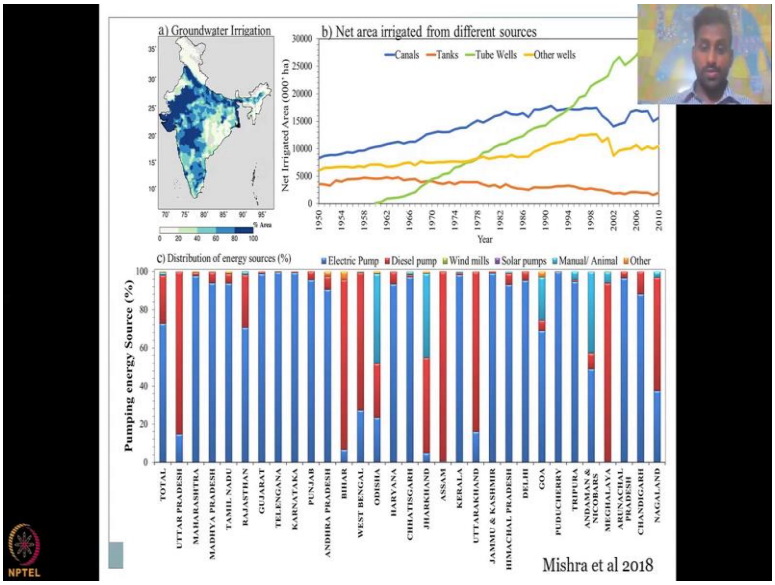

Another study by Mishra et al compare that the area that came under different types of irrigation change dramatically from 1950's to 2010 it clearly documents that the number of tube wells have increased and or replaced the irrigation system or the tank irrigation resources given in the decade. It was also given in blue line, it is almost stabilized, which means is not increasing. What is increasing is the green line, which is the Cubans or wells that take groundwater from the aquifers for irrigation.

So, those have increased and the area under the groundwater irrigation has dramatically increased. So, as the groundwater irrigation pattern has been shown in the figure 8, where you could see the percentage of area and mostly your north western regions Gujarat, Rajasthan, Haryana and the central regions of Maharashtra, also tremendous area under groundwater irrigation.

And that is where most of the wells are being used. And there is also a comparison on how the energy is being used there as electric pumps, diesel pumps, windmills, Solar Pumps, etcetera. So, all these have been as a result of industrial revolution, there has been a lot of technology and development for better pumping these resources to access groundwater. However, it is not an unlimited supply of water. So, you can invent all these pumps and engineering tools to take the groundwater out.

But it is not something that is unlimited, as they imagine, groundwater is a limited source. So, if you do not conserve and manage properly, the water is lost.

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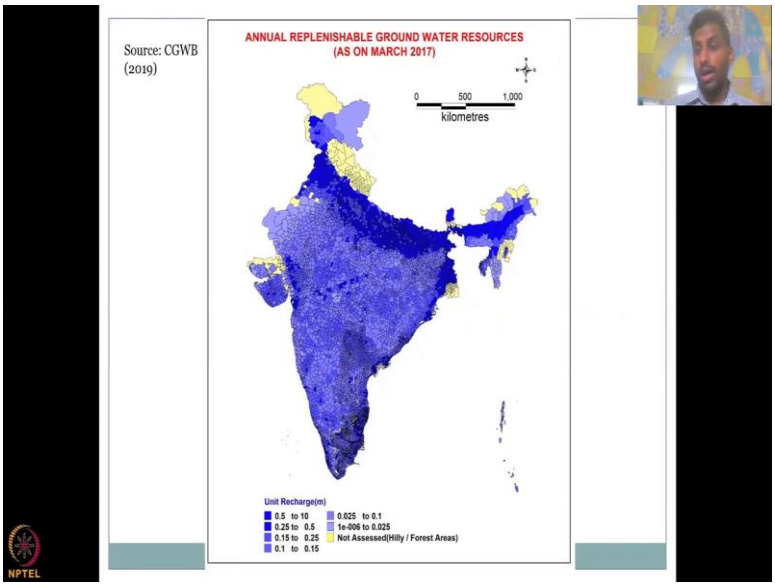

Monitors these groundwater levels in India, it is central groundwater waterfall, which is being government agency. They made these very informative maps. This is a block and build this diagram of India with boundaries, where you could see at a block level different, different colors to estimate the unit recharge of groundwater.

Basically, this map has been done for the 2017 year and this can be compared to the other data that we saw on groundwater basins, where groundwater occurs and how much water is being used. So, if you look carefully here, the darker blue sections are where groundwater recharge is the high and highest in India and occurs mostly on the floodplains are along the major river channels.

So, if you look at this, it is the it does get this great basin on and also this site is your Brahmaputra network, all having high groundwater recharge, but this is only recharge does not looking at the depletion and the Net groundwater availability this particular age. So, what

you also see is in some other regions in India, central and southern a lot of blue color which shows good groundwater recharge, and mostly in the regions where the water bodies are available.

The Kaveri basin, for example, the south and also regions where there is a good amount of rainfall, example, your Western grand's where the rainfalls can reach up to 3000 millimeters per year, compared to central parts of India were around 600 to 700 millimeters per year. So, the unit recharge has been estimated every year, every 2 years. And central groundwater board does put these levels across. They have around 15,000 wells spread across India. And they monitor every 4 months quarterly intervals and make these beautiful maps to show where the groundwater recharge is happening.

So, the hilly regions are not easy to access. So, it is left blank or without any assessments. But most importantly, the smaller levels are present in central India. And also that is where all the irrigation also happens. So, it is very important to understand where your annual groundwater recharge is happening.

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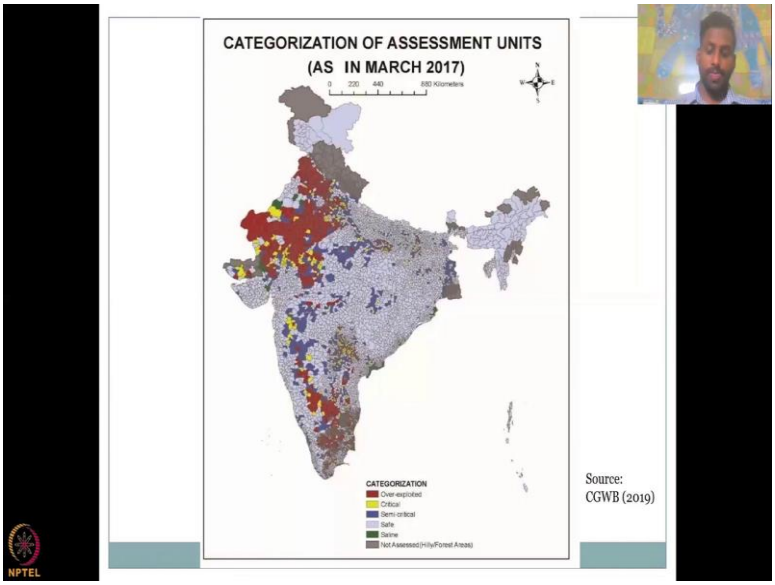

So, based now on the extraction, some groundwater recharge, and how much water is being extracted based on the agricultural surveys and also the water level after the irrigation session. As I mentioned, 4 times in a year they monitor groundwater. And at one particular time they take it during the peak also and then the whole recharge is happening groundwater gets into your aquifer. But after that they wait for some time, they wait for the irrigation to happen, the farming to happen and then they take a level. So, the difference between the level

before the farming and after the farming clearly gives you how much water has been depleted.

So, now you have an idea of how much water came in and how much water has been extracted. We will get into the actual data and practices in the following classes. But right now I would like to just be focused on the topic which is the importance of non-portrayed media and why we are studying this. So, if you look at this map in particular, at block level, you can clearly see that a lot of blocks are over exploited. Allow me to define what overexploited means this diagram?

Over exploited means you are using more than 100 percent of your research. I hope you remember the 2, 3 lectures, we saw how the international agencies give maps on how much water they extract and how much water recharges. So, you do a ratio if it is above 100 percent it is over exploited up to 100 percent somewhere near is critical 50, 60 percent would be semi critical and safe is below the 50 percent.

So, what you will clearly see here is the over exploited regions are really high, which is along the north eastern regions, and also the central regions where there is a lot of agriculture activities. The north eastern regions, so, not western regions could be tailored or understood because of the low rainfall and arid regions, whereas the other regions are purely depleting on water, because of tremendous use of groundwater resources.

Also Punjab, Haryana or a lot of red color here, so overexploitation is a concern, whereas the other regions are safe. And you also have semi critical, the blue color in some regions where slowly they are converting into the yellow, which is critical, and then red. So, this is how they progress if you do not take any action, a groundwater levels continue to decline.

And at one point, the groundwater is extracted more than the annual recharge. So, if you start taking water more than the annual recharge, you go into the over exploited scenario. This is not a good way to use groundwater, especially in a nation where agriculture is the major occupation of the people.

And agriculture also takes a bunch of bulk of all the groundwater reserves. So, it is very, very important to understand this diagram very clearly, which is based on observation data taken every 4 months, and also assessment of the recharge. So, they know how much recharge is there, and they know how much water is being extracted.

If your recharge is less than your groundwater extraction, then you are over exploiting your pot of water in your block. The other thing that you should clearly notice here is the red blocks do not isolate themselves or in other words, it is not a scenario that occurs just in one location. It is the combined effect or it is a localized kind of scenario where multiple blocks take part in this groundwater depletion.

So, if you take one water, and you deplete and continue to deplete, you are not pulling your own water, but also the waters of the neighboring blocks recharge maybe very localized you can see blue color, some blocks and it is localized, and because of the blue color around the neighboring blocks can also get water.

Same way that the red color indicates that it is over exploited. And once when a block is over exploited, it can easily pull water from the neighboring blocks, thereby increasing the radius of your red color, which is over exploited. So, unless the water conservation activities do not kick in your groundwater reserves will be gone. And this could be through government activities or community activities that we saw in the previous slides.

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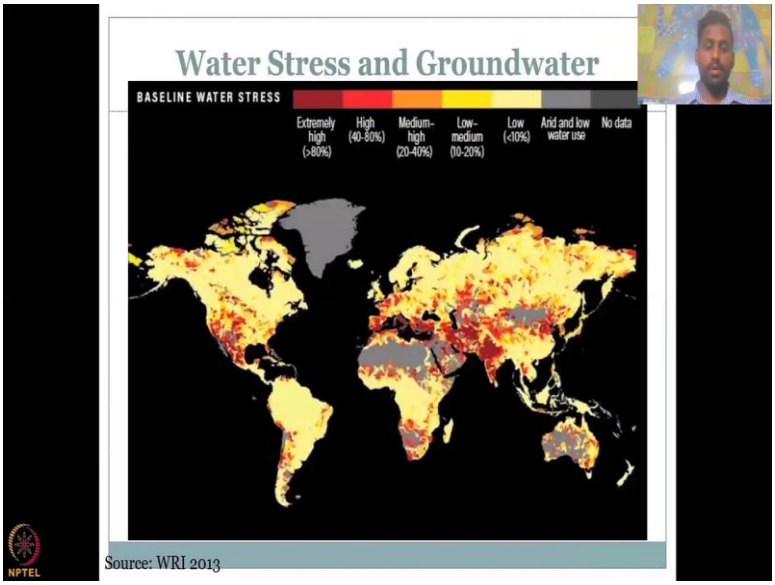

So, moving on, water stress has been calculated by the WRI and they clearly mentioned a tremendous water stress occur in the central and north-eastern regions. Also mostly the north-western regions sorry, and western regions constitute the Rajasthan, Gujarat, Punjab, Haryana, Delhi etcetera.

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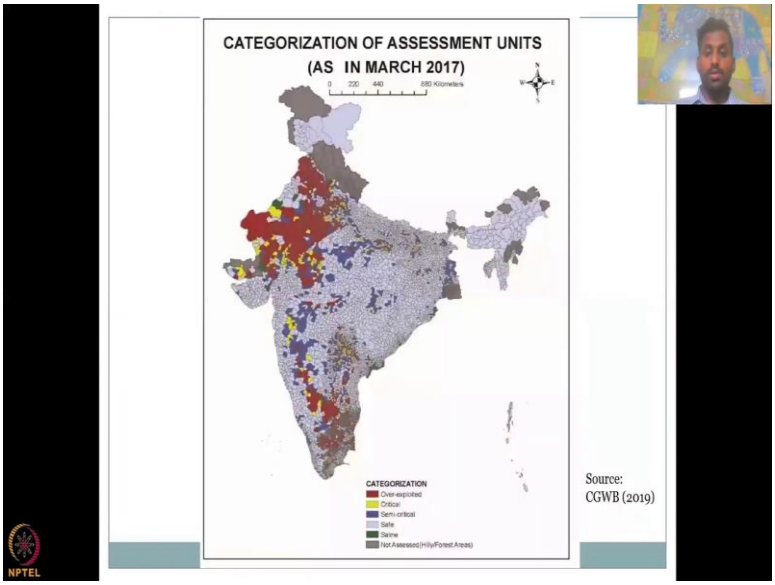

That it should be very different as per the blocks sample these could be due to agricultural whereas, your critical and semi critical regions along Bangalore, Chennai and Hyderabad could be because of tremendous use of groundwater for industries and domestic use. Even though agriculture is the major user of groundwater in local urban settings, if the non-water recharge is not happening, you are depleting your groundwater.

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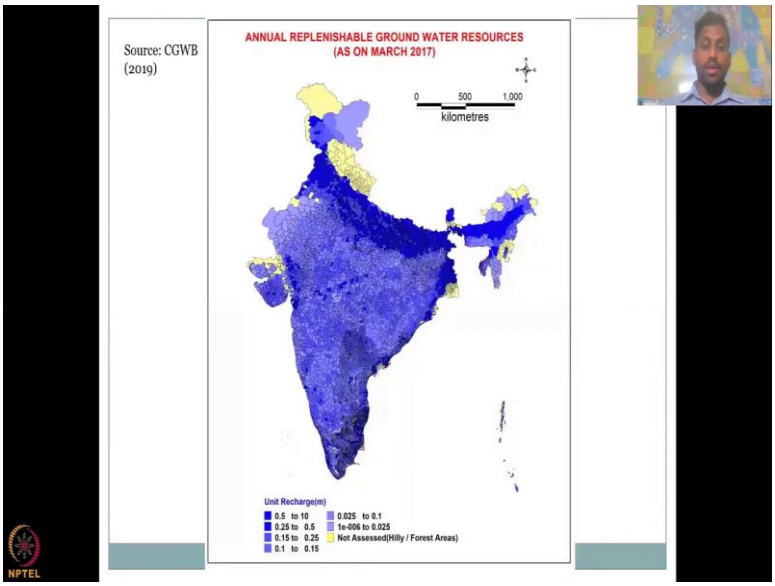

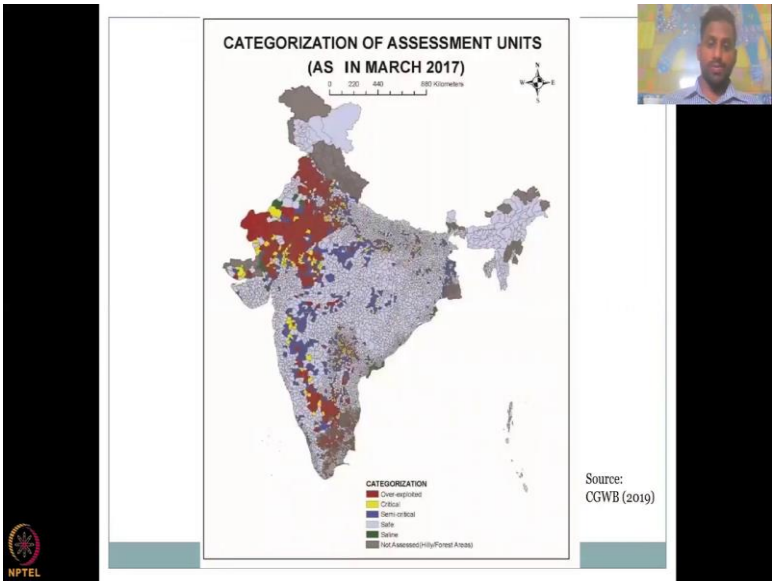

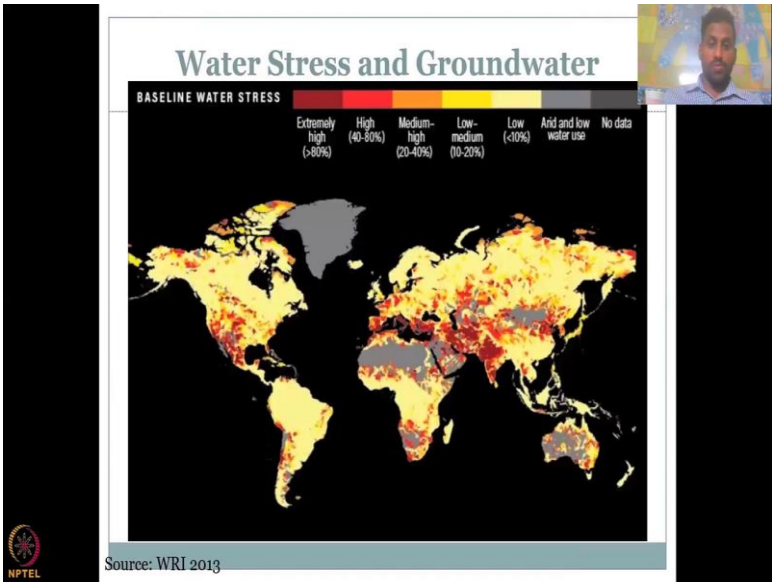

And that is also shown in this image. And suddenly when you have a combination of lot of urban settings, your recharge is coming down. So, once your recharge is coming down, you cannot use the groundwater based on historic recharge values. You will have to reduce your recharge groundwater consumption, so that your groundwater is preserved.

The other thing that is very important to notice here is that the agriculture areas are not monitored as regularly, because groundwater may not be pumped and the blocks wherever the 14,000 wells present may not capture the exact pumping scenario. This is because some of the wells are isolated from the groundwater pumping areas and due to regulations and sub and all they are concealed.

Unless the government would take in the groundwater, well record from the farmers, it will not be more representative. So, it is very important to understand that still there is space for

improvement on remote monitoring, and it will be good to use representative areas. This figure is also showing that the cropping pattern also drives the groundwater views on groundwater extraction.

So, these regions are mostly cultivating wheat, whereas, these regions cultivate rice. So, there is a strong correlation between the water use and the crop that it grow. In addition, there is also a correlation between the blocks of groundwater, overexploited blocks in correlation with the rainfall.

So, if you see here from this post, where you have the western grass at 3000 millimeter rainfall, it is almost safe and less critical. The water levels are safe, and no one worries about too much groundwater extraction whereas, these arid regions where there is groundwater less than the aquifer and also rainfall is less, you cannot be using the same water demand scenarios. This is where over exploitation happens.

So, you can look at over exploitation in multiple angles is it because the groundwater is being exploited too much more than the annual rainfall or the annual rainfall is very less and that is why people go for groundwater recharge? Either way, the groundwater recharge cannot sustain such activities.

And also groundwater reserves are not unlimited supply, which means it will run out dry soon as you would have noticed a lot of wells have run dry and your agriculture pattern has to change. This beautifully list along with your WRI image on 2013 at the baseline water stress where red color indicates a tremendous water stress.

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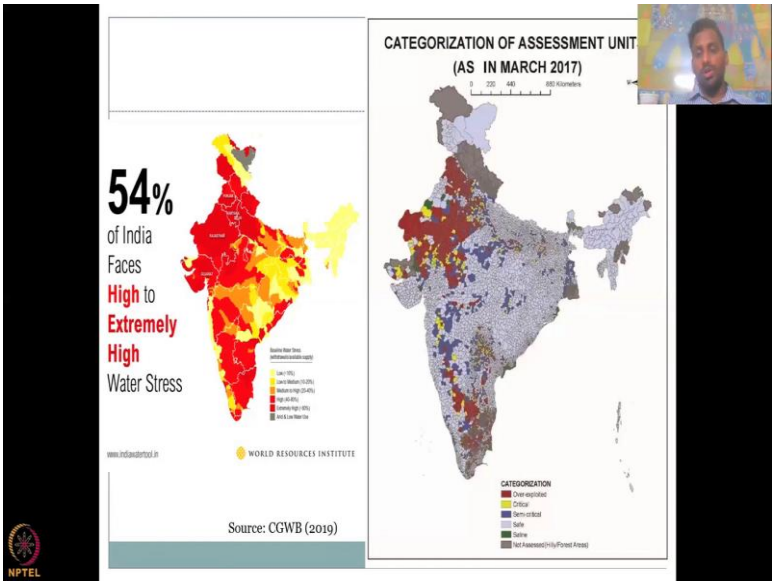

And if you map this along with groundwater blocks as it can be, you can clearly see the match study used data for multiple sources and also surface water and groundwater together. So, this is the image on your left looks at total water stress and says that high to extreme a very high water stress is going to be hit here pretty soon in the north-western region and also the central and southern regions and along the coast.

If you compare this with the groundwater block assessments as per CGWB for the year 2017. Now almost a year is a comparable, 2019, the study came out on the left whereas this study from CGWB also came out in 2019 for the year 2017. So, what you could see here is that the blocks are in correlation or in agreement with the WRI indicators of water stress at a state boundary.

So, Rajasthan is on the red color, where the water stress is high to extremely high across the state. And that also corresponds to really over exploited scenarios in the groundwater. So, the stress is already there, the baseline stress and the groundwater is low. So, unless you recharge and reduce your groundwater and water stress, your system cannot sustain such activity.

Let us take other examples where there is red and not much remote exploitation. So, along the eastern coastal regions of Odisha, Chhattisgarh etcetera you can see that there is not much groundwater depletion. However, there is potential for water stress. This could be because of tremendous amount of flooding's and cyclones that hit that area.

And if you come down on Karnataka, Andhra, Telangana and Tamil Nadu, Kerala regions, you do see tremendous stress that is being predicted by the WRI, both surface and groundwater, which is also in agreement with your assessments in central government board.

The Karnataka belt, Bangalore etcetera have been tremendously hit by water exploitation and also some parts of northern and central Tamil Nadu have shown some critical, overexploiting blocks that by both these different studies and different data are in agreement that the surface and groundwater resources are depleting as part of the array and 54 percent of India is going to be under height or extremely high water stress, whereas the groundwater board has estimated that most of these regions also will experience a groundwater depletion scenario.

So, if the stress is high and you do not have groundwater, it is going to be a very scary scenario. So, the concern is being based in this course. And also you would be taught how to manage groundwater so that even though you are projected to have a high water stress, if your groundwater reserves are good, or in a positive blue color, then you will be able to sustain the groundwater depletion scenario.

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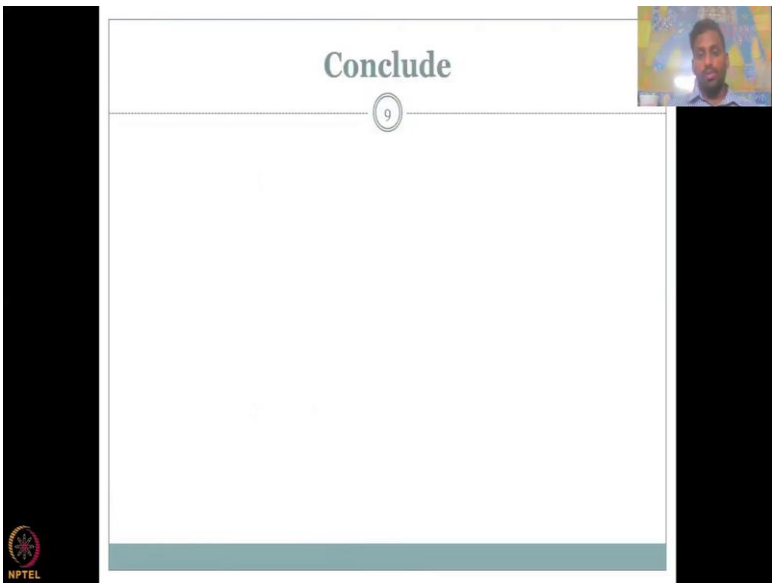

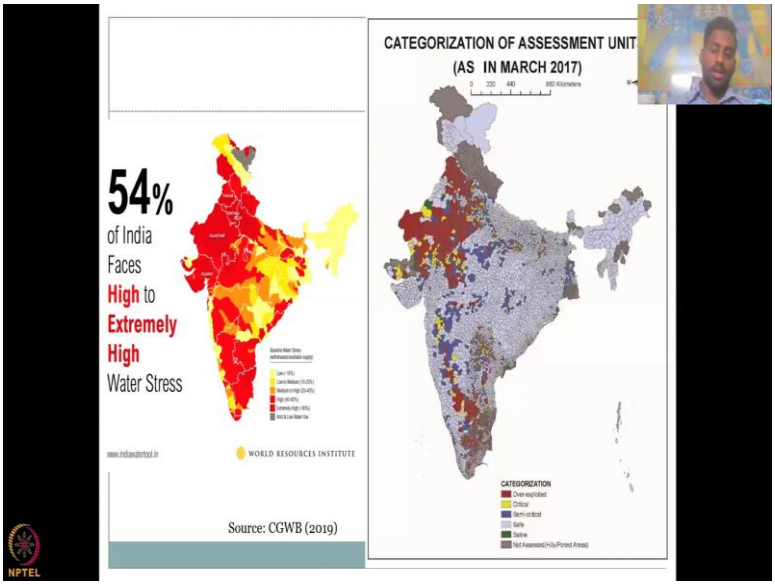

So, with this, I would conclude this week's groundwater lecture on importance of aquifers and groundwater system probably and also in the Indians scenario, we will also look at some case studies in the next week and we will wrap up this week so that we could start getting into the physical hydrology part. The physical hydrology part would explain the concepts of aquifer, block level estimation, how do you estimate your groundwater levels from the top and make these graphs on groundwater depletion scenarios.

You will also look at some quick models in an introduction to models to see how you could estimate a groundwater depletion scenarios based on the world record. So, for example, this central government board report has given you the well record and have mentioned where the water levels have more in the recharge and also on the depletion scenario.

And that can be incorporated into these models, along with other data like climate change to rainfall, to estimate the future in groundwater scenarios, which is very important to manage. So, with this, I look forward to this week's lecture on the importance of groundwater across the world, and more specifically, the importance of groundwater. Thank you.