**Rural Water Resources Management**
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**Week 03 Lecture 05**
**Recap of Hydrological Parameters for Rural India**

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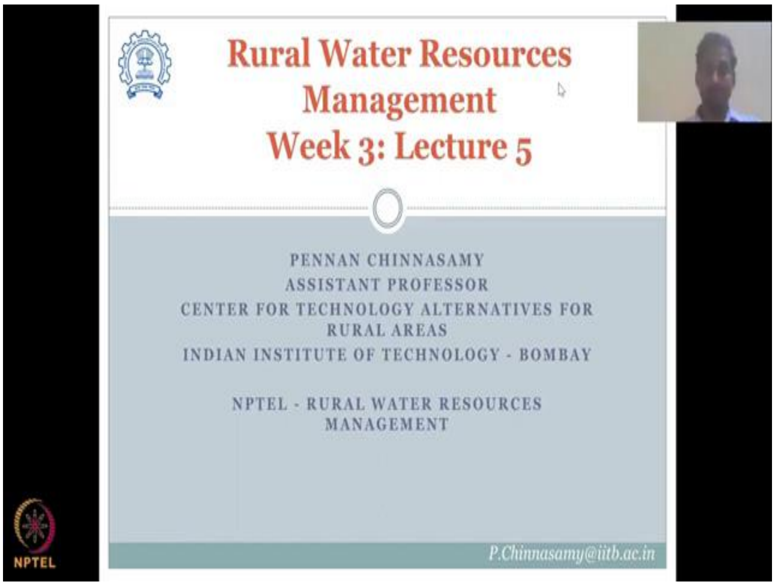


Hello everyone, welcome to rural water resources management, week 3, lecture 5. In the previous lectures, we looked about groundwater and spent some extra time on groundwater resource, because one of the important factors for rabbi seasons for non-monsoon irrigation for rural water.

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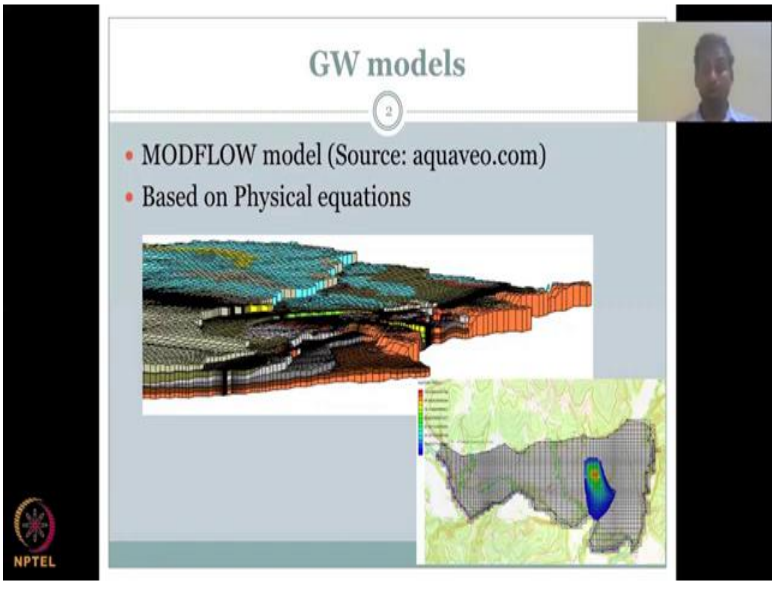

I stopped with some data collected from groundwater board and government data and we looked at how it is being used to understand critical blocks etc. So, that is one way of monitoring the groundwater availability, groundwater issues etc., in the country. But please understand that that does not talk about the movement of water, it only documents, we had a level here and now is it coming down or going up, where is the water going? It is very, very hard to visualize and connect, unlike your surface water. So, for that concept, we have groundwater models.

And these are very complex code heavy driven models, where you have equations solved groundwater properties, and groundwater hydraulics. So, the hydrology would look into how water comes into the system for groundwater, and then gets relocated along your porous spaces.

So, the models are many and plenty in number and I will be talking about one model that I have used in the past, which is MODFLOW and it is an open source model. And we will look at how it has been build. It is based on physical equations as I said, and physics of how groundwater moves from one place to the other and also on the soil properties and geological properties.

So, it is a 3D model, a model which first you would see from the top down, so maybe I am looking at a map from top down that you see a boundary, you see this is the boundary of your aquifer or boundary of your model where you want to model. And if you go deep into the model, you could see that it is a layered 3D model. When we were discussing about groundwater, we mentioned that visualize a cross section and inside the cross section you have layers, like a cake, I use the term like bouquet at this as a cake we have a cake layer, three layer, cake layer something like that.

Similarly, a 3D vision is needed. So, these conceptual models are being made by MODFLOW, wherein you have the first layer on the top and then layer which is impervious or it is stopping the groundwater movement and then a deep aquifer layer. So, here you could see the first layer is slight green and then a darker green layer, but it is not continuous, it is not continuous it goes and stops, which means some layers exist not for the whole part of the aquifer, but for partly and it could be because of the weathering on the rock.

Then you have two aquifer layers, which are slight grey and darker grey in color, they move a little bit higher than the green color and then you have the darker orange and orange which go through the boundary. So what you see here, that these images are taken from MODFLOW, there are multiple MODFLOW platforms. I am showing examples from aquaveo. So what do you see here is water comes from the top and then rainfall water infiltration percolation, then water gets relocated along the layer and after this recharge it goes down, down, down to the deepest part of your groundwater aquifer.

So in between sometimes it will not move beyond permeable layer. So all of this has to be captured in your model. How do you capture these in your model? It is by data and field observations. You should know how many layers are present, distinct layers in your location, and how long it extends. For example, if I take bore log here, I found 1, 2, 3, 4, 5, 6, 7 layers. If I go here, I only found 4 layers. So which means 3 of the layers are truncating. So, we should know by interpolation, which are the layers that are truncating.

So, all this is done by the model. All you have to give us at different locations, the water level record and the stratigraphy record, which means the layering of your aquifers. So, this requires a lot of fieldwork. And this is where the aquifer mapping activities of the Government of India is being done, that is why it takes a long time, you have to take multiple samples, bring it to the lab, analyze what material it is, if it is distinctly different, from a different depth, then it is a different layer, it is somewhat closer, then they just merge it into one layer.

Most of the groundwater models for study purposes, research purposes have three layers, that from the top ground surface, you have the unconfined aquifer, and then maybe one or two impermeable layers. So there is one layer unconfined aquifer, there is a confined aquifer, another confined aquifer, so almost three would be okay to model. Otherwise, you need a bigger model computing software, or even hardware like a good computer to model optics.

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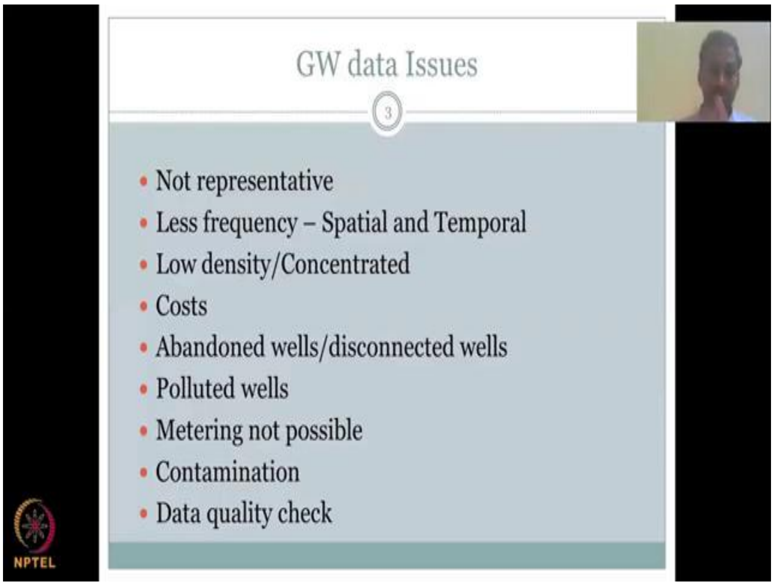


So as shown in that just data would be enough to understand just the level, but not the movement of groundwater. And to understand the movement of groundwater, there is a need for physical based models, when I say physical based, it is driven by physical equations, empirical equations. Empirical equations are based on statistics and it is just a correlation relation kind of a function.

Physical equations actually take the physics behind the groundwater movement, for example, hydraulic conductivity, the change in pressure ends, and then they calculate the movement of water. So for physical base system there is a need of a lot of data. So there are a lot of issues which we will go through, and I am defining what are the issues.

And please bear with me when I do extend the groundwater resource lecture because India is the biggest groundwater extractor in the world, studies and government reports say almost India's groundwater extraction is bigger than the next operators together, combined together, which is India is, which means that India's groundwater use is much bigger than US groundwater extraction and the extraction by China put together.

So we have to be more protective of the groundwater resource, yes, it has helped to improve the economy by means of increase in agricultural productivity, better livelihoods, good options like sanitation, and improved lifestyles, etc. But we need to preserve it otherwise, it would be back to base one.

So, what about the data issues? Let us go through some of them, some of them are not representative. When I was teaching the groundwater level wells, I told that some wells are former wells which are representative, which means that when you pump water from well, and then take the same reading or come again a couple of days later, then take a reading then it is a representative well, it represents the actual system where what was being used for pumping etc.

But in some regions, you would see that the monitoring wells are not disturbed, which means they are not pumped, it is only for monitoring. So, it would not capture the dynamics in groundwater because it is disconnected, it may be disconnected from the farm groundwater reality. So that is not representativeness.

Less frequency because of the cost in manpower and or collection of data, there is very less frequency of data both spatially and temporally. What do I mean frequency less in spatial? I mean that there could be much more number of wells, much better monitoring, we saw that Rajasthan, Gujarat is in the red colour, but the number of wells is also less. So some more coverage of wells can be there. So that is the higher frequency, improving the frequency of spatial representation of wells, deployment of wells.

Then we come to temporal issues, only four times a year it is been monitored. Is this enough? A lot of studies say that we need to improve it because the pumping does not happen only in those regions,  and is a cumulative effect. So what you have studying by looking at pre monsoon level is accumulated water use impact on the groundwater level. In the pre monsoon levels, in the post monsoon levels, it is also a cumulative effect of recharge. So, now here comes the question.

So, which month is most important for groundwater recharge activities? We do not know, because it is a cumulative effect. So we have to put much more effort in monitoring the wells, for example, in developed countries, you will see that the wells are monitored almost every day by automatic sensors, but it is pretty costly. But other wells are at least monitored once a month, at least once a month.

So low density and concentration, sometimes what happens is a state might have enough number of wells, but they are not spread out equally. Some areas are low density wells, some areas are concentrated. So you should be more or less taken care of the ways that are represented by the wells, else this might be an issue and running from groundwater models.

However, I do acknowledge that the costs issues involved, we need to understand that because of the complexity involved in groundwater, both the capacity, a lot of people know about groundwater monitoring, and also measurements, so there is lot of cost in bringing up the capacity, there is a lot of cost in putting a well and a meter, just one pressure transducer I was saying, that you put in a piezometer or a deep aquifer well, it will cost around 700 to 1000 dollars which is approximately 70,000 rupees.

And that tape measure I showed you is 1 lakh rupees. So, now, you could understand that it is very expensive to monitor these wells. So it is, we need to find better ways, we need to find better technologies cheaper, cost effective to manage and monitor the groundwater levels. Some wells are abandoned and are not disconnected, which means if you go and look at the data some wells would have data, data, and then suddenly no data.

Those are the abandoned wells, people stopped recording for some reason. And other ways is they are disconnected. So they are not connected to the pumping region, or they might be presence somewhere else. So these kind of issues, because they did not understand, the underground complexity and where to place them wells. I am not talking about a particular agency. Most of the agencies in India go through these issues. So there is lot of, different agencies that are monitoring groundwater board Central State, but we have to be understanding which wells that were monitoring.

Some wells are polluted. I was in the field we did see a lot of wells with polluted discharge, so which means it is level is increasing, but it is not groundwater. So we will have to be very careful, if you are monitoring and measuring good water or is it polluted water, for example, an industry might be discharging pollutants and that pollutants move into the groundwater levels and increase the groundwater levels. So, is it a good sign show higher water level, but with polluted water is the question? So it has to be good water, so always look at if the wells are polluted or not.

Sometimes metering is not possible because of the complexity of the wells, sometimes the size of the wells are so rugged, that it is not possible for metering. Contamination, pollution moves. So, pollution water moves and sometimes contamination also happens, some people purposely put in discharging bad water. So, like we you see how streams and rivers are black in colour in some areas.

Similarly, contamination also can be raising groundwater levels, because it is a storage underground. So if you push water in and water goes into groundwater, and gets contaminated, for them, it is easy way, just put the black water inside, but then they are actually spoiling groundwater. So, when you go and collect data, please be understanding of these issues for groundwater.

Always have to do a data quality check, which means data representing what is happening. For example, if there is rainfall in the monsoon, and you see a good water level increase, which is good, okay, so that is a good data quality check. But suddenly, if you see a groundwater level increasing and throw out the drought here, something is wrong. So that is what I am trying to say is data quality check.

Sometimes you would see the same water levels multiple times in data set. I am talking about a state data set that I recently bought for research and we saw a lot of issues in the data like data errors, duplication, which means one level is the same across all the months, which is not possible. And then sometimes you would see data which does not make sense because the units are being changed. So, please understand that I had mentioned earlier to be very careful with the units because if you spill the units here, then your data is off.

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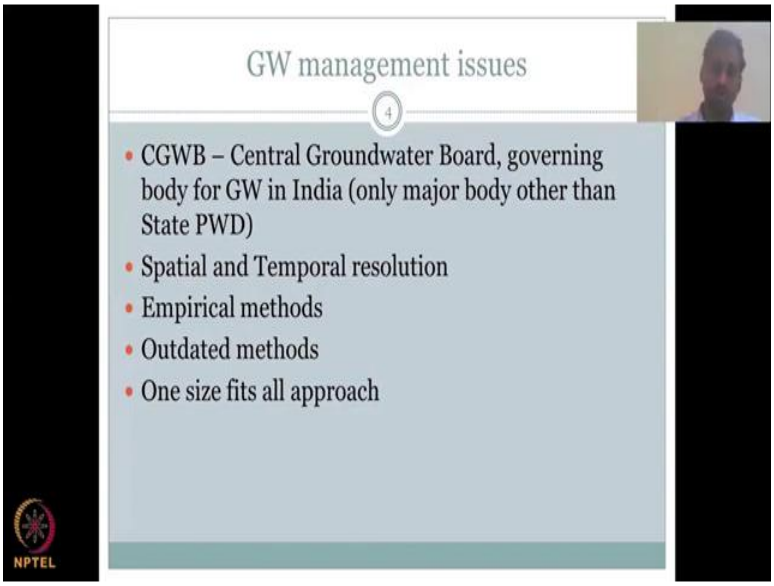


So, one side is the groundwater data issue, then the other side is a groundwater management issues. Right now, we have Central Government Board, which is body other than the PWDs. It will be good to have more agencies involved for example, irrigation looks at the, Irrigation Department looks at water supply for agriculture, but it is mostly through the surface water equation which is dams, canals, etc. But a good portion of water is also being used from groundwater. So, some convergence of management could help.

Then spatial and temporal resolution of the data, the management activities,  etc. it should can help. Some empirical methods are being used, for example, to understand the information recharge rates, those should be backed up with physical basements. It is time consuming to run MODFLOW, but in the long run, it does help because you have a 3D picture of your aquifer, rather than an empirical model, which is just a 1D, which means rainfall, infiltration, runoff.

So there is not much dynamics laterally also, so groundwater when it comes in, it does not only move down vertically, it can also move planer XY plane on, so it can move. So, along the Z axis it can move up and down, up you do capillary and down due to gravity, but also it can move XY plane. So that that cannot be captured by empirical methods.

Some methods are outdated, because how do you account for pollution, how do you account for deep aquifer level. There are too many wells that have been abandoned. So, all these need double checked. There is lot of, one size fits all for groundwater management activities for example, people claiming that wells can recharge groundwater, but it recharge across all of India is the question.

So just because it recharge one area, it does not mean that it can recharge across India. So, if you remember the traditional water harvesting slide I showed or the traditional water body slide I have shown, you saw that in traditionally across India it is not the same method that has been used throughout, for example, we had wells or ponds in Tamil Nadu and Terrace farming along with water storage along the terrace, you saw that in Jharkhand, Nagaland etc. So there is a big difference and so one size fits all approach should not be used.

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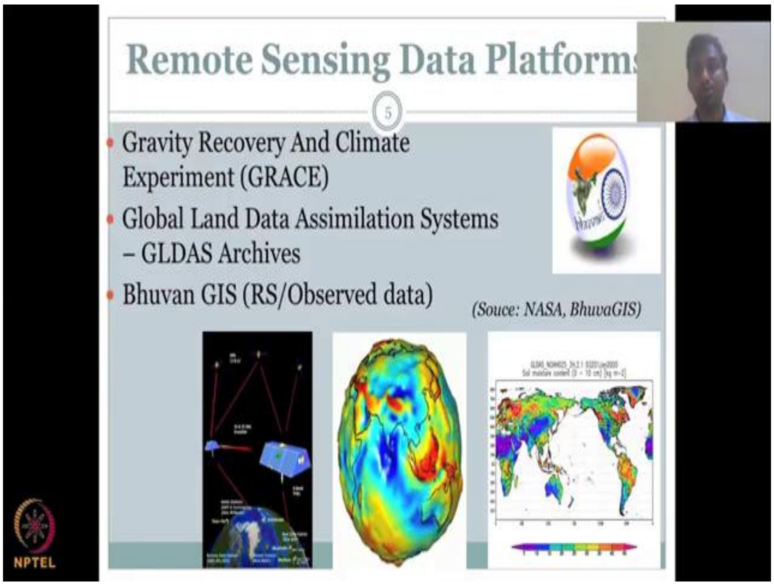


And because there are data issues, we should look at different data platforms to get remote sensing data  with the observed data. So here I am showing the only satellite in the world that can monitor and map groundwater, which is the Gravity Recovery and Climate Experiment or (GRACE), it is the combined mission led by the NASA team. And they also have other data from different satellites for other parameters that contribute to the groundwater hydrology for example, your soil moisture, your rainfall, etc.

So those data can be collected from Global Land Data Assimilation Systems or GLDAS. All of these are open source and the Bhuvan GIS are remote sensing observed data. So these are obtained from the government of Indias website where you could map the land use land cover. So if I know how much rainfall is coming, if I know by land use land cover map, what kind of crop is grown? I would know what water is remaining for the groundwater recharge.

And all these different parameters can be put together to understand water dynamics. So you can clearly see that I am not omitting observed data, observed data is important, it has to be the first data that you would use, but because of the spatial and temporal scale, you are adding some remote sensing data along with it.

So, this is how GRACE would look at it the globe, it is not the same smooth sphere, but there are a lot of disturbances on the land because of changes in gravity, gravity is not the same across the planet and using that concept it measures groundwater. So all remote sensing data are giving you a proxy of what is happening.

So, by these methods, you can actually estimate groundwater recharge at a higher spatial and temporal scale, only drawback is remote sensing methods cannot be used for a fields level analysis, or even a village level analysis, we will have to do it at a state level. So even state level is not agreed upon. But at least you know, South India, or Indian subcontinent level is okay.

So it gives you some pictures and you could see here that blue color means higher groundwater, or terrestrial water storage, you could see that higher water storage is available along the Himalayan regions because of the snow. Those kinds of things we could understand from this. Those were interested in GRACE papers can look at more GRACE related papers, there are multiple papers, even for India that has been published widely.

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On the whole, still, there is more data needed. And more people are needed to convert remote sensing data into a usable format, for which IIT Bombay led the mapathon event last December. And we actually look how we can engage people map different locations in India, and also use ISRO data, which is Government of India's data for research purposes, for analytic purposes, and to have a better understanding.

So we cannot expect every time a government agency to map and give you a land use land cover, for example. So it is those people who are interested should get on the ground and help these kinds of data activities. So this event was a great success, were we had 9000 participants, just to show that collecting data does not require just a government agency, but you could work along with the government remote sensing data platforms to generate some data and depending on the quality of data, someone can use it.

So that aspect is always very important. The key players here were ISRO because they are the Indian Space Research Organization for Indian satellite data, Indian ISRO Technology Bombay and AICTE and within IIT Bombay, we have the FOSSEE, which were funding and spoken tutorial, etc. So, it was a great success and we look forward to do like this again. Point of showing this here is to say that there is a lot of data needed and conversion of this remote sensing data into products can be done by collective action.

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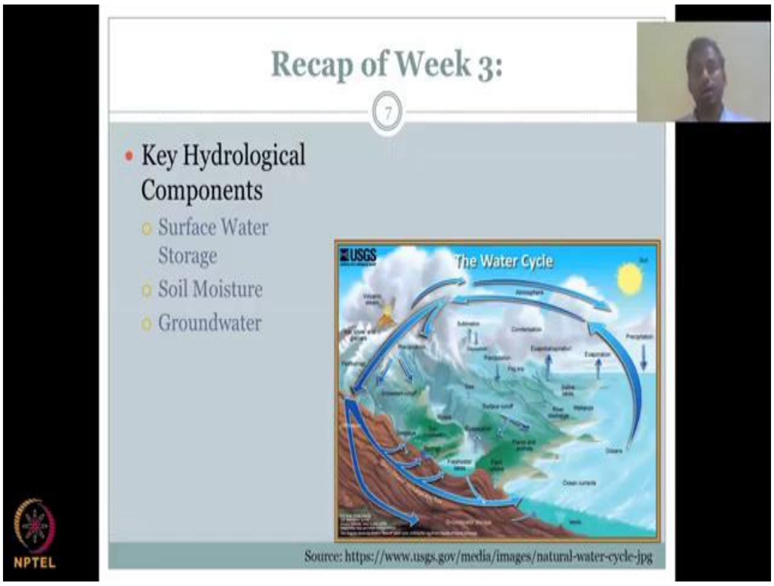


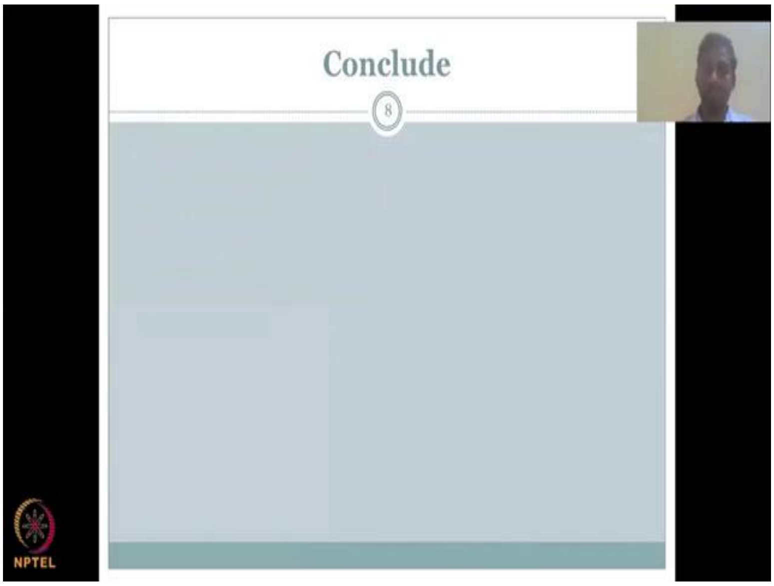


So, the recap for week 3, we looked at hydrological parameters. Overall we had 10, 15 parameters, but we said okay, for water management, it is not needed to look at all of the 15 parameters, but more important focus parameters. So, we looked at precipitation, evapo-transpiration and in the first week before this, and in the current week, which is week 3, we looked surface water storage structures, how water is stored in depressions, then leading into channels, streams, and finally rivers and lakes etc.

Then we looked at soil moisture, so whatever water is stored, and after that some water is runoff, whatever the remaining water does move down due to gravity, and it gets stored in the soil profile for plant use or evaporation, which is together called as evapotranspiration. So soil moisture, we looked into detail and we looked at how to measure all these different parameters.

And for groundwater, we took one more lecture extra, given the importance of groundwater and rural water management. And because now you cannot see everywhere people have any channels or canal command areas for their irrigation plots, but you do see groundwater pump and a groundwater well. So sometimes one well can be used for five different farmers on a rotation basis.

So the groundwater has actually increased the access to water, community farming, etc., etc. There are downsides which because if one person uses too much the other person does not have water. But those are the management issues that we will be looking at, when we come to rural water management issues.

So, this I would like to conclude the week 3, we have finished discussing about the hydrological cycle, we will go now more into the aspects of water management, because now you would have an understanding of what does precipitation mean, what does evapotranspiration mean, how do you arrest leakages or losses to the system? How to reduce the evapotranspiration? So, these aspects when we talk about, discuss in class, you will have a better understanding because we have introduced the parameters. Thank you and I will see you in week 4.