Groundwater Hydrology and Management
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Lecture 10
International Importance of Groundwater and Focus Groundwater Use in India 5

Hello everyone, welcome to Groundwater Hydrology and Management, NPTEL course week-2, lecture-5. In this week's lectures, we have been looking at understanding the importance of groundwater, both at international scale and at local scale. We also looked at different aspects and drivers of this groundwater extraction, basically crops, industries et-cetera. We also identify a lot of basins that are more important globally for groundwater management. The last lecture we look at groundwater importance for India, and will continue that with some discussions on the South Asia region.

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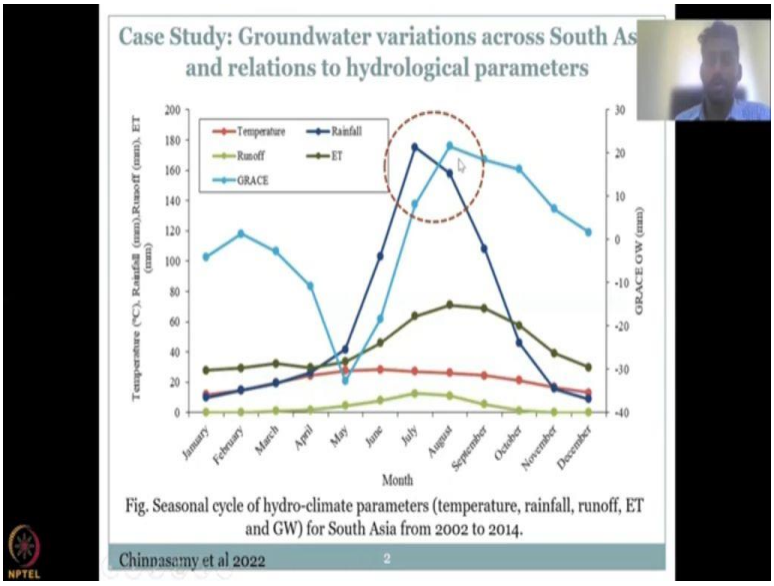

Let us take a case study. In this case study by Chinnasamy et al 2022, groundwater variations across South Asian regions were analyzed. As we discussed in the previous lectures, the Asian countries have been known for exporting agricultural products; and they are considered to be the food bowl for the other regions also; basically, extracting a lot of groundwater, conducting a lot of agricultural activities and then exporting the product. On this note, eventually the groundwater would be extracted a lot in these regions. So, this study looked at a long term groundwater

change from 2002 to 2014; and took into account the major factors that drive this groundwater use.

Basically, your agriculture which is represented by the ET; also, temperature and runoff were also looked at, to see what are the correlations between that and the groundwater. So, this is a average monthly change in the different parameters and you could see that for the South Asian region, the temperature was not changing much runoff; maybe increased slightly during the monsoon period. So, the rainfall is on average from May to October and November. So, the peak monsoon was between June and July on average; and also the grace which is your groundwater was analyzed.

So, the take-home from this slide is that the rainfall can happen and it can peak in suppose July. But, the groundwater peak a month later, which means there is a lag between the time; the rainfall occurs and when the groundwater raises up. So, it is not like today I am getting rainfall and tomorrow my wells will be full, it takes time. The same cannot be applied for surface water. Today, today it rains within a day or two, you will see water in the dams; the dams start to increase eventually.

And then within a day or two, and dam sometimes do like urban dams; they fill up as and when the rainfall occurs; but that cannot be said for groundwater. So, this is a very important note; in some regions, it takes years for the groundwater signal to show up. So, in the South Asia region, on average the groundwater peaks a month later than the rainfall; and stays longer than the rainfall peak. So, it does not dry down fast, slowly dries down. And you can see that the ET which is your agricultural component, the green line, peaks right in between your two peak month of rainfall and peak month of groundwater. So, when the rainfall comes down still the crop is supported by groundwater.

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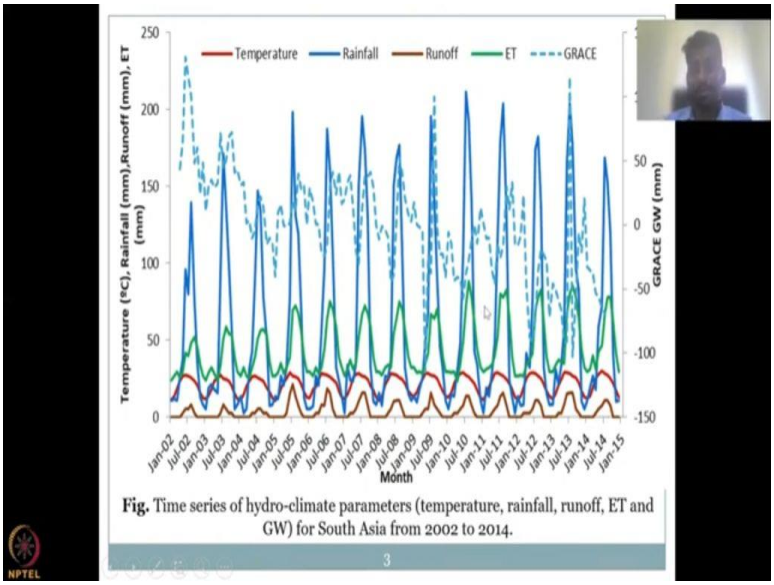

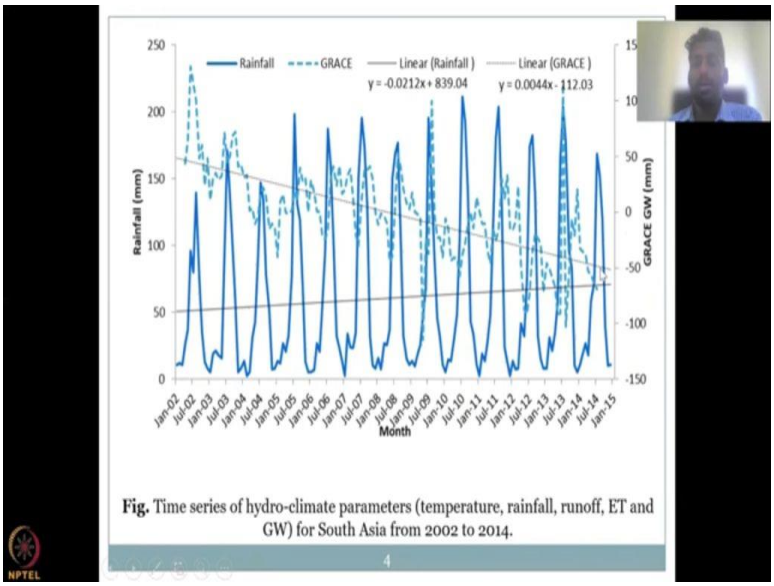

Let us look at the driving factors. So, you have all the parameters fit in this graph, your temperature, your rainfall, runoff, ET on your left axis. Your right axis, showing the groundwater, all in similar units to be compared millimeters for water, and temperature in degrees centigrade. So, you do see that the dashed lines which is groundwater has been coming down from Jan02 to Jan 15; so Jan 02 to Jan 15, you will see that the groundwater has been decreasing on average.

However, your rainfall does not show that trend, which means rainfall is not decreasing. The temperature and runoff are almost the same; it is cyclic and it is almost the same. However, you

ET has been increasing. This can be shown by different correlations between the two identities by removing all the other variables just keeping two variables. So, we have rainfall and groundwater, and you can see groundwater is declining. Rainfall is increasing slightly. So, there is no direct impact of rainfall reducing and that is why groundwater is reducing. So, some other factor is there; that is pulling out your groundwater.

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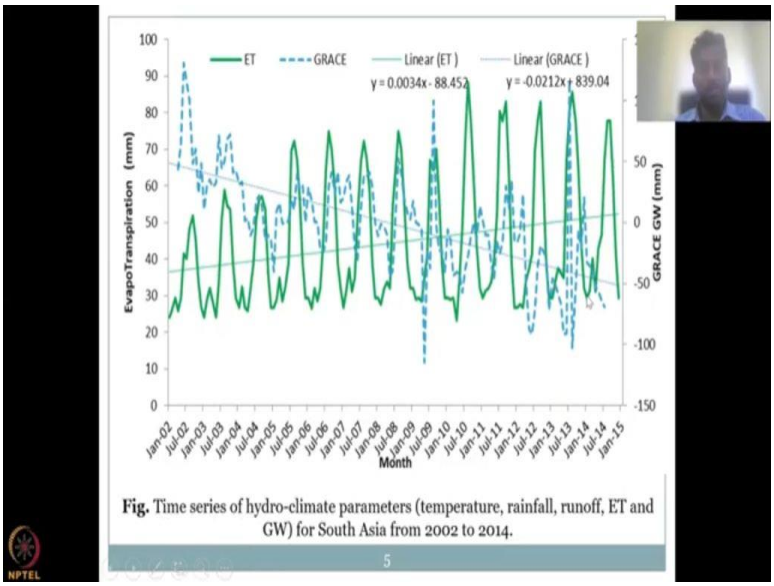

Let us look at now superimposing only the ET, which is your evapotranspiration. You could see that ET is increasing and your groundwater is decreasing, which means ET is a factor of plant growth. It is a function of plant and agricultural activity. So, what this graph clearly shows is that your agricultural activity has increased, forest agriculture and all those that evaporates and transpires has increased; whereas, that affects your groundwater.

So, with the same rainfall or almost slightly higher rainfall, you are showing that you are getting more product out. And that is only possible if you use another resource, which is groundwater. So, across South Asia, all the countries including the map that we showed earlier, Afghanistan, Iran, Pakistan, India, Sri Lanka, Bhutan, Bangladesh, all these countries put together, on average the groundwater is declining. And on average, the agricultural productivity is going up. There could be a reason where at one point it is almost balancing each other.

Your ET was balancing the groundwater use; however, after that, it becomes unsustainable, if you keep on extracting groundwater. If this curve goes on declining, then eventually you will run out of groundwater. So, this is a warning to the system that the rainfall has not changed.

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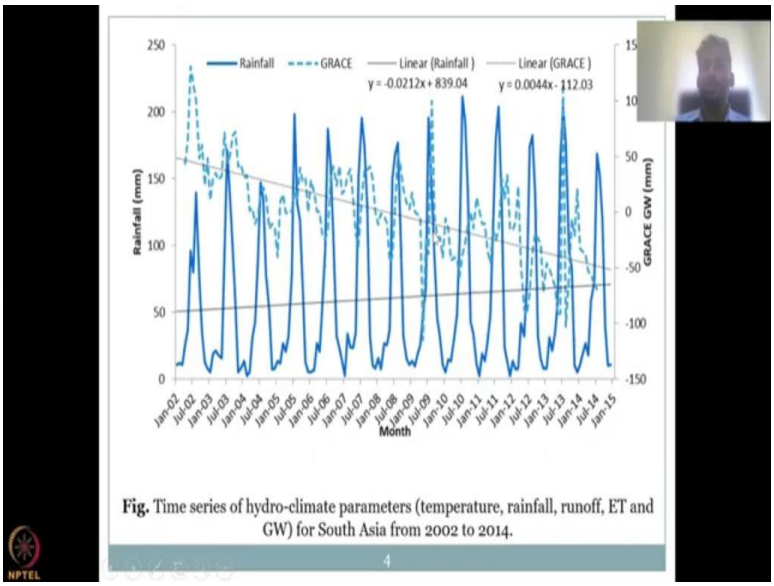

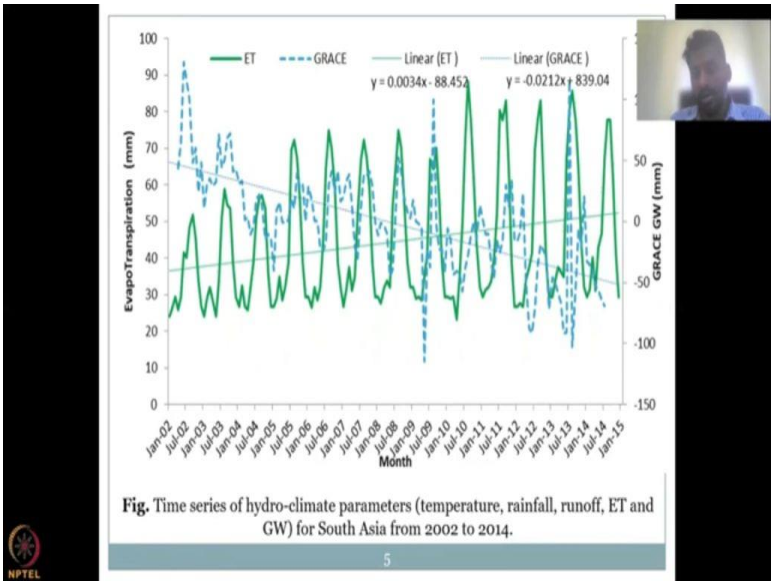

If you look at the rainfall, it does not change much; peaks are around 200. And the thickness or the length of the monsoon has not totally diminished or changed much. However, even though you have good rainfall, to be honest, it has been increasing. You could see that it has been an increasing trend; however, the groundwater is declining. The slope of the groundwater is around minus 0.0212. So, this is a very important find according to the study that even though your

rainfall is increasing, which is a source of your groundwater recharge; your groundwater is still going down.

And that can be explained only by the fact that the agricultural use of water has been increasing; because your agricultural ET has increased. So, moving on, this these are the studies that we discuss about groundwater issues and concerns in Asia. And we also looked at countries, such as India, which export a lot of this groundwater virtually; and also they grow a lot of crops. And because of that groundwater quantity in India is the highest that has been extracted in the world, followed by US and China.

And that is one of the reasons I brought into this picture, the most predominant South Asian countries. And if we understand this, most of the other regions could be understood that if you target groundwater, rejuvenation or management, you need to target the key variables that are causing the groundwater to decline. And in this case, it is the agricultural activities. So, how do you reduce it is the question of how do you change it; and which would be will be looking at in detail in some other lectures.

Moving on, we also saw that we have other issues in understanding other issues of groundwater; which means not only quantity, but groundwater quality is also concerned. And let us take a quick look at what are the key issues in groundwater quality in India. So, I am not going to discuss a lot; I will tell you why because that is beyond the scope of this course.

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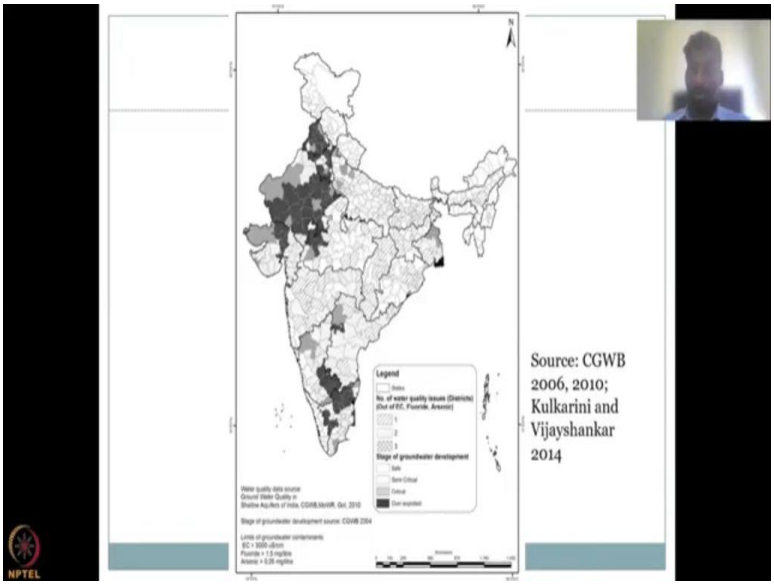

Let us take for example. Groundwater quality has been mapped by Kulkarni and Vijayshankar 2014, using the CGWB data from 2006 and 2010. What we find is the number of water quality issues district wise in this map; and what are the difference, what are the difference in between the districts?

Are they having multiple issues or one two issue? So, if you could see the coloring, one is represented by dashed lines, and two dotted lines, and three in boxed lines. You can see that most of the regions have in this side have dotted lines, indicating that they have two issues, two groundwater quality issues.

And they map that along with stage of groundwater development; and show that the groundwater has been declining in the regions where groundwater quality is bad. We look at these regions, already it has two issues. It could be EC, fluoride or arsenic any combination, and also the groundwater level is decline over exploited. So, as and when you decline the groundwater level or you take more and more groundwater without recharging it, your water quality is going to get bad; and these are the natural contaminants. It is not a pollutant which is introduced by industry; it is a natural contaminant.

In other words, these occur naturally and it is very hard to control this. The only way is to not use such high groundwater volumes in these areas. So, this study tries to indicate that the box lines where all the three issues have an EC, fluoride and arsenic are very less. But, mostly it is one issue or two issues and these two issues are also coinciding with over exploited regions. So, the study also says that the limits have been reached in most of these regions. So, if you drink this water with EC, fluoride and arsenic, you are actually spoiling your health. So, there is a lot of health implications in drinking these polluted water called natural contaminants.

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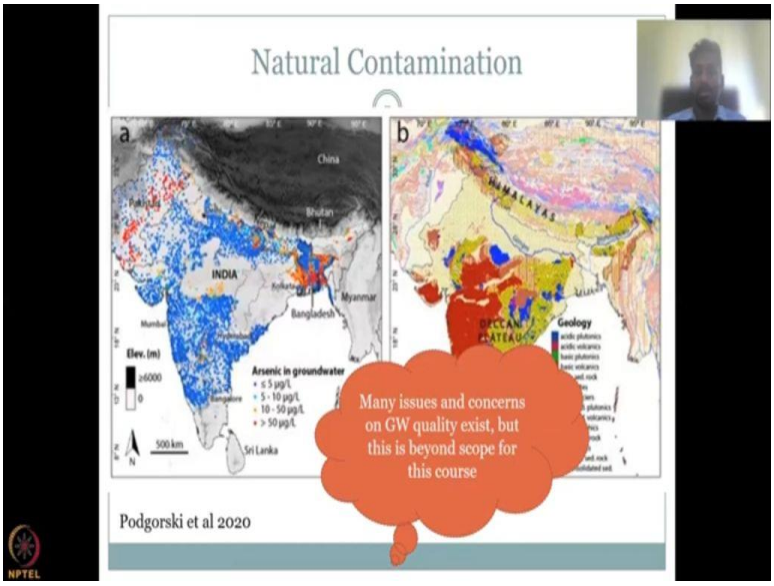

Moving on, another study by Podgorski et al in 2020 has mapped the groundwater quality concerns and also natural factors; for example, the geologic content across India. So, what they find is the greater the arsenic in groundwater are found in regions where we have unconsolidated sediments along with some basic volcanic materials. So, here we have some arsenic, but it is it is very less; the blue color is very less. However, if you look at the Ganges basin along the sediment area and the young Himalayan mountain range area, you do find a lot of arsenic contamination.

The arsenic contamination could be transported also; but, mostly these are groundwater well data. So, when they take well data and look at it; it is among the Ganges which is an Indus Basin, which is really really concerning. So, I would like to take a pause here, because as we have seen, if we start to discuss the groundwater issues in terms of quality, that will take a long time; and that focus is not part of this course. This is a groundwater management course. Yes. It is my duty to ensure that everyone knows that there is a groundwater quantity issue and a quality issue.

So here, if you go to the Ganges, there is a lot of groundwater. Groundwater is abundant, but is the water quality good; so, it is same as saying no groundwater. So, if I am going to make a map, and I have groundwater map for a particular village for domestic and agricultural use; I have to disclose that the water is available or not, and is the quality good for consumption or not.

Otherwise, I should plainly write the water is not available; because there is no point in having bad groundwater and claiming that groundwater is there. It is kind of misleading.

So for the use, which is predominantly domestic and agricultural use; the quality is a very very important factor. If you go to the Gujarat regions, some of the water has saline properties; a lot of salt content due to ingression and also infiltration along the sea. So, is that water useful for growing crops? It is not.

So, we cannot promote agriculture there, claiming that the groundwater is available; because the groundwater quality is not correct, or not up to standards. So, it is very important to have both groundwater quantity and quality to sustain good groundwater use, including your recharge networks have to be in line for domestic and agricultural use.

Industry is a different factor; they might use it very very differently. For example, a thermal power plant might use groundwater for cooling; they will not care more about the quality of the water. And if I industry use it for washing, maybe they do not care much about the quality. However, for agriculture and for domestic use, it is very important to have groundwater quantity and quality addressed.

So, make sure this is very clear in terms of understanding groundwater quantity and quality is important. However, for this course, for this particular course, many issues and concerns on groundwater quality exists including industrial pollution, anthropogenic pollution, when when humans waste just mixed in groundwater. All these issues are there, but that will be of course by itself; so that could be a groundwater quality of course, not a quantity course.

In this course, we will only focus on groundwater quantity. The methods will only focus on groundwater quantity, and maybe in the future there will be a groundwater quality course. So, it is beyond this course. So kindly excuse that part; there is a lot of materials available for self learning on groundwater qualities. Some chemistry background would be beneficial, but not necessary to understand everything on groundwater quality.

So, from now on, we would only focus on the ground water quantity issues volume; how much is there? Why is it there and how can we improve it? If you see the case studies also; I was careful to pick case studies only on groundwater quantity, both internationally and nationally. But

nationally, I also had to showcase this in this lecture; so that you understand it is not only quantity, but quality also.

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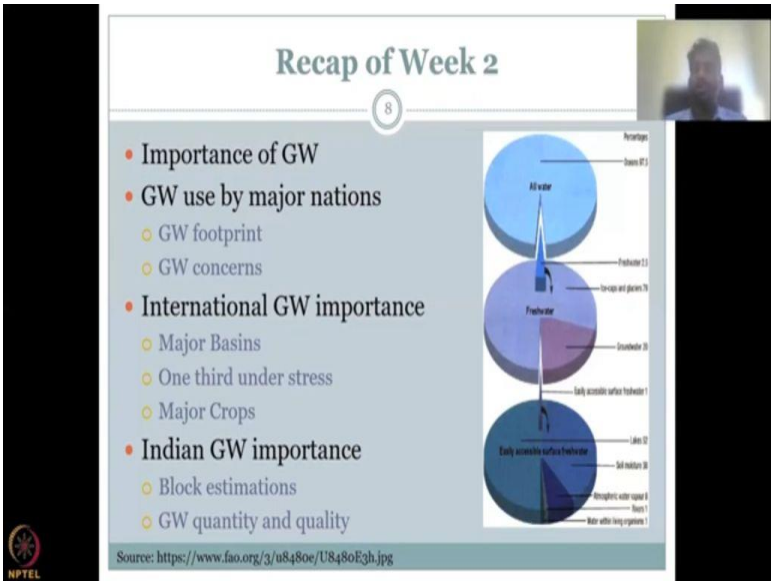

So, moving on, let us do a recap of a week-2. What we started with is by quantifying the different water sources in the world. So, of the 100 percent water, 97.5 percent as per fao is locked in your oceans, seas and saline water bodies. Only 2.5 percent of that is freshwater; and of the freshwater 80 percent is logged in the icecaps and glaciers. We discuss that in mountain regions; it is very hard to take mountain water. And then say I am going to have freshwater; because the distance and transportation is not going to work. So, of the freshwater the easily and locally available is your groundwater, which is around 20 percent. And all of that other 1 percent of freshwater is in lakes, soil moisture, rivers, streams, et-cetera et-cetera.

So, even though you visualize lakes and rivers are being big water bodies, it is not as big as the groundwater. So, the readily available and easily available resource is groundwater for freshwater. And because of that it has been widely used across nations. This widely used attitude for groundwater has caused its decline; a lot of groundwater issues have happened. So, in this week, what did we do? We look at the importance of groundwater by establishing these water budgets; how much water is available? How much of that is aligned and locked in icecaps? And how much of that is groundwater?

More importantly, when you talk about lakes and rivers and streams, someone have to be very close to these water bodies to access the water. However, groundwater is more or less distributed. So, if you take a village and river flowing, only those who are near the river can

access the surface water, which is the river water for agriculture. But, everyone can do a pump and extract the groundwater, which could be charged by your surface water, which is your rivers and streams.

And rainfall also occurs, so, locally also you can recharge. So, groundwater is a very very important tool for equitable share of water; and it promotes a lot of farming in small scale farm. Because, a small scale farmer may not have the connection to surface water body or a dam. But still, they can take a groundwater well or share wells between two three farmers and then use it for agriculture. We also look at groundwater use by major nations. We looked at even developed countries such as Australia, India and China suffering from major groundwater abstraction.

We looked at groundwater footprints and understood that of the major basins, almost three to four times area is needed to sustain the groundwater use, the current groundwater use; it is not sustainable. So, it is very important to make sure that the groundwater extraction is sustainable; otherwise, all the users that are currently going on will have to stop. So, we looked at footprint, the area required to sustain these activities. And that gave way to a lot of groundwater concerns where water can be recharged, how much water is extracted, is it above or beyond the annual recharge et-cetera.

So, we visualized bank unit and your salary is the water that is coming in. If you keep on taking water more than your incoming, then you will have been eating on your savings. You will be taking water from the past and so it is not sustainable. So, because your future needs water, so you need to leave water behind; and those groundwater concerns we looked at. Once these general groundwater concerns we looked at and footprints, we looked at the International groundwater basins. Very importantly, we looked at the major basins in India, China and Middle East countries, Australia et-cetera.

We found that one-third are under stress; so good percentage 30 percent of them and above have groundwater issues. And it does not stop in only Asia, but also in developed nations such as US and China, Australia. We also identified through study that major crops which are grown in these groundwater, extensive used basins. And we found that rice, wheat, sugarcane are the key crops that continuously extract a lot of water, which is unsustainable. So, these major crops have had an impact on the groundwater use.

And most of the time it is not a very wise use of groundwater; because most of the crops are exported for a very low price. And the groundwater is also exported along with the product. So, there is a big necessary point to change the attitude of groundwater use to change the crops that are irrigated by groundwater, so as to sustain groundwater for longer term. Then, we focused on the Indian groundwater importance, while India is because yes, this course is conducted in India; but more importantly, India is the groundwater extractor at around 260 to 265 kilometer cube per year.

And this is much bigger than the second ranked nation which is US and China even put together. So, we have to start the assessing the importance of groundwater in India, and also understand the physical processes that drive groundwater recharge, so that we can manage it properly. We also looked at blocked estimations. So, how the Central Groundwater Board divides Indian states into blocks and districts. And each block and district they take groundwater values for once in four months. And then they establish these indexes, basically to say if the groundwater level is okay, critical or semi critical.

And if it is safe, then it means that the groundwater can be further used; but, if it is critical and semi critical, then we need to have concerns. We need to properly manage groundwater, if it is over exploited; which means groundwater use is about the groundwater recharge. So, if I am putting 100 rupees, if I take 110 out, one hundred 10 rupees out; that means it is over exploitation. So, if that happens, then the idea is that we are using groundwater from the past. And that we looked at some images to show that it happens a lot in Northern India and Central India including Karnataka, Andhra, Tamil Nadu, and along the north-west.

We had Rajasthan, Haryana, Punjab, all exploiting groundwater more than the annual recharge. In this today's lecture, we also looked at the groundwater quantity versus quality. We made sure that it is important to study both the quantity and quality for groundwater management. Especially, we looked at some natural contaminants which included EC, arsenic and fluoride. These contaminants are present or driven by the geologic setting. So, we looked at a study which showed these different groundwater quality concerns across India; and how the groundwater level coordinates with this groundwater quality.

It was found that it is very important to understand both these important factors for groundwater, groundwater quantity and quality. However, just for the course structure and the course progress,

we will only focus on groundwater quantity, issues, methods, and what are the forward steps for groundwater quantity conservation. The quality will follow as a separate course. With this, I think we have covered the major importance part of the lectures; and from week-3 onwards we will look at the physical hydrology, the different components that explain the groundwater pattern.

And then, we will follow into some research and teaching on case studies in India and also groundwater monitoring, monitoring by different agencies. Then, we will also look into models which actually collect all this data; and create databases or results to better manage groundwater situation. With this, I would like to stop for today; and I will see you in week-3 courses of NPTEL groundwater resource management. Thank you.