Groundwater Hydrology and Management
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Lecture 7
International importance of groundwater and focus groundwater use in India 2

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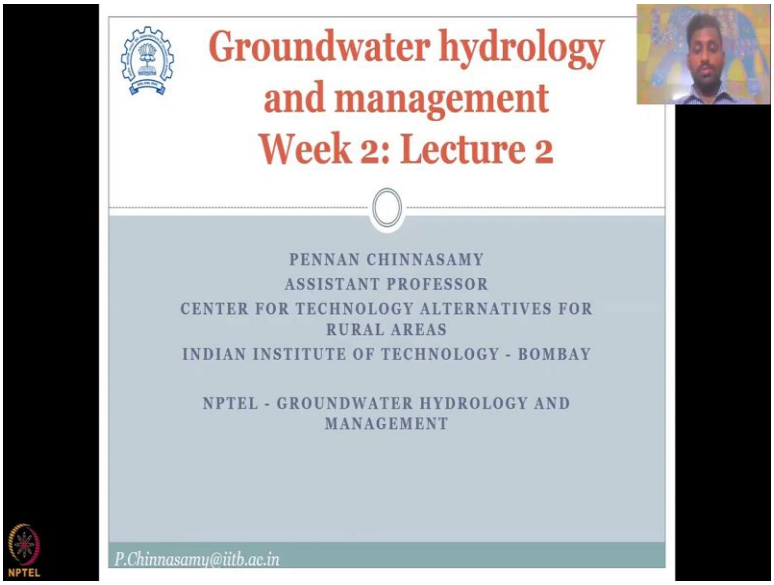

Welcome to Groundwater Hydrology and Management NPTEL course. This is week 2, lecture 2. In this week, we are looking at the importance of groundwater, both at the international stage and also at that national stage. In the last class we looked at the volumes of extraction per country. And also we looked at globally where the groundwater resources are maximum, we looked at the major aquifers or major hydrologic groundwater units, and also some complex units, where they are and what is the recharge rate.

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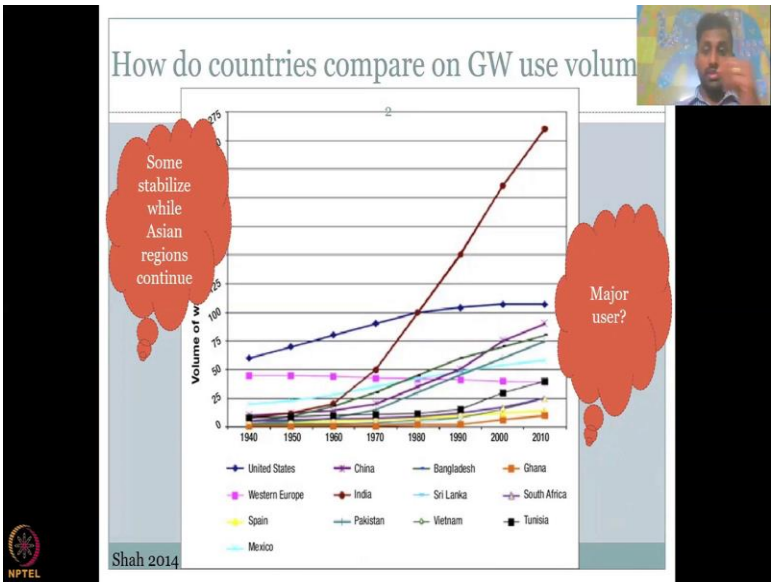

We will continue assessing why and how these groundwater volumes differ by country. This is very important to understand so, that we get a sense of what management activities are needed for groundwater management and conservation. So, as we saw in the last class, we pick up from the graph made by Professor Shah in 2014. Looking at the groundwater extraction rates decade, that is every 10 years. So, we did notice that India has the most extracted volume with around 260 Kilometer cube for a year and the second rank goes to us around 110.

And China comes third with around 95 Kilometer cube per year respectively. And we also saw a very important note that India extracts more if not less than the combination of the next two countries in line which is combined groundwater use of US and China. We also notice that these Asian countries ever increasing in groundwater use including China and all the major agricultural economies on groundwater use is keeping on increasing with the most deepest increase noted in India.

See this curve is exponential whereas others are almost any growing but every year it is increasing but whereas in the Western countries are more or less stabilizing US, Europe, etcetera. This clearly shows a shift from the groundwater use and or where they are using most of the water. It is very imperative to understand where the groundwater is mostly used. So now I have an idea which countries are using it and by a fair understanding of what the chief economy is driven by in each of these countries, which tells us where groundwater is being used.

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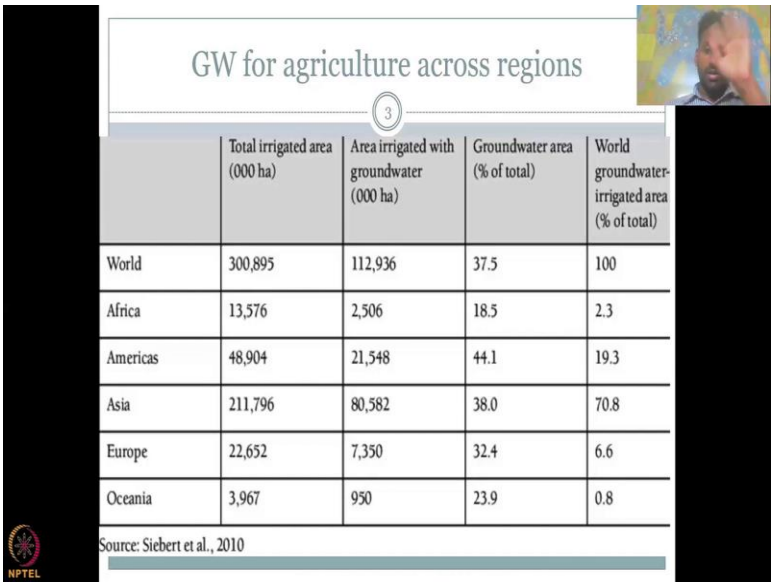

Let us have a deeper look at it. So, the major use as we saw is in the Asian countries and those Asian countries are also noted as they are Chief food exporters in the world. They do a lot of agriculture and they exported to these countries, especially where the groundwater use is almost stabilized in Europe and US for example, let us take some data.

So, of the world irrigated area, which is around 300,000, acres, so you can see the units here you do have almost the of the area irrigated with groundwater is around 37 to 40 percent. So of the total agriculturally irrigated land, it could be by surface irrigation, it could be by tubewell, buying water etcetera etcetera. Damn water almost 37.5 percent is from the groundwater itself, which is a big number.

So, moving on, let us see how the major continents are using water for irrigation. So Africa uses around 18.5 percent of groundwater total area, irrigating only 18.5 percent is under groundwater irrigation. And when you compare it to the world, it is very small 2.3 percent. So if you remember I did show you that big big aquifers with big recharge and good volume are available in Africa. However, it is economically very expensive to take the water out. Therefore, they do not use much of groundwater. They are limited with energy resources, pumping mechanical resources to actually access this water. So it is called economically stressed situation.

Let me go to the America's, which is north and South America, you would see above the world

average of 37.5 we have 44 percent of the total irrigated area under groundwater irrigation. This shows that most of these regions where irrigation is happening, they are almost 50 percent nearly 50 percent is tapped for groundwater. If you look at what they grow in these countries, it is mostly nuts horticulture, which is fruits, orchards, etcetera. And a lot of exports, a lot of water is also used for grass to feed the meat market, livestock and other things and then export the meat. So a lot of their water is used for that. When you compared to the world, it is almost 20 percent of the groundwater irrigated area.

Let us move on to Asia where as I said most of the agriculture is happening. So now we are going to understand that groundwater is a big user in the world, in Asian country. So that is why you see a lot of volume being extracted. So if you look at the area under irrigation, irrigation is application of water for crops. So it is not rain fed. It is the rabi season that we call it India. So it is the non-monsoon season or season where you apply water. And as I said, most of the waters apply by surface water, groundwater, or combination of both.

So in Asia, almost 38 to 40 percent, which is almost near the world average is taken from groundwater. So almost the average sinks in, where it is a bigger bigger chunk is when you look at the area. So of the total area irrigated in the world of groundwater 70 percent happens in Asia. And that is why you see India's groundwater extraction high. China, Bangladesh, Sri Lanka, all these Asian countries pumping a lot of groundwater. So even though your percentage of total area is small, because these are agrarian nations, which means a lot of agriculture's activities happening, and because of that most of the water is supplied by surface water structures, whereas the Rabi season and the non-monsoon season is supplied by groundwater.

So 38 percent of the total, however, of the groundwater use area in the world, 70 to 71 percent, is from Asia. So Asian regions are combinedly the most extracting regions for groundwater in the world. And when you go to Europe, the irrigation is very small, look at the area size, it is almost that of Africa, which means not much irrigation happens, very less agricultural productivity. And of that even lesser is for groundwater irrigation. So only 32.4 percent, much lower than the world average and of the world area only 6 to 7 percent is under groundwater irrigation in Europe.

So the pumps and all the technologies they use may not be applicable for Asian countries. Please understand this. Yes, there are a lot of technologies available in Europe and western countries.

But the system here is totally different. The volumes we extract are totally different, much much higher. So we need better engineering and natural solutions to manage groundwater.

When you come to Oceania where it is very, very negligible. So if you just look at the major continents, as I said, Asia has been the chief producer of agricultural products, and especially your more water intensive crops like sugarcane, rice, vegetables, fruits, etcetera. And they are exported. So you export these products out for a very low amount of money. So this data clearly shows where the food is mostly produced and how it is also shifted to these other countries for a very less price.

And so you are exporting your groundwater for a very, very less price. So most importantly, without the price concept, if you look at it, it is very important to understand that most of the groundwater irrigation happens in Asia. And also on top of that, so above and beyond that, around 62 percent of the irrigation is by surface water. So, please do not disconnect surface water and groundwater because surface water leads to groundwater so that we will discuss in the Physical hydrology section.

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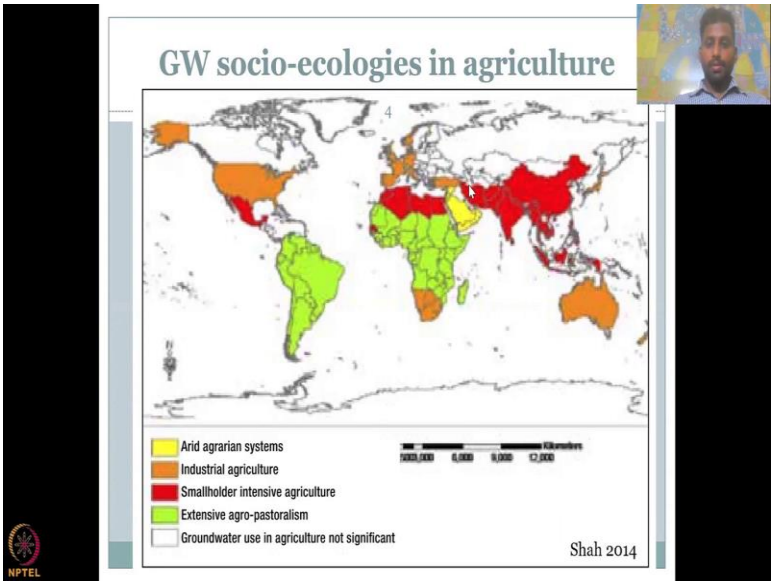

So, moving on we will take a look at the groundwater sociologies in agriculture, which means now we know that where the irrigation is happening, where how much groundwater resources are being used and let us see what they use it for. I was giving examples like price sugar cane,

based on my reading and experiences on these countries, but it is also important to see what data shows so the yellow region is the area agrarian system, which is very less water. And based on that there are some agrarian systems example some some vegetables, fruits, dates, palms, all those things so you see, Middle Eastern countries are occupying that.

Then the groundwater where it is used for industrial agriculture. So industrial agriculture includes mass farming, like acres and acres of land, managed by one well, or a big, massive well. And then also industrial agriculture includes livestock varying at an industrial scale, so there is a lot of these countries if you look at that, Europe, and your US and Australia, come under the industrial agriculture category. And they are mostly the well-developed countries. So they are very developed nations and they use the water very wisely, thereby conserving water and using it for more industrial and profit, so industrial activities and profits.

So, you can see South Africa comes under that and all these European nations and Australia, US come under that, then we go to this small landholder intensive agriculture. So this is where the chunk of Australia comes sorry Asia comes, if we look at most of Asian countries, are agrarian in nature, dependent on agriculture, and they are small landholding sites, China's data is not available to compare that very clearly. However, if you look at India, you have the average land holding size, approximately at 1 hectare. So these are very small land owning units and a lot of agriculture activity intensive agriculture. So here is where groundwater is being extracted at unsustainable rates across Asian countries.

So and also the northern part of Africa and Mexico. So these are the places where groundwater management is needed. And or there is no collection users, these is no options for collected use because they are isolated as small land holders and there are more and more management needed, then we get into the extensive agro-pastoralism. So, this is the face or this is the vertical where you see more agriculture is for varying livestock and those kind of activities, as I said, meat industry, and then poultry industry, chicken feed all those things. So there is agriculture happening. And there is groundwater use for that agriculture.

But the product is not mostly for human consumption, but for livestock, cattle other types of meat industries, like chicken and other things where it is converted to one form to the other. And that meat is being exported to countries as a product so you always see meat coming from Brazil

and other things. So here is where extensive agro-pastoralism happens and the groundwater use is there.

So, roughly you get an idea where most of the groundwater activities are which are the red zones and it is intensive agriculture for food, so rice, sugar cane crops etcetera. Whereas your agro-pastoralism is for grass for example, which may not consume as much as water as sugarcane and rice. So and then we get into the industrial phase.

So we do have now a good spread of countries and fortunately, unfortunately, if you draw a line between the red and the orange countries, you see that the red countries are mostly the underdeveloped, developing poor nations like Nepal, is there for lower economies, Pakistan, Afghanistan, Iran, all those countries are there and India is there as a developing nation, along with China as a developed nation. So all these nations are cornered in the small intensive agriculture for groundwater, whereas the developed nations, including Australia, US and European countries, use it for industrial agriculture. So there is a big difference in what we see.

Moving on, we can also see countries where groundwater use is not significant, including Russia, Canada, and all those cold countries Finland, etcetera. So here groundwater use is negligible for agriculture. And that is very clearly understood with what they do. So groundwater in Canada is just very less maybe for industrial it is not for industrial agriculture. So where does the food come for these countries, it comes from most of the Asian countries. So here is where most of the virtual water footprints, and also the water export happens.

So now we have a good idea of which other countries that are using more groundwater? And what are they using it for? They are using it for agriculture? And are they using it for high-cost agriculture or industrial, very smart agriculture? These things have been discussed in these chapters.

So the big question is, if we continue like this, then the developed nations will always be developed and rich, whereas the poor nations will be using more water for a very low profit. And they will, never make good profit and or become developed nations. In terms of agriculture, it is very difficult, because the groundwater resources coming down. So that is what the core of this course is, we are aiming to management water properly, so that it is more sustainably used in the

future.

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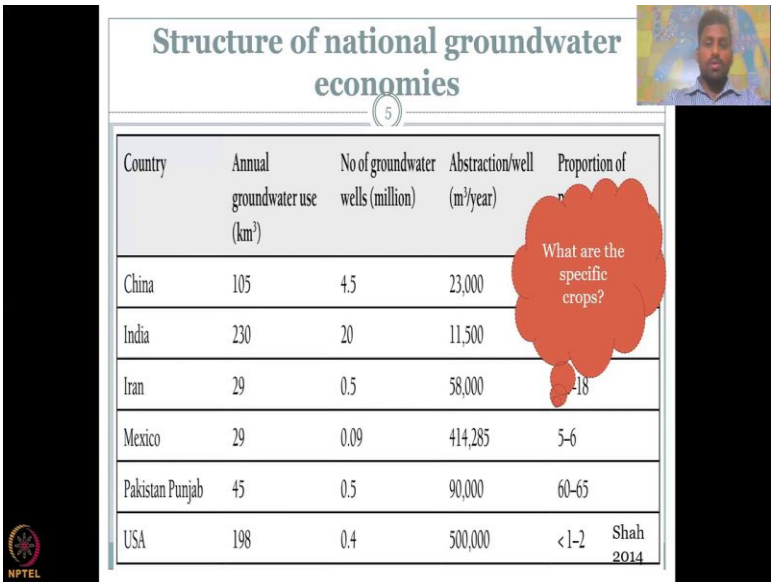

So given that groundwater has become a very, very important aspect of Asian countries, it is important to see the structure of groundwater economies. And so here is where you see the annual groundwater use by different data data from different resources, you see China using 105 Kilometer cube per year, annual groundwater extraction or use. The good part of this table is it shows you how many wells are they using for extracting that much of volume of water, And abstraction per well.

So if you have one, well, how much water on average do they extract? And what is the proportion of population use the groundwater? So if you look at China, 4.5 million wells are there, will be more now and the obstructions 23,000 cubic meters per year per well. So what does this tell you is the number of wells spread across the country?

And also what are the techniques, technologies that they used and the size of the land that they irrigate from one well, so look at 23,000 cubic meters per year, that is a good fair amount of land that can be irrigated, we jump down to India, where India is a major user of groundwater 230 Kilometer cubed per year, these numbers would differ, varying on the reports that you see or the studies you see.

So for the actual values, I recommend you to look at the central ground board report data, where

it parks down 265 260 Kilometer cubed per year. So here in India, the second row you see 20 million wells, more than 5 times a wells in China, look at the size of China Look at the size of India and 11,500 cubic meter per year per well. So, that also gives you an idea of what is that land size that is used for one well.

So is it economical? Look at the energy that they put in a well how much extraction goes how much wastage goes all these things. So it is clear that most of the population is consuming groundwater look at 55 to 60 percent. And most importantly, they individually use it. It is not a collective use 20 million wells compared to 4.5 million wells in China. And the amount of water that is extracted per well clearly shows that it is more localized use of groundwater rather than sharing, or mass farming, mass use of groundwater.

So, this causes multiple multiple wells to be installed. Just think about it, you have a land and your neighbour has a land, instead of having one well for both the land just adjacent to each other two lands together, instead of having one well in between for both, you will have one farmer having one well the other farmer having another well. So this is how wells multiply in India. And the cost is expensive because driller well, one well is almost the same, depending on the location, so instead of drilling one, well, with a particular depth now you are drilling two wells, and that is expensive.

The water is also being used very inefficiently, energies loss in pumping those kind of things. As compared to other lower user countries like Iran, Mexico and Pakistan, you have almost 0.5 million wells and .09 million wells in Mexico. And if you look at Mexico's groundwater extraction per Well, it is humongous 414,000 meter cube per year, which means they have bigger wells and bigger extraction wells and that is used for industrial scale, because you take it and or give it to consumption units like cities, domestic use units.

So, it is good to understand from this table that countries use groundwater, but most importantly, are, they isolating it by different partners and added too many wells those kinds of things energy loss, what is the population using it. Come to Pakistan's part of Punjab and you could see 45 cubic meters per kilogram kilometer cube of water is used with 0.5 million Wells 90,000 meter cube per year, which is much much higher than India in terms of per well abstraction and 60 to 65 so more percentage of people are dependent on this water.

So, a lot of what water is being extracted by very, very less amount of wells. So, this also looks at maybe sharing of groundwater or central agency, which is pumping the water and distributing to other regions, come down to US, which is 198-kilometer cube per year according to this report. But the number of wells they have is very, very small. If you know, most of the groundwater wells in US have to be permitted by the government, you have to declare, and they monitor it, every well is almost monitored.

So you do have good data. And those are massive, massive wells, look at the pumps, those are industrial pumps, which pump a lot of volume of water and cater to large pieces of land, not one hectare. So it is big, big lands and mass farming happens. So, you do not need that many wells. And you have an industrial agriculture system as we saw in this image. So mostly it is used for industrial agriculture and the population which is dependent for using it is only less than 2 percent.

So, this gives a clear idea, this image gives a clear idea of how the water is used, where the water is used and the number of wells spread across the countries and a well abstraction, it gives you a very short experience on the well is shared or used individually and other countries how they use it compared to India.

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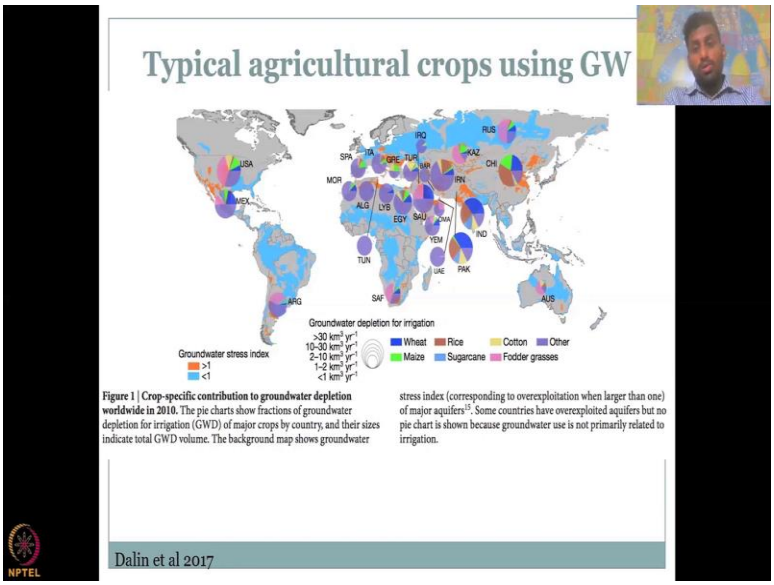

So now the specific crops. It is a very, very important slide which is done by a by Dalin et al

2017 mapping the major groundwater uses in the world. So all these countries that you see up here groundwater countries not all the countries but some countries are in the size of your pie chart gives you the size of the in order extracter.

So if it is circulators of 30 Kilometer cube, you know that India, Pakistan, US are all above 30 Kilometer cube so they have a bigger circle. And also they map the key crops that they grow.So I have been telling you where the water is used, how many wells they use, and how many wells z per million are used in the country and per well, extraction rate.

Now let us see what crops they grow most of the crops using ground water. So, you see that the chief or the key highly ranked India in terms of the use, you see more wheat and rice being used by groundwater irrigation. So, wheat and rice are used now, followed by sugarcane, all these are highly water intensive crops.

And then you have cotton, another good water intensive crop followed by other which is very diverse. It depends on where you are in India, it could be millets, it could be turmeric, chilies, horticulture, anything you could name it was very diverse. So you have a lot of other agencies here.

But when you go to your china, you see that more of the groundwater is used for rice. And because there are rice eating nation when compared to wheat, India has almost half and half rice and half wheat. So China has a lot of rice plus maize. So maize is used a lot and groundwater is being shared for all these, cotton very less come to comparatively less, if you come to US which is the next ranked groundwater extractor, you could see a total change now more pink colour is there for fodder. Further is the grass that the cows and livestock eat. As I said they are industrial groundwater uses. They use it for meat industry, rather than crops and then rice and those kind f things.

So rice is very less. So after fodder, it goes to other which is including horticulture nuts like almonds and stuff that you get from US, even in Indian market. And then you have maize, So maize, a corn, they use a lot for sugar and also Ethanol. And then you have Australia's very less compared to other parts of the world. Mexico has a lot of other crops. So it gives you a very clear understanding of where the groundwater is used.

What are the key crops that they grew to, to sustain this groundwater use and activity? And are they diversifying their crops? So for the belt China and India, there is not much diversification for rice, means more groundwater use, same as wheat. So wheat and rice also having equal proportions in India, when it comes to consumption. So North India has a lot of wheat, whereas South, they have a lot of rice.

So these are typical crops that are grown using groundwater. Now we have an idea of, can you do something? Can you do something for changing this behavior? To take a step back and answer this question? Is it that easy to change a dietary preference by these nations? let us take China, can you change their rice eating habits, it is really going to be very difficult same as India. So if you go to India south, he cannot quickly change them to another diet.

And or the North from wheat to something else, a less water intensive crops, for example, maize, or millets. So this is where the groundwater demand and supply scenarios have to be discussed. And the study clearly shows you where these major economies are in using groundwater, and how much do they use in terms of groundwater volume is a by a range above 30 kilometer cube to less than one kilometer cube. And what are the key specific crops that they grow? And the other question to answer in these key countries in extracting groundwater is, they need that much. Do they need that much productivity because at the most of time you start exporting.

But is the export water also added into it? So you are exporting rice from India to the western countries or from China to Western countries? How much are you calculating the groundwater is the question, because it is an unseeable quantity, that you cannot put a value for groundwater. And that is a problem for groundwater management.

But as the other countries, the Western and Europe countries, they have clearly understood the value of groundwater and using it for a high profit. So one kilogram of meat is much more expensive than one kilogram of rice. If you look at the comparisons, the same goes to maize and other things that they grow.

So it has to be used to communicate some important decisions to the policymakers and farmers in India. How do you conserve groundwater? And what can be done to change the attitude of groundwater use in India? we will see more of this in the next lecture because such use of

groundwater is very unsustainable. I have been using this for a long time, but what water are you using as a question? Are you using the animal rechargeable water? Not exactly. Are you using water from 10 years to 30 years ago? Yes. That is what we will discuss in the principles of Groundwater and occurrences of groundwater etcetera.

So if this habit goes on where you use groundwater for mostly highly water intensive crops it is very unsustainable and more likely the groundwater system is going to be under tremendous stress and the agricultural system may collapse. So it is very important to understand groundwater use in these countries.

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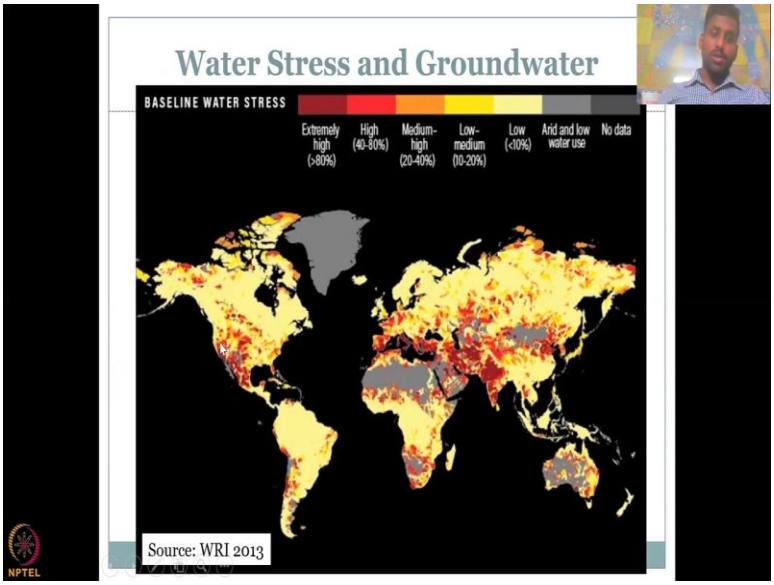

With this I just will introduce the water stress and groundwater map, which we will be discussing more in detail in the next class but just if you look at the previous image and where the major groundwater used and what are they do and the study by WRI on the water stress indicators and countries where water stress and groundwater are going to be it almost matches.

For example India the highest groundwater extractor is also showing a high water stress index compared to China and other countries. Similarly, wherever the groundwater is extracted you are going to see a lot of water stress, even in US in some regions where groundwater is highly extracted is going to be under tremendous stress. So we will discuss this in detail in the next class.