Rural Water Resource Management
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Week 03 Lecture 02
Surface Water Storage

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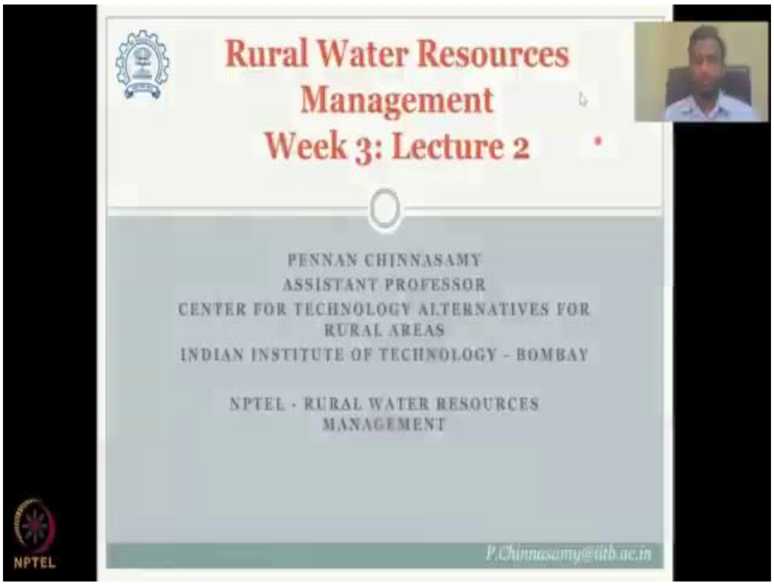

Hello everyone, welcome to NPTEL course on Rural Water Resource Management, week 3, lecture 2.

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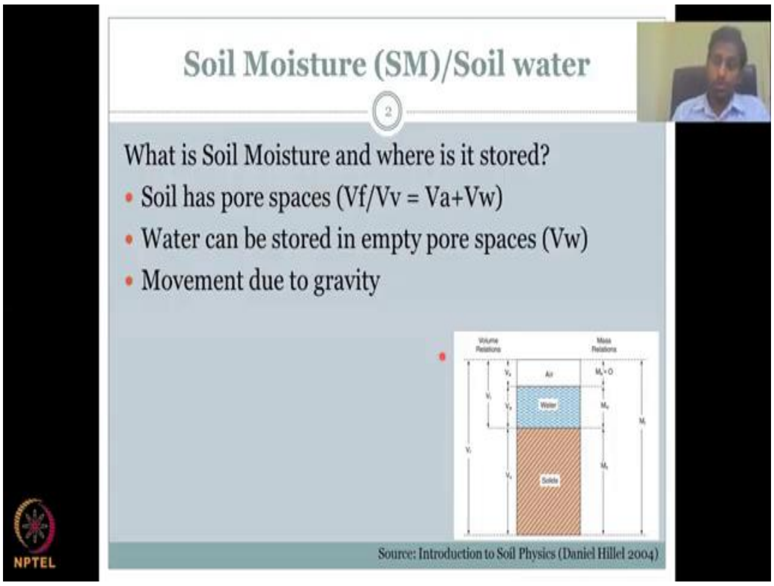

In the previous lectures we looked at some important hydrological parameters and one of them which is also very important for rural water resource management is soil moisture. Soil moisture can also be called as soil water and by other names in different regions. Let us look at what is soil moisture.

So, soil moisture is the moisture or water which is stored in the soil profile. So, let us look at a cross section of a soil profile, we have 3 different materials which are there. There are solids, the solid part of your soil which is a rock, weathered rock formation and other things, some organic matter etcetera etcetera and then there is void spaces.

So, soil has pore spaces apart from the solid phase which is Vs and Vf or Vv. So, Vv is called the volume of voids or the space where the soil does not have a solid material. And within that material or within that space, you do have some volume for air and some volume for water. It depends on where you are. So, this void space is where water can enter and that constitutes your soil moisture or soil water.

So, water can only be stored in the empty pore spaces. So, there is a lot of air water cannot push the air in come out. So, it depends on where the water can enter. So, it cannot enter a solid phase. So, there are some pore spaces or space within the soil with holes and imagine like your sponge, the sponge that you use for washing dishes and that sponge is yellow normally in yellow in colour and it has holes in it. So, within that holes water can get stored and some of it goes into the yellow sponge.

So, the key force that acts to bring the water down through the soil profile is gravity. So, when rainfall occurs, gravity is the force that actually attracts the water down while movement. So, water gets into the soil profile and when there is a pore space it gets stored there.

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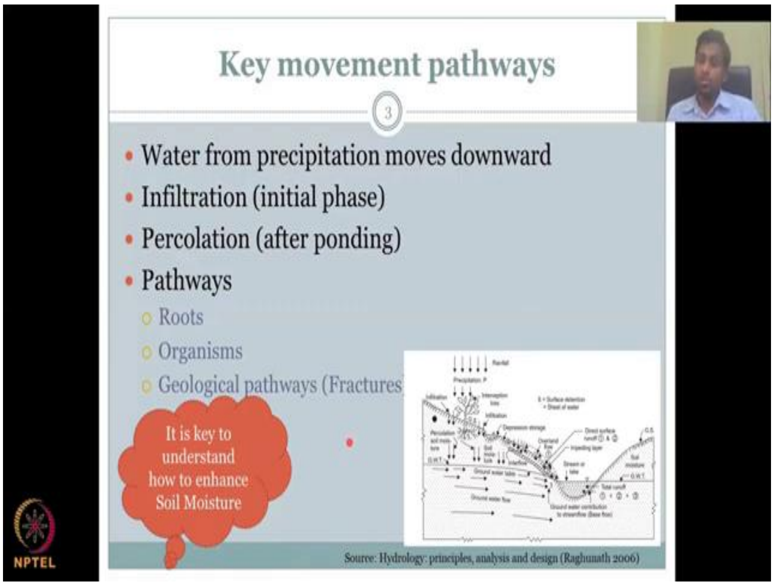

Let us look at the water cycle again to understand how soil moisture comes into the picture. So, you do have precipitation and then you have the precipitation converting into runoff. Some water gets into the soil through infiltration and that infiltration, if it is prolonged and there is more water stored it becomes percolation.

So, soil moisture is up to here because after that it becomes deep aquifer water or groundwater table we do not call that as soil moisture, so please differentiate between soil moisture and groundwater. So, when we talk about soil moisture, we talk about the phase where the root zone or root depth is. So, soil moisture is mostly for your plants. Now do not think about trees and trees might have roots that can go deep, deep and so those do not constitute a soil moisture.

So, soil moisture mostly for plants with shorter root depth or even trees with shorter or shallow root depth. So, rainfall is the key water that comes in and after infiltration, some water gets stored in the soil profile, because there is space, the void space. So, water moves down due to gravity. The first phase of moving down where it hits the land and moves into the water soil profile is called the infiltration and the water gets reallocated through the pores, through the spaces in the soil and gets stored.

Not, all water which gets into the soil profile stays there because gravity is still acting on it. So, as and when the gravity acts, water moves downwards. And then you have percolation and which is a higher movement of water much deeper into the soil profile and that is achieved because there is a higher ponding of water on the top.

So, mostly like for example, you have a lake and then there could be percolation or further soil moisture gets heavy because when water comes in the soil profile gains more mass because of the mass of water and that actually has a ponding effect which pushes water down for and that is percolation, I have a slide on it to show how percolation happens.

What are the pathways in which water that infiltrates? So, first step is infiltration, if you have a concrete, no soil moisture. So, the land has to be open for infiltration. So, the water rainfall or any water that you apply on the top, irrigation water for example, if you want to grow plants, you apply water on the land and water infiltrates. So, once it infiltrates the root zone can pull the water in soil moisture and take it out for plant use.

So, the roots actually create pathways for water to come into the soil and think about the roots. The roots can only expand the territory in the void spaces, they can crack out the soil, solid soil, but only when there is a void space. So, it creates a void space or reallocates the void space, so that the root zone can enter into the soil and you have water now coming into those empty spaces. Once water comes into the empty space the plants can take it up. So, plants play a vital role in actually changing the structure of your soil.

Then you have organisms like earthworms, you have snakes, you have rats, which can dig deep into the soil and what happens is now because of the holes because of the trajectory or pathway they create, water can move into it. When water moves in then the infiltration is much faster. And once it goes into these slow small channels, then water gets into the void space.

So, then water can enter the soil moisture profile. Then there are some geological pathways like fractures. So, you have fractures along the soil profile or rocks where water can just enter and then seep in. So, that seepage gets the water into the soil profile. But as long as the void space is there water can be taken up, if there is no void spaces, then water cannot enter. For example, think about the soil with is full of solid then where can the water go? It cannot.

Similarly, if the air pockets cannot move out, then your soil water cannot go in. So, I will have a figure to explain how these in the next slide. So, it is key to understand and how to enhance soil moisture. Now, we understand that soil moisture is the water that the plants uptake for growing and transpiration. So, it is very important to increase the water otherwise the water will not go into the ground it will move on top as surface runoff or overland flow.

So, it is very important to store the water in the soil moisture. So, think about soil moisture as a tool for storing the water not just for plants, but for water to be there for a longer period. So, that plants and other organisms that need water can take it up.

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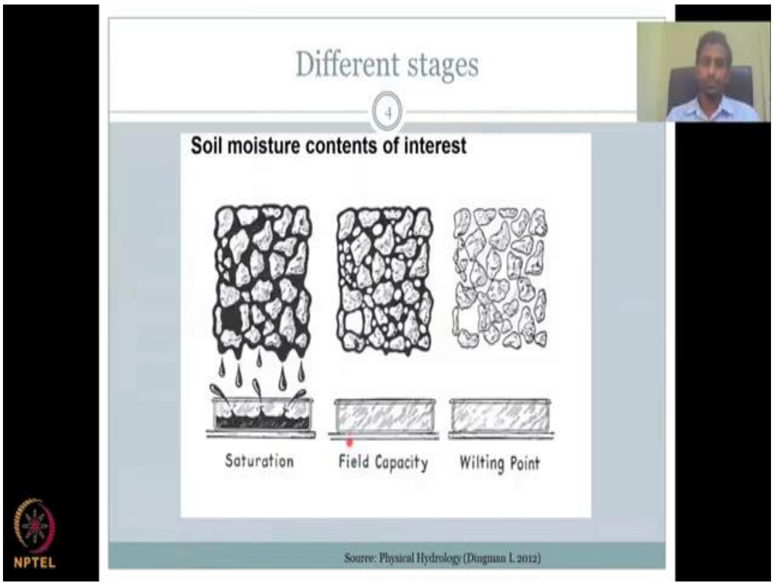

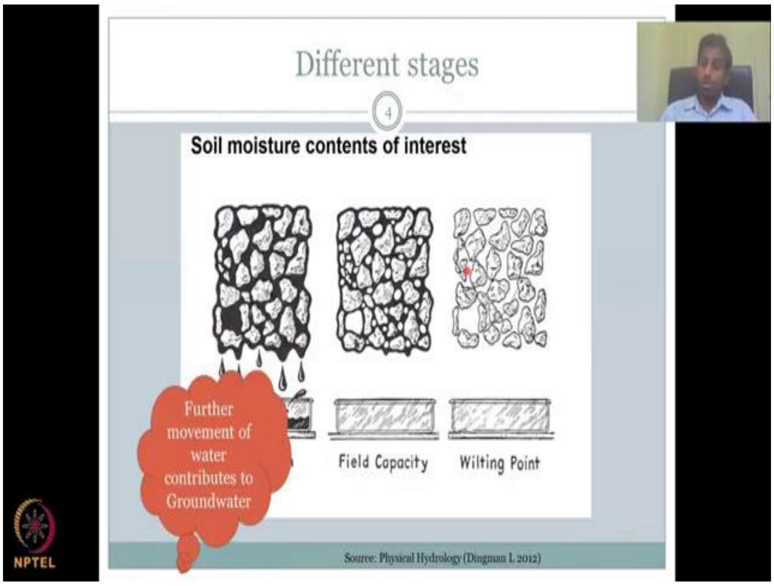

Let us look at the different stages. So, in all the 3 diagrams you have a soil profile, soil sample. This material is your solid and in between you have void space, which is empty space. Now the empty space can take two, air or water. So, if air is there, then some water can push the air out and come in. So, a good system is where you have air and water. But let us see how water enters this. So, imagine this is the first stage for example, imagine a stage where you have solid material and some space inside.

Now when rainfall occurs, water gets into the soil profile, it moves in because of infiltration and percolation at the deeper phases, so let us keep infiltration water infiltrates into the soil profile and it gets reallocated along the soil profile. Water still moves down, why, because there is more water and gravity.

So, if the water stops, then just relocation and then it stops, but as long as gravity can pull the water then still water can be moved along the soil profile. So, that is saturation, saturation means all the void spaces, all the empty spaces which were initially with air or water is now full through water.

So, that is the case when we call a saturated soil when the soil moisture is 100 percent. So, of the void space which is Vv which is the volume of air and water now, 100 percent of that volume is filled with air, so 100 percent soil moisture is reached. Then we have field capacity. So, this is the property of the soil wherein the soil attracts and holds on to the water molecules by tension and it is a very important function of the soil. So, it is greater, the attraction is greater than the gravity so, there is no more movement of water downwards.

So, the force that exerted by the soil particles and the attraction it has would store the water in the soil profile. This is very, very important. Think about a soil if it does not have this property of attracting and holding on to the water what would happen? All the water would go into the soil and go down because of gravity.

So, it is a beautiful property of the soil to hold on to the water as long as it can. So that, the plants can slowly pick it up. And this is the phase where the water interacts with the soil, the water interacts with the nutrients and makes it soluble, so that the plant can readily uptake. So, all this is beautifully linked and looped along the cycle through the plants.

So, water is now inside the soil profile and gravity has stopped acting on it because it cannot pull more water. The soil is holding on to the water. This is the beautiful stage where plants would love to have water because here what happens is as saturation the roots can suffocate too much water is also a problem. But in this stage there is not too much water it is beautiful that the plants can take it up.

The wilting point is the other extreme. So, on one extreme you have too much water and the wilting point too less water. So, at this wilting point stage there is no more water in the volume of voids or empty spaces it is full of air and all the water which you see as black colour on the soil is adsorbed to the soil, which means the soil cannot let it go. So, that is the property by which it falls on to the water.

So, if it did not have the property it will lose all the water. So, there are some water that it can never be removed from soil by plants. So, that is called the wilting point stage. So, these are the 3 stages. Why is it called wilting point is because at this point the plant dies. The plant wilts, wilts means it just drops down, changes colour into yellow, it cannot take water and this is a time when the farmer rushes and irrigates the field.

So, here is where irrigation happens. And then they have to stop because too much water. This is the best phase for plant growth because it has been watered and plant can take it up. This is a phase when you need to apply water, so almost 0 percent soil moisture and it is very, very difficult for the plant to take water from the environment.

So, the movement of water contributes to groundwater. So, from the saturation stage and the field capacity, whatever water is lost due to gravity still moves down in the soil profile and quantities to groundwater. We will look at groundwater in the next lecture. We will still continue with soil moisture.

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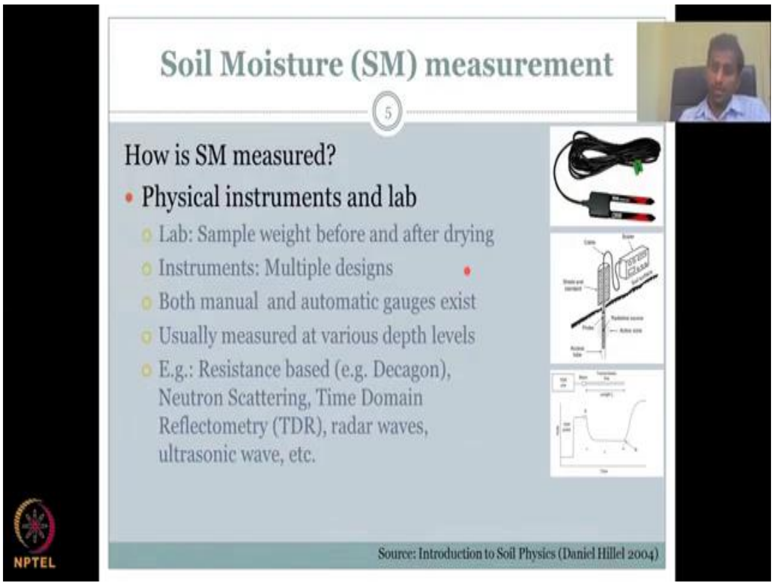

So, now we will understand how water comes into the soil and we understand that soil has some empty spaces. So, water gets relocated and stored in these small, small units and those units contribute to soil moisture. Based on soil moisture, how do you measure to understand to tell the farmers not always a farmer can look at a plant and understand, should I be irrigating the field? Or he can he or she can take the soil and crush it to see if there is moisture?

No, it is not that easy and common. So, what happens is to better manage. We need some measuring devices, so soil moisture as measured mostly by physical instruments and lab methods. In the lab, soil can be taken to the lab and then crushed and then weight before and after drying. So, if you weight before, the water volume, the air volume inside the soil, so you take a sample weight with the water, then what you do is, you dry it, when you dry it, then the water goes off. And when you crush it, it is only the solid particles.

So, the drying is not easy, we have to put it in an oven for a couple of days, 100 degrees centigrade for 2 days or at least 1 day overnight. So, intense heat will drive off all the water and then you have 0 water. So, this method gives you an understanding of this field reality of how much water is present, it is the best method. But think about each time you have to go to a lab, weight the sample, put it in an oven and weight for 1 day and then come back, the farmer has lost?

So, he or she cannot use that information for irrigation, there is a big delay and there is a big cost. So, there are a lot of instruments which indirectly measures the water available in the soil. So, there are multiple gauges. A gauge is a measuring device, we have precipitation gauge, we have discharge gauge. So, similarly, we have soil moisture gauges. So, there are both manual and automatic. Manual means you have to read it and write down the records or you install it and then read it from a display when automatic would record the data and send it or wire it to the farm through SMS or other advisories.

Usually measured at different depths. So, as we said water moves down the soil profile. So, if you take one measurement, you might be losing the total picture. So, normally we take it at 10 centimetres, 20 centimetres and 40 centimetres up to 200 centimetres you can go. That is a good depth for soil roots zone. So, it is measured different levels and given as a total picture. Some of the market instruments are resistance based. Example the decagon that we used in the field, you see the first image which is the decagon or what it is, it is basically a resistance based instrument.

So, when soil moisture has been built up in the soil, the resistance changes or the conductivity changes. So, basically it is a very simple device where in this one prong,, you have 2 prongs, one prong sense an electric pulse, and if it is transmitted through the soil quickly that means there is conductance and less resistance because water is a conductive material it can conduct current.

So, when water has been stored in the soil and this is a prong and this is a soil, an alternating impulse is sent and if it quickly goes down because of the conductance nature, then we can understand how much is your water present, or opposite is your resistance. So, there is no water when it resists the movement of a current.

So, this simple logic is being used in these beautiful instruments and you can place it at different depths. Only issues is sometimes when water ponds it gets into some error reading. So, that is why we have multiple different methods, the Neutron Scattering method which is a radioactive instrument, but very accurate, it sends out a radioactive material and then reads out the soil moisture, time domain reflectometry TDR’s then beta waves, ultrasonic waves etcetera.

So, what you understand here is soil moisture can be measured from the lab and through instruments and depending on the budget you have and the accuracy you need, there are multiple instruments.

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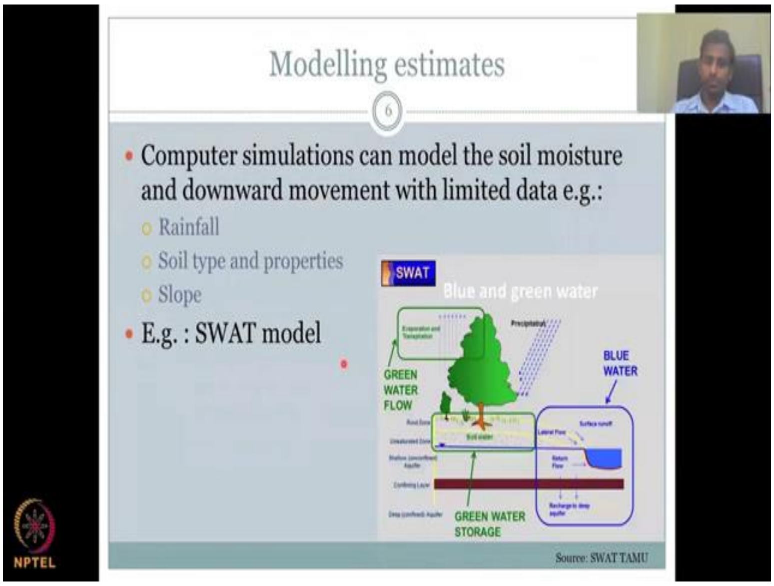

Then we have Modelling Estimates. So, similar to other hydrological parameters, you can estimate, you can model your soil moisture based on the properties of the soil, rainfall etcetera. So, computer simulations can model soil moisture and downward movement understand the process of soil moisture. I do it that every soil has a property of voids and water volume and the void space, the empty space is a property of the soil and the management, how the soil is managed.

So, if you know if you take a soil sample and you know how much void spaces and you know the slope angle by which water is coming in and the rainfall and other properties you can estimate your soil moisture. Again estimate is not as good as a physical measurement, but in some regions it is the best measurement that you have.

One good model is the SWAT model, I will be referencing the SWAT a couple of times in the hydrological cycle because it is an open source model which means, anyone can use the model it is free of cost, and it has been widely published at least including the Indian regions. So, it is based on a water balance approach or hydrological cycle approach where if they accurately measure the other water losses in the system, they can estimate the soil moisture.

So, precipitation occurs, then they know how much water is runoff, how much water is groundwater, evapo-transpiration based on the land, then they indirectly estimate your soil moisture. However, you have to give the properties of the soil and the land use land cover and rainfall. So, what we are trying to get in the model is an indirect estimate of soil moisture, but it is driven by the properties of your soil, it means measurements are very important.

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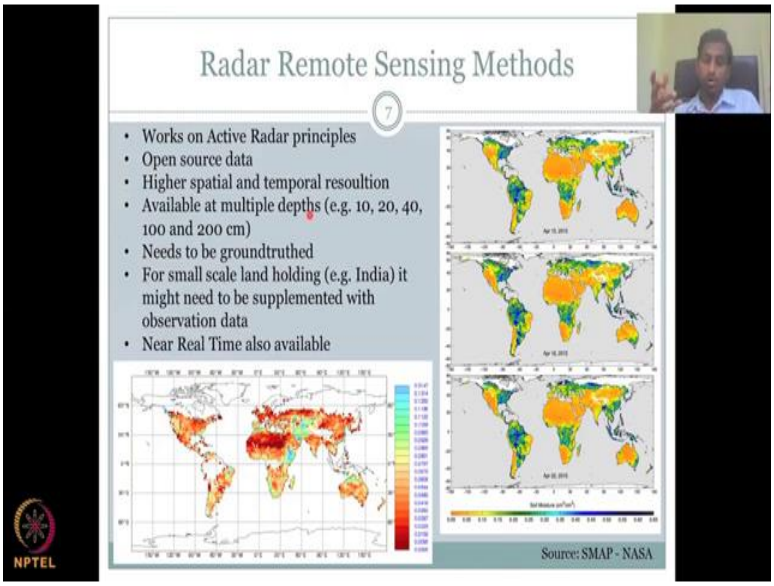

To estimate other parameters, we also have a satellite based remote sensing method for estimating soil moisture. It works on an active radar principle which means a satellite which sends pulse sends energy in the form of radar and radio waves, it goes in, penetrates into the soil and gets reflected back. The reflection is based on the amount of soil moisture in the soil, you will be amazed that the satellite can estimate soil moisture up to a depth of 200 centimetres.

So, distance 3 to 4 level of pulses, the first pulse is 0 to 10 centimetres step and bounces back. Then we have 10 to 20 centimetres bounces back and then 20 to 100 centimetres it bounces back then 100 to 200 centimetres. So, what will be a soil moisture the total of all these levels, and it depends on which plant and type of land.

It is open source data. And it is available at a higher spatial, spatial for the entire globe and temporal resolution. Because those instruments in the lab exercise that I mentioned, you can do maybe once a month, or once a week, but it is too expensive to do every day in the lab, too time consuming and the satellites can give you every day and some satellites can do every 3 hours if you look at these models.

So, an example is given here April 15, April 18, April 22. So, within 3 days difference the soil moisture is changing and you could see as ratio, so a percentage of 100 is full. And you could see that Indian regions within 6 days from 15 to 22nd of April 2015. It is changing from green which is okay. So, a moisture too yellow, which is much lesser soil moisture. And other region is getting blue, maybe good rainfall, better use of water etcetera.

So, available at different depths 10, 20, 40, 100, 200 centimetres, as I said, needs to be groundtruth, because it is an indirect measurement, they are sending a pulse, they are looking at a reflection of a pulse. So, it is not direct you take water and measure it. It is a property of water to reflect this radar wave. So, you need to be ground truthing which is expensive, but there are some studies which have been done for Indian regions basically they give you an error estimate for these data. So, you still can use it.

For small scale land holding example in India, where the farmer has a very small scale. It might be supplemented with other data from government and other observation data. For example, if the satellite can give you every 3 day data record, you can compare it with monthly record from the government for an observation record.

So, in good intervals of time you can take data and compare how your remote sensing data is performing. Near real time is also available which is within hours for some countries because they have spent more money on satellite technologies and that actually gives information to farmers if you need to educate now or later. So, instead of going to the field, they just look at this map and then give a real time estimate of how much water is there, where is the stress, how much I should apply?

So, an example is given below on water availability. So, the blue colours would eventually mean a better water availability compare to red colour. So, the farmer or the managing agencies can actually look at releasing of water from dams and irrigation projects or supplementing water through groundwater for irrigation.

So, soil moisture is a very, very important aspect in the hydrological cycle, where water has to be stored has to be kept in a good amount of time for plants to take it, take up plants is very slow. So, you need to give enough time for the plant to take up the water otherwise, the water would just move down or suffocate the plant. So, both extremes can happen. So, soil moisture, we can look at it in the hydrological cycle as a key process where water is being stored and drives the evapotranspiration loss from the system.

So, there are multiple methods to conserve soil moisture, where we will be looking at the conservation slides when we look at it at the end of the lectures. With this I would like to conclude the soil moisture lecture. Thank you.