Groundwater Hydrology and Management
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Lecture 6
International importance of groundwater and focus groundwater use in India 1

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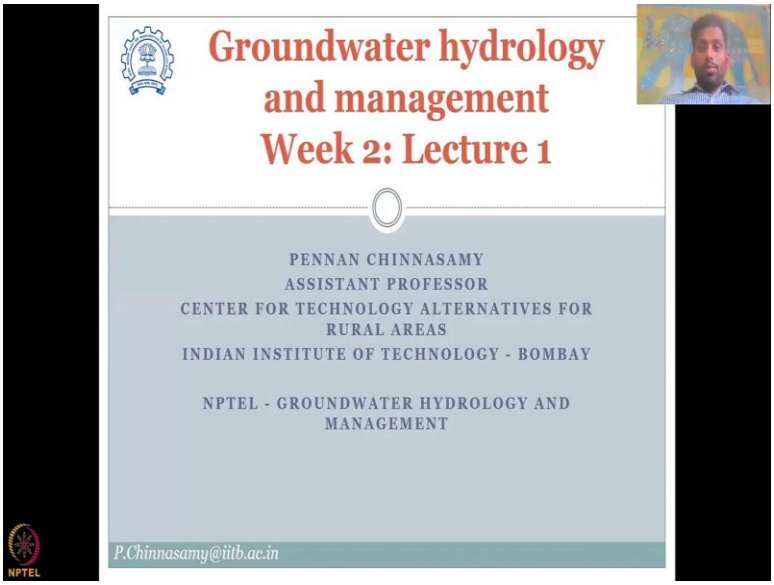

Hello, everyone. Welcome to the Groundwater Hydrology and Management course on NPTEL. This is week 2 lecture 1. In the first week of groundwater hydrology and management course, we looked at the course content, the weekly break up of the classes, and also a small introduction to groundwater.

In today's lecture, or throughout this week, we will look at the importance of groundwater. So, someone might ask us, why are you looking at groundwater, why do you want to study groundwater. So, for that aspect, it is important to understand the relevance of groundwater in hydrology both internationally and globally, also with the Indian market.

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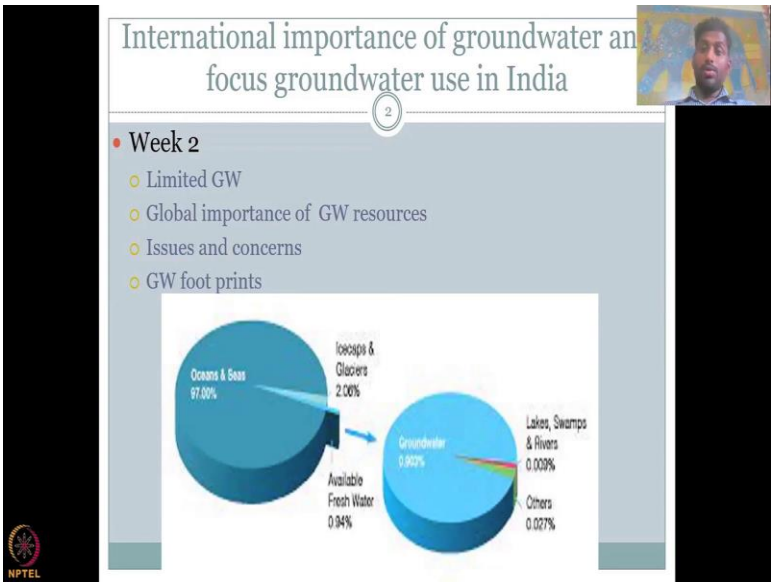

Why? Because, as I mentioned in my earlier slides, India is the maximum or most extractor of groundwater in fact, ranked number one, followed by US and China. Most reports it is mentioned that India consumes more groundwater than, US and China put together. So, before we get into the statistics of that, let us understand the water balance. Mostly water which is available 100 percent of the water, 97 percent is locked in oceans and seas.

So, you see vast amount of water which is locked in oceans and seas, and you all know that it is not readily used for human consumption, domestic use, industrial use and agricultural use. Domestic, when I mean domestic it is for drinking and also washing, cleaning, bathing, etcetera. So, the available water is very less, approximately 3 percent. And of the 3 percent, the freshly available water, only 2 percent is locked in ice caps and glaciers. So most of the fresh water available, which is 3 percent of the entire water balance, is already locked in your glaciers and ice caps.

It is not readily usable or readily available. What do I mean when I say readily usable, It is in a ice format. So you cannot bring ice to your table and then melted and use it for drinking. Some countries where they have the nearby they may use it. But think about using Himalaya ice water for somewhere in the north or northeast, it is not possible. So, what is the next part of the freshwater only 1 percent of the total available. So, of this 1 percent, most of the water is groundwater, which is 0.9 percent.

Whereas the remaining are in lakes, swamps and rivers, and other resources. The Other resources include biological water stored. Water storing in crops, plants, fruits, etcetera. So, all the big big lakes and rivers that you see in the world can only hold a very, very small percent of freshwater which is 0.009 percent approximately. Whereas your groundwater can hold most of it. So that is where when you talk about freshwater. Groundwater plays very very key ranking or key importance, both internationally and in India. Because this is a water that can be tapped for domestic use, agricultural use, and industrial use.

So, in this week, what we are going to look at is, why and how limited groundwater resources are the reality of groundwater resources globally. It is not an endless supply of water. It is not as big as the oceans and seas which is 97 percent, it is very very small when you compare to the net available water on the planet. However, when you talk about freshwater, it is the biggest component. So, it is very important to understand the global importance of groundwater resources which we will be looking at in this week's lecture.

Also I encourage students to look in the news articles and also update yourself regularly on the ground water importance. Issues and concerns will also be discussed in this week on groundwater resources, where it is highly used, why is highly used? Those kind of issues and concerns because of unsustainable groundwater use. What are the concerns? How much water do we have for the future generation, and children. So all these issues and concerns will be discussed in this week. And we will also look into groundwater footprints.

So similar to carbon footprints, similar to water footprints or virtual water, we also have groundwater footprint to understand where or how the water that is taken from one location travels across for as a product, or as an economic viability or drinking water, or any other use. So basically, how do you take one water and then export it to another region and also understand how much area contributes groundwater.

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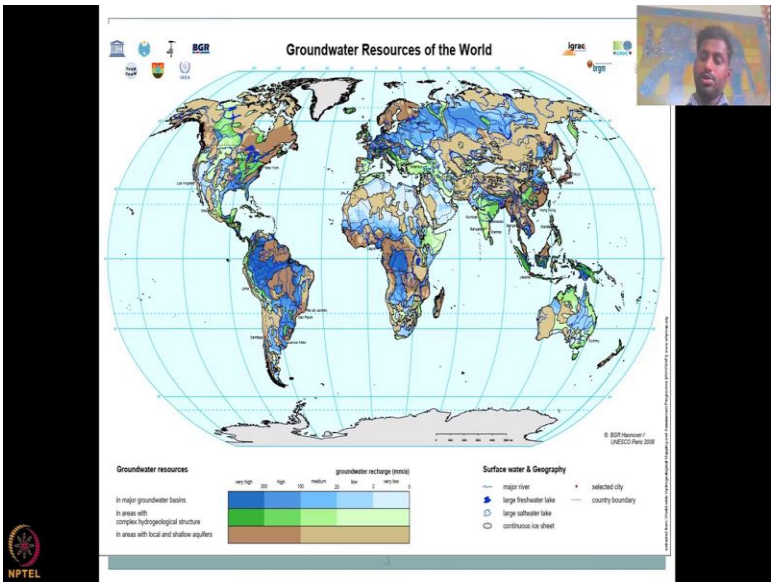

So, let us look at groundwater resources in the world. So, that will be a quick introduction. So what you see here is a big map made by all the major international players, who actively work on groundwater protection conservation. For example, UNESCO and IAH, International Association of Hydrogeologist.

And what you see is the world can be mapped predominantly into three categories for groundwater resources. One is the major groundwater basins, which is in blue color. And within the blue color, there are variability in groundwater recharge. How much water can get into the system is called kind of a proxy for how much water you can take out. So, that is given as your blue color.

And within the blue color, you have different shades of very high groundwater recharge to very low groundwater recharge. So visualize your groundwater storage, or groundwater unit as a bank account. There is a simple analogy we can make. So you have a bank account. And it is not an unlimited supply, nobody is going to be putting money every time without your knowledge. And it is not unlimited. So it is a constructed limited resource, that is your groundwater. And in that monthly, you are putting your salary and then you are taking expenses out now and then, using credit card, debit card, ATM, whatever it is.

So similarly, you have a groundwater unit. And inside comes your recharge, and discharge can

happen multiple ways, your recharge can also be in multiple terms. If you have your bank account, you can get your salary, you can get your interest from your account, you can get your rental that can come into your account.

So similarity, visualize a groundwater unit, groundwater storage unit. And inside that, there are multiple water that can come in and save a discharge can happen multiple locations and different rates. So you do have a very high groundwater recharge aquifer or a unit for now let us keep it as a groundwater unit.

And most of India in the northern part is in the blue color. So let us look at first India and then globally. The Indo-Gangetic plains and the Brahmaputra plains have very fertile resources for groundwater. So, you can see the recharge is very high and the land and environment and hydroclimate is very conducive for water to recharge rapidly. You also get a good rainfall. So that helps in recharging actively the aquifers. So, aquifer is the unit for groundwater storage. So, similarly, in watersheds and hydrology, we saw that you needed a watershed boundary here we call it aquifer. So, an aquifer is the storage unit for groundwater.

So, the Indo-Gangetic Brahmaputra aquifers are very, very highly yielding and very high recharge rates. Whereas most of the other parts of India come under areas with complex hydro geological structure. Complex means it has different geological setting rocks are different and the storage within the rock is very different. So, we will look at it in detail in the coming class when we talk about physical groundwater hydrological units. What constitutes hydrology we will discuss and also we will look into the different aspects of groundwater recharge.

So, you see most of India has very complex structure, especially in the middle, central and eastern regions. And when you come to southern regions, the complexity is available. Also, the groundwater recharge is very low. And that is where you see a lot of people putting in borewells digging new wells but getting into loss. So, this is the scenario of India, we have both the high yielding aquifers or high recharge aquifers, groundwater resources. Also we have complex non groundwater resources where water availability is very low.

Then we have some areas with local and shallow aquifers, which is very small aquifers, very localized, it does not yield that much recharge, and groundwater is a concern. So, that part you

can see here in Gujarat region. Moving across the world, the blue areas, most of European regions Australia, part of Australia, Africa, Central regions of Africa, South America and North America have good yielding aquifers, good giving groundwater resources, the recharge rate is very high. And this area with all the big rivers and forested ecosystem as a very conducive environment for groundwater resources.

The remaining regions, the area is very, very localized and shallow, if you look at Canada and Russia, where the groundwater recharge is very low, and also very localized, because of the geological setting, most of those areas are frozen, not much agriculture happens. So not much extraction happens. And so the recharge is also very slow. Some central parts of Australia and Africa also come under the picture.

Then you have the three areas with high complex structure, and you could see that most of India comes under it. And similarly, Canada, wherever you see a very high complexity, the groundwater recharge is very low, comparatively, and storage is very low. So if you look at the Middle Eastern countries, the Arab countries, they also have such aquifers along with Australia.

Someone might ask, so groundwater in Africa is very blue in this picture, But still, if you look at images from Africa, they do not have enough agriculture, they do not have enough water, they are struggling for water, what is the reason? The reason is the aquifer is present, groundwater is present at high high volumes. However, the way to access it is very expensive.

In India, It is very shallow. And so you can put a pump and take it out, energy is available, you have hydro power, you have solar power for groundwater extraction, diesel power, fossil fuel powered engines, pumps, but in Africa they cannot afford it, because they cannot afford it, the groundwater resources have not been tapped.

So this is the understanding why some regions are still blue and still under the water starvation countries. If you look at European countries, they have very good aquifers of groundwater recharge. But they also use very less use because they do not do much agriculture. Most of the agricultural products are imported like India supplies, Pakistan, and Vietnam, China, Malaysia, they supply food to these countries, and so they do not grow much agriculture, they do not need that much groundwater. So India is pumping a lot, producing these agriculture outputs, and also

exporting them. We discuss this in later on.

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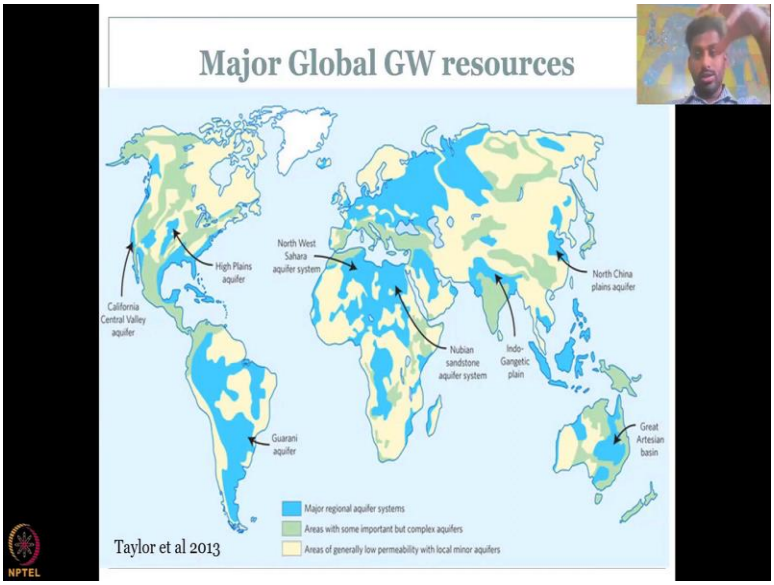

Here are the major global groundwater resources. There are multiple studies. So, we will look at the previous slide. We saw many, many universities, UNESCO, IAH coming together and IAH these International agencies coming together to map the groundwater resources. However, there are other agencies and studies like Taylor et al 2013, they have made also similar maps using different methods so the measures may not be the same. However, the overall groundwater mapping is similar.

If you look at their study. Their major regional aquifers, or major groundwater systems are in dark blue and they are in India it is the Indo-Gangetic plain some parts of Brahmaputra, India, Australia is a great artesian basin. Along the African regions, it is the nubian sandstone aquifer system, northwest Sahara aquifer system, And then the US is the high plains aquifer in California, Central Valley. These are very high yielding aquifers and if you look at these regions, that is where a lot of agriculture also happens.

If you come to the South American countries we have the Guarani aquifer, and in China, it is a north china plains aquifers. These are the high yielding major regional aquifers. They have high yield and high recharge. And so they support a lot of populations. If you look at the groundwater use in the Ganges basin, it almost caters to a big population that surrounds the Ganges plain. It is

very hard to put a number but indirectly the Ganges bay is being supports 1 billion population and that was with surface water and groundwater resources.

Let us move on the areas with some important but complex aquifers are in the green as similar to the previous study, and that encompasses most of India and some parts of your European nations North and South America or Australia, New Zealand. So, they are very complex and the complexity comes because of the geology, the ground under the ground, what is available. The rocks, the sediments that determines the complexity. We will get into that when we discuss the groundwater hydrology and physical parameters.

So now this is better to understand where are the major systems and why are they major, etcetera. So major also reflects a good healthy groundwater status. So if you look at most of India it is under the complex, but the Indo-Gangetic plains still has a lot of water. Similarly, if you look at the European regions, there is a lot of groundwater. And as I said earlier, there is a lot of groundwater in some regions because they do not use it much. If you come to South America, there is a lot of forest and healthy big rivers that flow like Nile.

So, what they do is they have a lot of water resources that recharge the groundwater, and also a healthy forest system that supports healthy groundwater. So, there is always a link with the environment and the geology, on assessing the groundwater status. Areas of generally low permeability and local aquifers. So local minor, very small, small aquifers are present in the rest of the world. Iceland, there is no need for looking at it, but in Greenland, but if you look at other regions, there are fairly lot of complex aquifers, or groundwater systems and mostly localized groundwater systems are present.

So, what happens with the local is, there is a lot of complexity. So, a groundwater status, how much water you can extract might differ from one location to the other location, because it is very local and the properties change. So, that is what Taylor et al shows here in China and most parts of the Americas, you see that it is a very locally aquifer system, locally in terms of very localized in small small pockets and a property scale. So you cannot apply one recharge rate or one yield rate for all.

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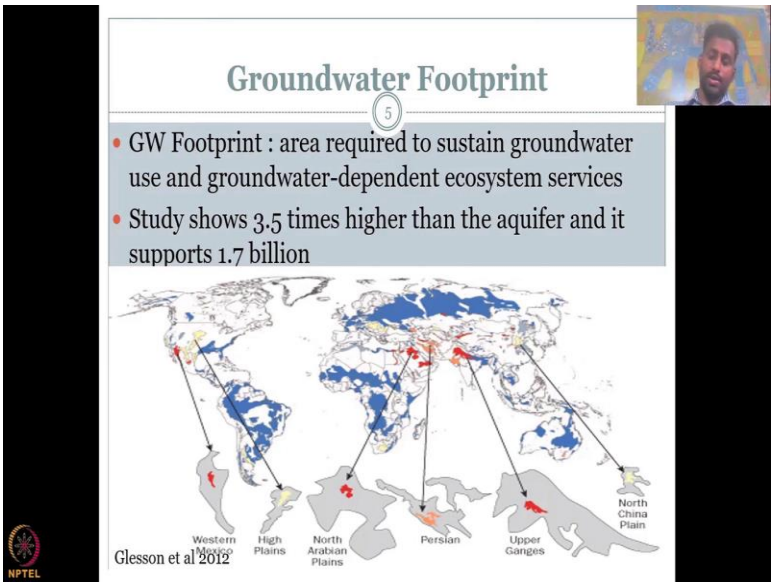

On this note, it is very important to understand that groundwater footprint because as I said earlier, it is these aquifers are present, but it is also present because we may not be using the water much. So we need to tap on how much water is actually used and what is the footprints. Let us define groundwater footprint as per Glesson et al 2012.

This paper argues that groundwater footprint can be coined or determined as the area required to sustain groundwater use and groundwater dependent ecosystem services. So ecosystem services is all the biotic and abiotic services or living organisms that need water and contribute to the environment like worms, trees, etcetera.

So, how much water they need etcetera is documented. So the groundwater footprint could be the area that the groundwater aquifer or the groundwater system needs, so that it can satisfy all these groundwater systems dependent ecosystems. So it is the area need to sustain the groundwater use. It shows that this study shows that 3.5 times higher than the aquifer, and It is supports up to 1.7 billion people. So, all the major aquifers they map and they looked at how much area is needed activity the current activity in the aquifers.

For example, groundwater aquifer, or a storage can be used for agriculture, domestic, industrial, so they took account of all this water that is needed, budgeted all the water, and then looked at the areas that the groundwater aquifer needs to sustain such use. And what the study found was

very concerning, because of the groundwater demand, almost 3.5 times higher is the area that needs to sustain such ground water use.

So to visually put it look at the Ganges basin, or upper Ganges basin. The area is 4 times up to 4 times bigger than your actual groundwater. So to get water into your groundwater aquifer, or unit, you need to conserve an area which is almost 4 times and that is the area that is required. So water should be caught, water should be pushed into your aquifer system or infiltrated recharged and then the groundwater use, so it is up to 3.5 times.

And more importantly, they documented who is using it and what is the population that is directly linked to these aquifers. So main aquifers are the western Mexico aquifer, the High Plains Aquifer in the United States, the North Arabian plains, the Middle East, and the Persian along with the Persian aquifers, along with that the upper Ganges basin and the north China plains. All the others are aquifers, but groundwater systems, but they are not as important or as predominant as these aquifers discusses this paper.

So, what these major aquifers are doing, are catering to a big population according to 1.7 billion in 2012. That is almost by saying every two people out of seven are using the groundwater from this region. So at that time, let us approximate the population to be 7 billion. So out of 7 billion, approximately 2 billion people are using water from these aquifer systems or are dependent on these aquifer systems. So it supports these people both for food, for domestic, industrial, etcetera. And that is where the dependence actually the dependence causes more importance to the aquifers and more land needs to be piece up.

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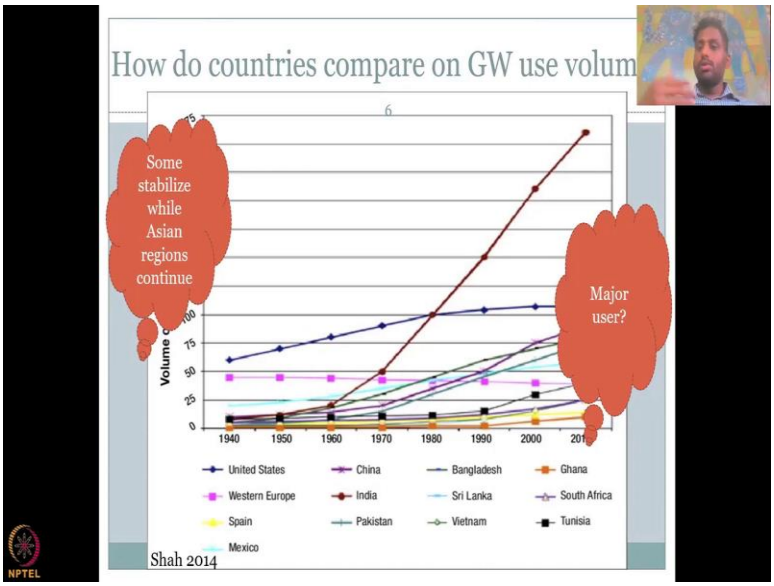

So, when we have these aquifers in picture, please understand that there lot of transboundary aquifers, which means Ganges water can be used by our neighbouring countries also. So it is important to understand how much volume does everyone use. So we looked at the different groundwater aquifers in the world, we looked at the groundwater footprint or how much water is being extracted. This is the area that needs to be conserved. Let us now look at the actual volumes so let us put numbers here.

And this study by Shah in 2014, Professor Shah collected these values and plotted it very beautifully to show that the volume of water extracted in the globe by groundwater pumps and other resources is approximately 260 to 255 Kilometer cube per year for India, whereas it is much lesser for other countries even though it is high.

So India is ranked number one and the rate is around 260 to 255 Kilometer cube per year. Whereas the next country, which is ranked two is America or United States with around 100 or 110 cubic meter for years, followed by China with around 80 to 90 Kilometer cubed per year. So if you add all this, you will see that the total is still much lesser than the amount water India uses groundwater.

In other words, the groundwater used by India is more than the next two countries combined, which is US and China. But that is not a, look at this size of the countries, US and India are

comparatively very different in land size, India is much smaller compared to US and China. However, our groundwater use is much, much higher. So this is a concern. So, as one concern you see from this graph, the other concern you see is most of the Asian countries are still increasing.

You look at India, it is slowly started in the Industrial Revolution area, and then the green revolutions time it just pick up and It is still going on, there is no sign of it slowing down, in the groundwater volume, every 10 years, it seems to increase. Whereas the other countries like Western and European countries have almost tapered off, tapered means it almost stabilizes.

It has hit the bench and it is stabilizing, it does not go above a particular level, or does not keep increasing, it is not as increasing like here, we see an exponential increase, whereas this increase is almost stabilized. Same with China, it is increasing but not as rigorous as India, and other countries like Western Europe is almost coming down in ground water use, whereas the Asian countries are slowly pulling up.

Ghana, Coming up Spain, but most importantly, Pakistan, Sri Lanka are slowly coming up and they started to move upwards after 1980s. Whereas India started 1960s, 1950s, and it did not even slow down. So this is how countries compare. And as I said, some countries have already stabilized, while Asian countries are still continuing.

Water extraction, which means it is going up. So what does it show to you in a different quantification is that the Western countries are shifting the focus of water, where to use, how to use water, whereas the Asian countries are still using water for agriculture very, very, less efficiently. And groundwater is tapped readily without understanding the consequences. So that is a concern, and everyone has to look at it.

So as I said, why these countries are using so much groundwater is the concern and for that it is very important to look at what are the key uses for these groundwater resources, just looking at these nations like India, China, and whichever countries, you have Bangladesh, you can clearly understand that there is some trend why these countries use so much groundwater.

You should first look at the groundwater use volume. So here we looked at it 260, 255 Kilometer cube in India. And then we should look at what are the key resources that are being used for

groundwater, or which are the key uses for this groundwater. Let us say agriculture, industry, domestic etcetera. So if you divide all this, we can clearly understand for each country, what is the major use for groundwater? And that we will look in detail in the upcoming lecture, in lecture 2.

So now, let us stop and understand where our major user is, which are the key countries that are using this groundwater. And also understand that most countries in the Western part are slowing down in groundwater use or stabilizing, whereas the Asian countries are still on the up. Is this sustainable? Is the question that should come up? Is this good? Or is this bad? So bad as in the sense can we continue such a behavior of using groundwater without stopping? Or can we or should we stop? So all this we will look into in detail this week. Let us start with the major user for groundwater, the upcoming lecture. With this I would like to stop the week 2 lecture 1.