Groundwater Hydrology and Management
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Lecture 8
International importance of groundwater and focus groundwater use in India 3

Everyone, welcome to Groundwater Hydrology and Management NPTEL course, this is week 2, lecture 3. In this, we are looking at the importance of groundwater resources, both internationally and nationally. Better understand and manage groundwater, it is very important to estimate where groundwater is used more, and what are the chief uses for the groundwater.

Also, it is important to understand which countries are consuming more groundwater. And also, what are the plans and management activities they are undergoing. We are still in the past two lectures looking at the stress on the groundwater system. So, let us continue with that discussion and notes.

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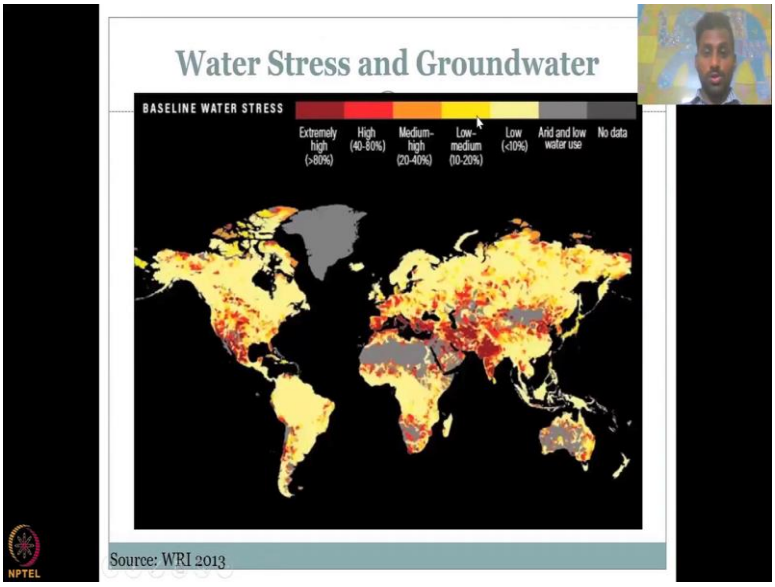

In the last class we looked at this slide by the end where we looked at water stress and groundwater. So, this data which is on water index, is made by WRI in 2013. And you could see a red colors indicating extremely high stress on what resources regions with extremely high stress, no data is where they could not collect data, whereas the yellow is low stress, and low to medium would be in the orange color.

So just looking at the baseline water stress the current scenario, where the water stress is high, you could see most of the water stress in the Asian region, especially in India,

Afghanistan, Iran, those kind of regions, and also along the agriculture belt, Thailand, etc. You also see a lot of water stress in the African region, both in the north and south, and European context along with the developed nations of US, Canada and Australia, pockets, very small, small pockets, they extremely high-water stress is mapped along the Indian subcontinent where groundwater and water resources are heavily used to supply water for the big population. And also, for agricultural, industrial activities.

So, if you map the groundwater uses that we looked at in the previous lectures, you could clearly see that the water stress already mapped across the globe also makes your groundwater use. So, why would someone spend energy and take groundwater is when you have water stress. So, if a region has good groundwater resources, they would not use it until there is a stress.

For example, you have good dams and connections to water that you see in US and in Chinese regions, we do not see much water stress. So only when the water is not enough, you would spend energy either electric energy, diesel pumps, fossil fuel, burning pumps, solar energy to extract ground water. So, the water stress and ground water go together, hand in hand to explain that people would go to extremes and also costly methods to get what because that is what drives the economy.

If it is agricultural nation's example India, Vietnam, those kind of countries and or for development, industrial development like China, US, etc. You look at US even there, you have a lot of agricultural activity on the southern south-western part California. And there you could see a lot of water stress and also groundwater use. So, all these clearly indicate that wherever there is a water stress, either the government or the locals would extend their water use to tackle the groundwater issues. This actually cumulatively impacts your groundwater sustainable use.

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Let us see how these groundwater global promote change occurs we are going to look at water stress, and we are going to look at the major aquifers and how the annual groundwater change. So, this data from the Earth Observatory of NASA, clearly documents that the annual change in groundwater is really concerning. In most of the major aquifers across the world. One third of us large groundwater basins because as we call them in groundwater terminology, are rapidly depleted.

And mostly for anthropogenic use humans, consumer for domestic use, industrial use or agricultural use, there is very less data. Because not all regions are monitored by observation well. So, this study from NASA uses satellites, it is very normal and very high-tech use of satellites to monitor groundwater. We will discuss that when it comes to tools for groundwater estimation.

Here, the study results clearly show that most of the big aquifers, one third of the big aquifers across the globe are highly stressed, the annual change in groundwater is in negative. So, negative is presented by brown color. And what it means that, every year your brown water is coming down, there is no recharge, there is no going up in the ladder.

So, the volumes where you see the positives are mostly in Australia, some parts of Africa and regions of North and South America, where agriculture is happening, I would say the other regions are not that much of interest, because in these parts, not much agricultural activity happens.

Remember, we discuss the groundwater economies, socio economics, here, there is not much in Canada and Russia, groundwater use for agriculture. So, let us focus on the regions where groundwater is used for agriculture. And you could clearly see that the major aquifers that are giving water for agriculture are highly stressed.

And as a result, every year your groundwater comes down. Is this sustainable? Certainly not, because you are taking, think about the analogy I use for a bank account to taking, continuously taking amount without putting it back. So how much can you take only until you run out of the groundwater, and once you run out, it is going to be disastrous? So, it is very, very important for groundwater management.

And this image clearly shows you where the hotspots are for groundwater depletion, especially in Asian regions. And along the regions where there is less rainfall, like Middle Eastern, African regions, etc. There is still less amount of data. So, this also is urging for policymakers and scientists to collect more observation data, to better monitor groundwater use.

So, the annual change in millimeter thickness of groundwater, I will explain the units later, is in the negative sign, so you compare the use here to this year, already minus 20 millimeters in India, then it go on and on. If you want the volume, you can multiply it by the area to get the volume. So, it is equal and water thickness is tremendously falling down.

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Moving on from another study by IGRAC the previous NASA study was in 2015. This one IGRAC is an international organization for groundwater studies, also shows a similar pattern in 2014. What they have done is they have taken a year 2010 as the study year, and developed the groundwater development stress manner. So, where the groundwater development and stress is happening a lot.

And you could see that is made by using the value, one is abstraction and the annual recharge. So, you have your bank account, you know how much money is coming in and how much you are taking off, including all the users. So that is what they have done here in this example. And they have mapped it across the globe as continents and national boundaries.

What you clearly see is the abstraction rate is really, really concerning in the Asian region. And all the less than 2 percent of annual recharge is very, very good, which means you are not using your groundwater you are not using much. And 2 to 20 percent is also pretty good until 50 percent.

No problem is if you look at the light, light brown colors up to 50 percent there is not much problem and up to 20 percent the government should look at how can you better accesses groundwater for a better economic development that is a flicker. So, as I said, there is a lot of groundwater here a lot of recharge happening, but not much groundwater here.

So, can you think of activities where you could put in some ground water networks for better what we use for sanitation, health, and other economic activities, agriculture, livestock, etcetera. But since this is a course, on groundwater management, we have to discuss on the

stresses on where the concern is. So, if you go to the darker brown colors of 50 to 100 percent, you could see the countries which are using more than actually what is coming in.

So basically, you are using water that has been stored for years and centuries, because you are already taking out all the annual groundwater, and you are eating into the reserves, or something that you say, it is a long time. So, India would come under the 100 percent, almost range. And if you break it into states, you will see some states will go above and beyond the 100 percent. Which is really, really concerning.

So, in this map, you see the northern parts of Africa, Middle Eastern countries, Afghanistan, Iran, Pakistan, all extracting more water than they get. So basically, they are extracting water from the previous years. And historic groundwater as we call. Whereas India is on average, on average is between 50 to 100 percent of the groundwater according to this study, which is also very concerning, because you are not leaving any groundwater for the next year.

Suppose the next year is a flood year or a good rainfall year, then the three scenarios the next year would be a good rainfall year, a good flood year with a lot of water, and a drought year. So, these are three basic scenarios. If it is a good rainfall year, you recharge is happening, so you are not worried too much because you extract it. And the next year, water comes in fine. In a flood year, not all the water will go into your aquifer, because big floods will carry the water out of your watershed, not enough time for recharge. So that is a very concerning situation.

Moving on, we have the other as a drought, which is the most common stress during climate change, what happens so you have already taken 100 percent of your groundwater that has been recharged, so you do not have much water for the next year where there is a big stress and not much annual recharge happening. So, suddenly, you will have to change how you use groundwater and or how we manage groundwater. That aspect is very, very important for better groundwater management.

So, India ranks right there, up to 50 to 100 percent which means we are seeing climate change extremes of droughts and floods. And if we do not manage the groundwater the next years, we will not have enough ground water for sustaining your activities sustaining your agriculture or even drinking water supply. So, it is very important to manage that.

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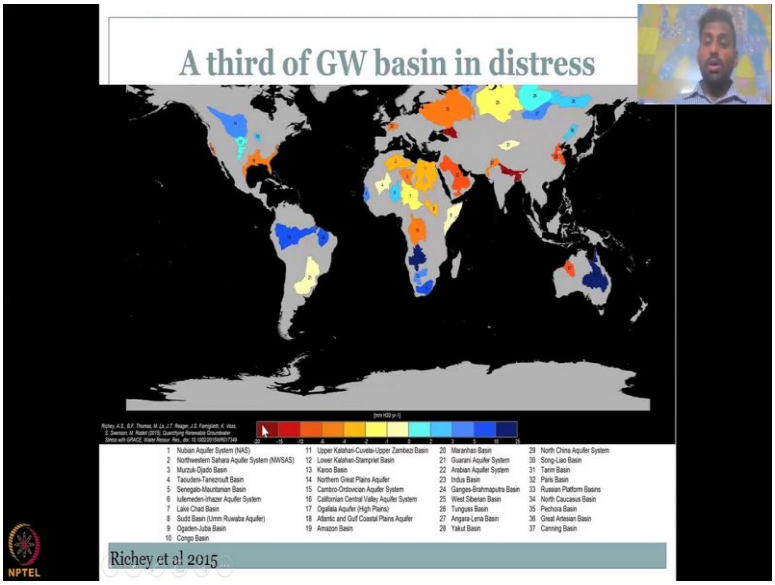

Another study very coincidentally. So, this is done by IGRAC in 2014 and the previous was done by NASA in 2015. Another study by Richey et al also using the NASA collaborators showed that one third of the ground water basis in distress, similar findings and what you notice here is that the labeling of where these aquifers are the major aquifers.

For example, let us take it from the Indian region number 23 is the Indus Basin it is in the negative, so which means every year your groundwater is depleting. So, right from your yellow, it is all the negatives till red and white to 25 which is the blue. So, blue means it is recharging, which is fine. So, if you look at where the positives are happening, Central Australia, Northern Russia, a parts of Canada and US and South America, where not much of a agricultural use is happening in these regions, even Africa.

When you come to the yellow and orange regions where it is depleting but not as drastically, is still a big concern. You could see the Indus region here, the number 23 Indus basin is depleting faster, along with number 29, which is the North China aquifer system. And number 33, which is your Russian platform basins. So, all these are pretty concerning in terms of, it is a warning that you need to start better managing the groundwater number 22 including, which is the Arabian aquifer system.

All these are warning bells that you need to stop using how you are using groundwater, because you are already taking more than what is coming in, you are in the negatives. If you do not, then it will become red, or very, very highly warning situation such as that exhibited in the Ganges water basin and Brahmaputra, which is under 24. So, Ganges Brahmaputra

basin you could see it is in red color along Nepal, parts of China and Tibet, India, Bangladesh, all are facing tremendous groundwater extraction. And because of that groundwater stress, along with number 34 basin, which is a North Caucasus basin.

These are the major basins which are highly highly under the stress minus 20 millimeters of equal water thickness per year. So, now you see a special distribution of where these water resources major in the groundwater basins. And also, you can clearly see where the groundwater aquifers are highly depleting.

Now, if you compare this with your previous lectures, typical crops that they grow, we can clearly understand that the crops that they grow are not going to be sustainable. Especially let us take India, here, for example, we looked at rice, wheat and other crops. So, if we just look at rice, and wheat, and sugarcane, this constituted around 75 percent of the groundwater that we use. And that is not going to be sustainable.

As per this figures estimates of groundwater depletion, every year, groundwater is depleting. So, if you do not stop and reorganize yourself, then the groundwater system is going to be lost, you will not be able to grow your sugarcane, wheat, and rice as you were growing. This could lead to equity issues, because not all farmers have access to groundwater.

And not all farmers can spend more money to dig deeper and have high energy pumps, higher efficiency pumps to be used for agriculture. So, this is where a lot of equity and poor and rich farmer divide is going to happen. So, it is very important to understand where these aquifers are. What are they doing in the aquifers? And is the volume, is the volume rechargeable? Minus 20 is very hard to bring it back to 0 annual change, and how are we going to do it?

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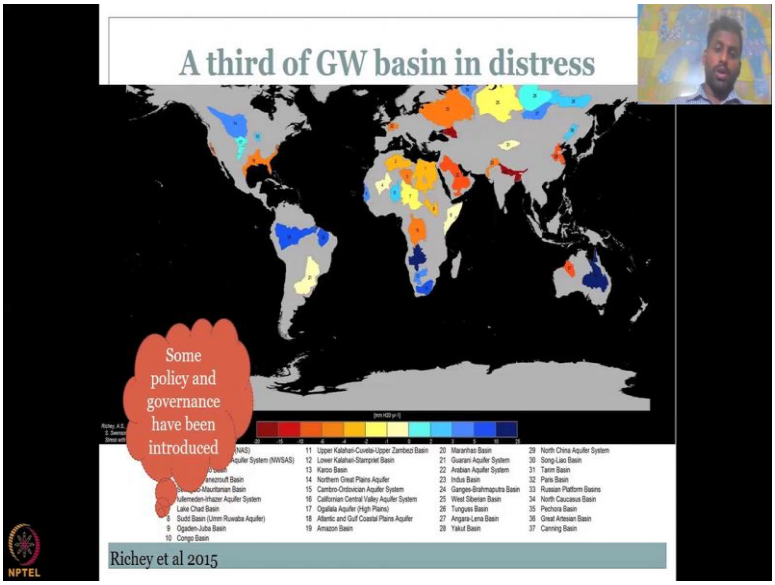

So, how do we do it? By the introduction of some policy and governance, we can quickly look across the world where they have introduced these policies and how they are different when it comes to groundwater management. So, here you can quickly look at where the major aquifers and major depletions are happening.

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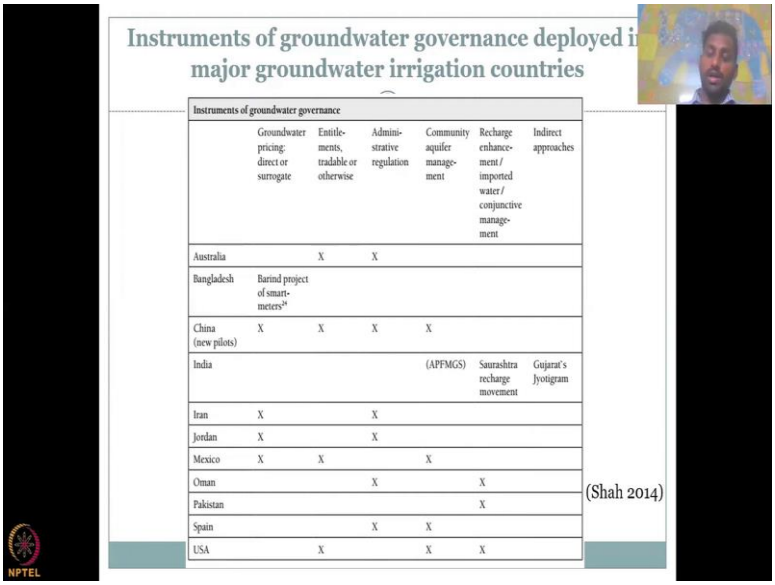

And we could add that with the instruments of groundwater governance deployed to these irrigation countries. What we saw is, Australia is a major irrigation country using ground water. They do not have ground water pricing or any type of metering estimated ground water, as per Shah 2014 and there are some entitlements which means they would legalize

certain people to use groundwater. So, entitlements are given and administrative regulations are based on checking and monitoring of these groundwater, but there is no pricing.

So, there is some regulations, but not much pricing. There is no community management or recharge, development and indirect approaches are not present, and also they are not much concerned because Australia's ground water resources as per the previous figure are not much depleted, or in the red zone.

When you come to Bangladesh, which is in the red zone or for sure, there are leaders present, so leaders are being present in the country to monitor the groundwater use, which is a very important step in identifying equitable share, and where the groundwater is going, the others are not present.

The other mechanisms are not present. If you come to China, yes, groundwater pricing is there. So, as you must have to pay as per the unit of groundwater daily use and the users also given guided by administrative regulations, entitlements. And also, a lot of community management is happen. I will come to India as the last, so that we can discuss more.

But Iran and Jordan work similarly, they have meters for groundwater use and they price the volume use, which is governed by some administrative regulations. And Mexico is thereby entitlements only some people can use groundwater or you have to get permission. And that is also been metered with some community management.

Oman, Pakistan, Spain, also follow administrator regulations, and also work on collective recharge methods. US which is the another big country using groundwater, not allowing everyone to put in groundwater, you cannot casually put groundwater, you need to get entitlements.

And also, it has to go through the government where you want to put wells, how much water you want to use, there is no pricing, but it has to be through regulated government entitlements. And there are some community recharge enhancement methods to increase the freshwater in these aquifers.

Now, coming to India, there is no groundwater pricing, we have more than 20 million wells to think about. Even the price of meter all the wealth is going to be really expensive, really time consuming. And also, will lead to a lot of sensitive issues like in estimating pools using more water. And is it accurate readings and those kind of issues will happen.

It is not as easy as just monitoring the power, because groundwater is not readily converted to your crop output, because your crop might not grow for various reasons, but it can be blamed on groundwater, like fertility, water loss during application of groundwater organizations. So, because of that, there is no groundwater pricing. If you go across India, you will not find groundwater pricing for irrigation, nor domestic use.

There is no entitlements, which means everyone has a right to put in groundwater, farmers I am saying and they can pick a location in their own farm, they put it or they have a community well, with an agreement with villages and or the community which means for farmers to come together and then put in a well.

So those entitlements are not needed in India, there is no administrative regulations, which means, if there is two farmers two different wells, there is no regulation on what depth the wells should be. And there is no regulation on what volume farmer A should pump and farmer B.

So, for example, farmer A can pump more than twenty thousand kilometers per cubic meters per year, whereas farmer B cannot afford that much power. And he or she just wants thousand cubic meter per year. There is big difference, because there is no regulation. However, if there is regulations like in the US, it is set at a particular rate and you cannot go above it, you can come below it, which is fine, but if you go above it, you will have to pay extra or shut down your license.

So, in India that is not available, and this has led to unsustainable use. And also, it is becoming harder to monitor which areas exactly are using more groundwater. For example, if I can take a village boundary, there are multiple wells in the village, it is very hard to distinguish who has more extracted, more water because there is no metering. And they do not follow the rules on I will use water only at this time.

Also, if the power that is needed for groundwater extraction is given at a very low cost, what would happen is sometimes the farmers would pump more than what is needed, and the water will either go down into the aquifer or get evaporated, which is a loss to the system. So that is where the regulations and entitlements could help, but it is very complex to get them implemented. And because of that, there are community aquifer management programs. Something, something different depends on where these schemes are introduced.

For example, there is a scheme for money, manage aquifer recharge to village level interventions, where the community comes together. They manage the groundwater in Saurashtra region, (())(24:47) etc. And they properly document what can constitute a good sustainable groundwater use, a plan that all the villages said to agree to use this system, also they have a recharging enhancement or conjugated groundwater surface water management plans. Something as an example is given at the Saurashtra recharge movement. Also, indirect approaches are there, which is an example of Gujarat's Jyotigram.

So always progressive states or states that value groundwater more, they have put in a lot of measures to actually increase the groundwater, reduce the consumption and also monitor the groundwater use. The governments have also notice that it is going to be difficult for a government agency to set up these regulations.

However, if you trained the community, the community also knows how much water is available, and the community can decide as a unit where the water should be and how the water should be. For example, if you have a government regulating you that you should only use thousand meter cube per well, per year and two farmers are there and they do not agree because they cannot grow, what they want, then there is disharmony, then the plan will flop.

But if a community comes together, for example, all the farmers in a particular village they come together and assess the situation, this is how much groundwater we have and all of us will collectively grow only mustard, this year, we will not go cotton or sugarcane, it will lead more groundwater and we will not grow for the benefit of the village.

So, all the villages will grow mustard, conserve their own water and use it for the next year provided benefits. So, this mechanism is kind of the community use of groundwater and when they use also they also do some aquifer management plans, wherein they construct buns and the other natural types to recharge the groundwater catch the surface water and then recharge it into the ground. So, you could see that India groundwater use scenario is changing at least in the management aspect, but much much more is needed, because the volume of that we extract is at a large face.

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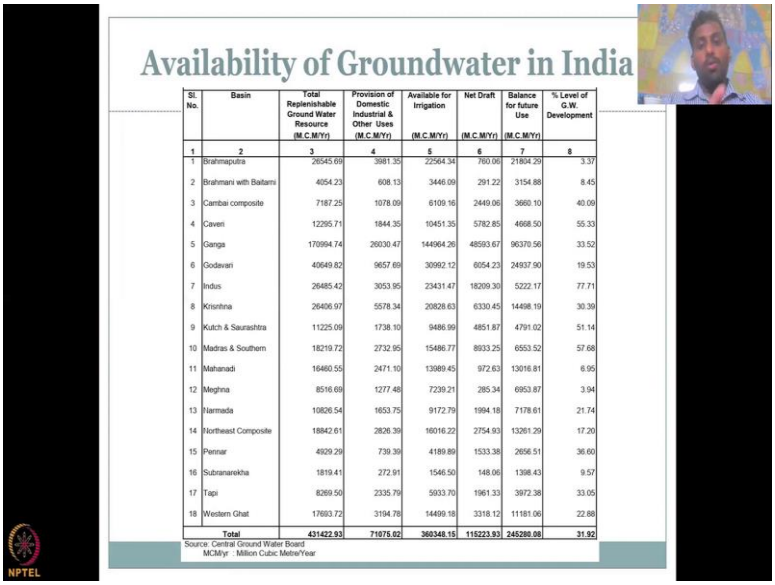

So, for this, it is very important to understand the groundwater availability in India. And for this, we are, I am going to discuss the central groundwater board data which is the predominant groundwater we see in India, and what you can see here is the different basins in India and the key basins are the Brahmaputra, Indus and Ganges basin.

And the first column talks about the basin names, whereas the next column looks at how much groundwater is actually being recharged. And then out of that, how much is being used for domestic, industrial uses, comparatively, and then if you abstract both after your domestic and industrial use, most of it is available for your irrigation, but only x amount for number 6 problem, only some amount of number 5 is used for irrigation, it could be because they do not need it or they do not have the resources to extract the groundwater. Moving on, then we looked at how much is remaining.

So, number 7 is how much is remaining for groundwater use and the level of development is the ratio of water available to the balanced water. So, what you see is the ratio here the last column represents the total the replenishable water and the how much water is actually being used, level of groundwater development. So only 3 percent which is used in the Brahmaputra basin. So, you have a lot of excess water remaining, which is also shown here as balance number 7 column.

So, let us see quickly how do you come to these numbers. So, 3 is your recharge which is estimated from the rainfall and geology. Number 4 is based on yours, your number of industries and population available for education is just a subtraction of 3 minus 4, which

gives you 5 and then the next draft is how much water is actually used as per the irrigation and agriculture departments. And if number 7 is just basically 5 minus 6, so the percentage of groundwater development or how much is extracted is the ratio of the total available for irrigation or for the total replenishable groundwater and how much draft, the total draft which has been used.

So, it is only 3 percent in the Brahmaputra basin, let us neglect the smaller basins in terms of percentage of development as we noticed anywhere from 20 to 50 is on the borderline of being concerned. So, if you look at that 20 to 50 combined composite, the Kaveri basin, the Ganges basin are all under the 30, 20 to 50 almost region, Saurashtra region, etcetera.

Concern is when you go above and beyond it. For example, the Indus basin as we clearly saw the both the Indus, on the Pakistan side and India side are tremendously exploited for groundwater. And as a result, in in the Indian side, we see 77 percent of the water is being used, and most of the water if you look at the numbers is being used for agriculture. So, out of the twenty-six thousand million cubic meter per year, you are using around eighty thousand million cubic meter, the year. That is around 77 percent of groundwater development.

Moving on you also see around 57 percent in the Madras and southern basin and also I can include here again the Kaveri basin which is at 55 percent. So, at a basin scale, these are the different numbers, but when you break it into blocks and districts and state, you will see a different different picture because every state will have their own their groundwater use preferences from and also the based on the population and agriculture, but not every use will be different.

So, this introduction to available the promoter India, I will move in the next lecture to discuss the groundwater per block how much it is and what are the issues and concerns right now, where we need to put in more effort for groundwater management.

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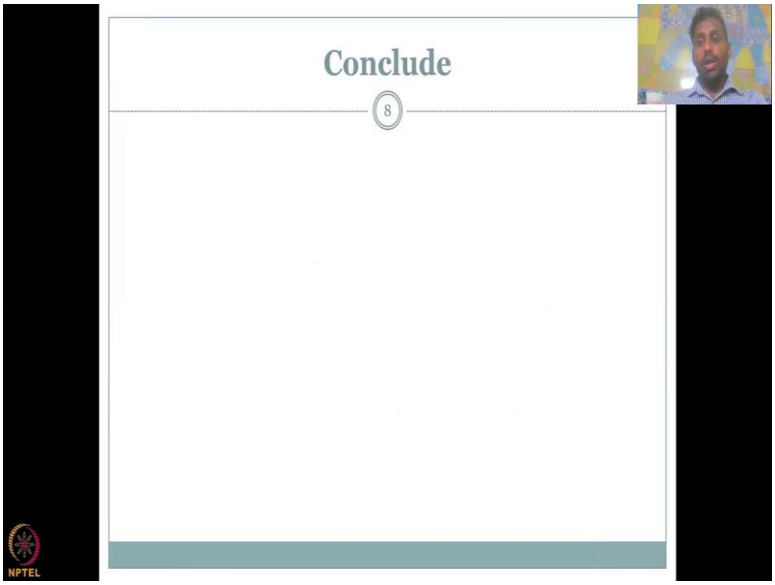

I will see you in the next class on the same lines to discuss issues on groundwater for India. So, the over the past couple of days, we are looking at mostly the importance of groundwater internationally. And then we slowly moved into the subcontinent and Asian regions and now we are moving into the Indian context of groundwater issues and things. I will see you in the next class. Thank you.