Rural Water Resources Management
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Week: 02 Lecture: 03
Evapotranspiration

Hello everyone. Welcome to NPTEL course Rural Water Resource Management, week 2, lecture 3. In the previous lecture we looked upon hydrological parameters number one which precipitation, which is the input to the system.

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In today's lecture, we will look into the evapotranspiration which is one of the key losses to the system. Please understand when I say loss, it is a water which is taken away from your watershed or unit of analysis. In our unit of analysis it is the rural watershed or farmland.

So, imagine this is your farmland on the bottom and you have precipitation, which is the incoming water resource and transpiration is the water that the plant takes, uses and then gives it out back to the atmosphere, transpires, so that is transpiration. Evaporation is the loss of water from the surface of the earth, soil, land surface, et cetera, and open surfaces.

So, just look at some fundamentals, evapotranspiration, in short, it is called ET, is the loss of water from ground to the atmosphere. It is mostly on the ground because plants and open surfaces are on the ground. ET includes two components, very important components, one is your evaporation and then your transpiration.

Evaporation is the process where water is lost from open sources, example, urban land, land and water. So, urban means, for example, your roof, you can have rainfall on the roof and it can evaporate when it is hot, example of an urban setting is also roads. If you go on a highway you see if it is raining, still the road is dry, because it evaporates faster.

Then you have evaporation from land as I shown in the image below, you have evaporation happening in the land surface because of the sun, evaporation does not happen much in the night. So, you have mostly happening with the sun, which is a driver of the hydrological cycle. Then you have water evaporating from your water bodies.

For example, freshwater, you could see the evaporation arrow going up and you can see water evaporating from oceans, water going up. So, all this is included in your evaporation term. Transpiration is from living beings. So, it includes all living organisms from which water is transpired. Let us take examples, the biggest transpires are trees, because trees take a lot of water and they consume the water and they give it back into the atmosphere.

Why plants need water is because it is like a medium of transport of nutrients. So, there are a lot of nutrients in the soil, water mixes with the nutrients and since plants cannot readily take the nutrients, what it does is it takes a certain soluble nutrients in the water. So, it takes up the water and all the nutrients stay in the bank whereas the water is left out of the system.

So, that is transpiration. Then you have water, the same process, water can be transpired from plants, which is smaller form of a tree if you want to look at it, the same process and other format is humans, for example, is part of a human being. So, if you run all the water or most of the water in your body is transpired as sweat, you could feel a sweat coming out. So, that is when water in your body is lost to the atmosphere or out of the body.

So, losing water is by this process is transpiration. So, you could see that both evaporation and transpiration is a water loss to the system. Moving on, let us look at the other components from where evaporation and transpiration can happen. Transpiration can happen from living organisms; here we have soil, grass materials, et cetera, et cetera.

Whereas evaporation can happen from your oceans, lakes rivers, because even flowing river when it is hot you could see, not only stagnant but even some evaporation can happen, limited, but still some can happen. And then water which is falling on the rocks, et cetera can evaporate. So, evaporation is from non-living organisms, whereas transpiration is from living organisms.

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Why is evaporation estimation important? Evaporation and transpiration, why is it important? It is very important to estimate the loss of water from open surfaces. Let us take one by one and in this (())(5:29) while evaporation is very important. Look at the two images that I have taken in a field visit in Maharashtra. You could see that there is a big lake and then there is a field.

This first image field with water and on the other hand you have farm ponds where water is being stored in ponds for future use, maybe they want to use it in a dry season or after a couple of days, after the rainfall has stopped. So, in both the cases water does not stay there because it is stagnant, some water is lost to the groundwater, but most of the water is evaporated.

So, that is the biggest loss. So, if the sun is shining bright and dry, and there is less humidity in the air, then evaporation process will take up. So, there is a lot of loss from the system because of evaporation. So, that is why it is very important to estimate the loss of water from open surfaces. There are some projects in India where they wanted to close the cannons on the top.

So, you have a dam and from the dam water is taken to irrigation, plot areas, field using channels or cannons. So, both, if you have a lined, cemented cannon or a channel, then water can flow through, it does not go into the ground water, but some what they did is they wanted to arrest the evaporation. So, they put solar panels on the top. So, they arrested the water from evaporating from the channels and cannons.

So, they understood that water is very important in that area and they could not afford to have any losses and one of the key losses as I said is evaporation. So, it is important to estimate because the remaining is the water that can be used by others, as long as the sun is coming up every day there will be some evaporation. So, unless you understand how much evaporation happens it is hard to quantify what is the water remaining for your agriculture or other uses, the domestic use, et cetera.

And this is very important for rural areas. Because for example here, if you have a farm pond without understanding the evaporation, you put the money and the budget in time to put the structures, you see the structures to capture water. But if you did not understand that the evaporation is so high that you will lose the water within a day or two then the whole point of the farm pond is lost, so that is where we are trying to say it is important to understand evaporation.

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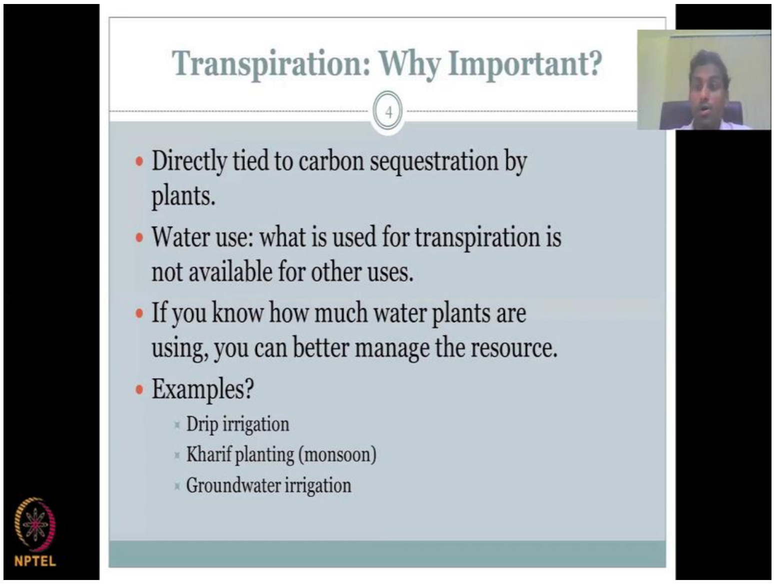

Transpiration, as I said, transpiration is from living organisms. Why is it important? Directly tied to carbon sequestration by plants. Why would that be? Because plants when they grow, when they want to grow they need nutrients and as I said in the previous slide, new things are transported from the soil into the plant biomass using water. So, water is a vehicle or a transport mechanism, just like our body, we have blood flowing in the body.

What is a key work of the blood? To take oxygen, oxygen from one part across the other parts of your body. It is the same thing, water takes nutrients from the root to the other parts of the plant, some water is remained in the plant as fruits, some wetness when you crush a leaf, you have some wetness, some fruit juice, et cetera. But most of the water is given off.

We do not give the blood off but that is the closest analogy to look at, so water takes, is used by the plant to take up nutrients, first soluble nutrients and then goes up. So, if you understand how much transpiration happens, you could understand how much plant growth happens. If you know how much plant growth happens.

You could indirectly measure the carbon sequestration by the plants or how much carbon is kept in the plant or trees. So, when a plant or a tree grows, let us take a tree for example, the biomass, the wood that increases is a good part of carbon sequestration, the carbon is brought kept in your tree. So, it is very important for Indian Government and other working on climate change mitigation adaptation to understand how much carbon a country is capturing.

And trees one of the most important and valuable natural resource that can capture carbon very effectively and very cost effective. So, by the rates of transpiration we can understand how carbon sequestration happens. We can understand water use. What is used for transpiration is not available for others. As I said, if you have plants and trees growing, the water is first taken up by them and only the remaining water is available for the other aspects of the hydrological site.

So, for example, your groundwater recharge in infiltration, percolation, all this is after the plant has taken up the water otherwise the plant’s potential to take up the water is much-much higher, rate is higher than your infiltration and percolation in some regions. But in some other regions where we have a very slow moving material then it could be opposite, but most regions your transpiration is the water that is lost from the system.

Even though it is a benefit for the plant it is lost, it is taken up and given out into the atmosphere. So, it is very important to understand how much volume we actually transpired. Humans, animals, living organisms transpire very less compared to the water budget or compared to the hydrological cycle parameters. So, it is not a big thing to put in equation in a water cycle.

So, you did not see a human transpire in a water cycle because the plants transpire much-much bigger and the domestic transpiration rates are very small compared to that. If you know how much water plants are using you can better manage the resource. This is the important part of your Rural Water Management course. If you know how much plan transpires and how much the soil underneath it evaporates.

Then you can have multiple methods natural and artificial methods to control the evaporation, or to reduce the evaporation and transpiration from the field. If you do so then you store more water in your system and that is why it is very important to understand how much water the plant is using and the plant used water is directly related to your transpiration.

So, for better managing now you have come up on the different terms, for managing rural water you need to know how much water comes in, we got the precipitation and how much water is lost which is one of your transpiration or evaporation and the remaining, the remaining part would go in as use for other resources.

So, now if I know how much transpiration occurs and how much I get. So, for example, I get 100 millimeters of rainfall plants are going to take up 120 millimeters of water. So, the 20 millimeters I have to substitute using other resources, like groundwater, irrigation, et cetera. It might be expensive. So, the measure of transpiration which you could do before the planting or rainfall can help you to better manage the resource.

Some examples are drip irrigation, wherein instead of applying for the entire plant, body and other areas of your field, you apply only directly to the roots of the plant. For example, you could reduce the evaporation because all the soil is not wet. Only the soil under the plant is wet. And that would reduce your evaporation. Transpiration also can be reduced because you directly apply only little bit amount of water in known quantities, not too much water.

Kharif planting in the monsoon, knowing your transpiration rate can help encourage planting, because if you know your rainfall, as I said 100 million meters, however, your crop needs 120 millimeters, then you change your crop or reduce the acres to come back to the volume which is equal and to your rainfall. So, your rainfall volume should be more or less equal to your land, crop water demand, otherwise you will have to substitute from some other resource.

It is also important for groundwater irrigation because once how much water is taken up by the plant, you know how much can be substituted by groundwater. As I said, not always rainfall is given new water so some of the water you can take from groundwater irrigation.

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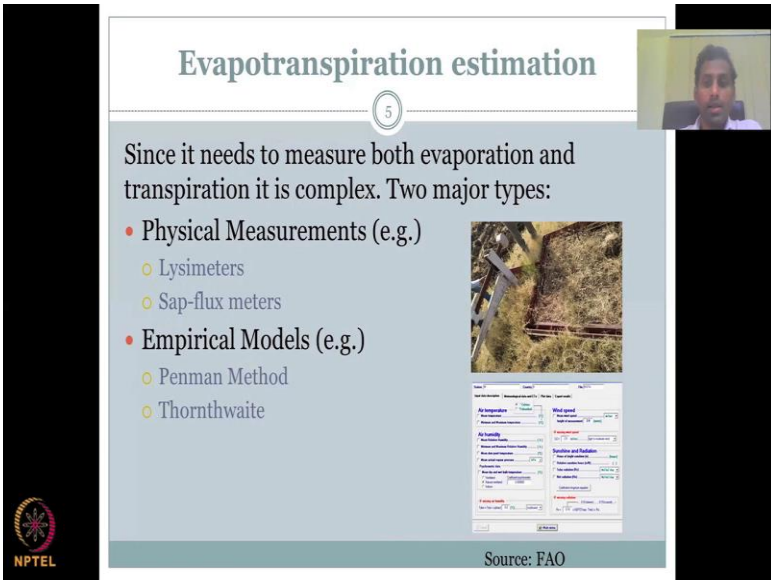

Now we have come across these two important terms evaporation and transpiration. Let us see how we could measurements. Since, it is measured mostly together. So, evaporation can be separate, transpiration can be separate. However, in most rural cases where we are doing farm assessments, or field assessments we club it with transpiration, as measuring both together it is kind of complex.

And there are two major types, which is your physical measurements and your empirical models. Let us look at the physical measurements, you can have the FAO prescribed method on the screen and you can see that it is a big mass which is being measured before and after applying the water. I will show you the cross section, so that you can look at it the first method is Lysimeters and other meters Sap-flux meters.

For the flow of the class I would explain one method which is the most accurate which is the Lysimeters. Empirical models are models which are statistically made by relationships with other variables. And knowing one variable, you can estimate the ET. So, knowing couple of variables, you can estimate ET because the ET is a function of those variables.

So, some other models are like Penman Monteith or Penman method, the first method was Penman method, then people worked on it to convert it to Penman Monteith. Thornthwaite, method, et cetera. We would look into not the equation, but what goes in and out of the Penman. And there are very simpler model sites, KC method, so I will go into the KC method by FAO. Let us at the physical methods, which is your lysimeter.

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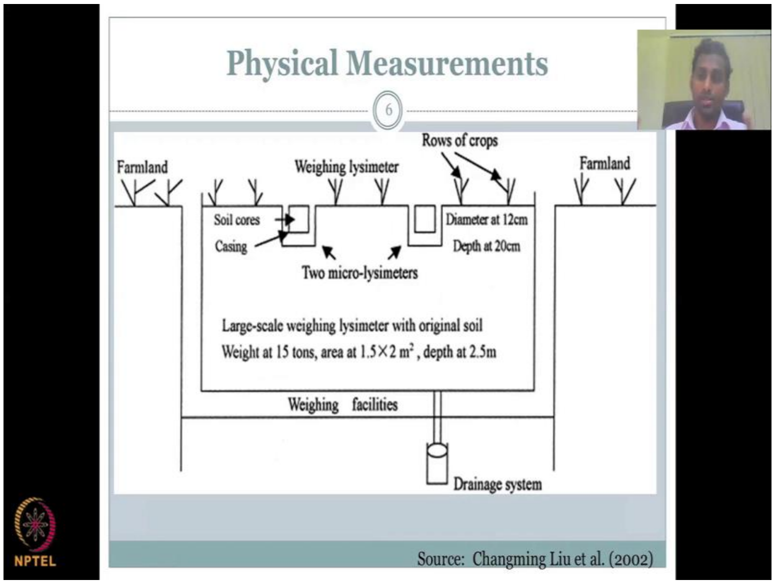

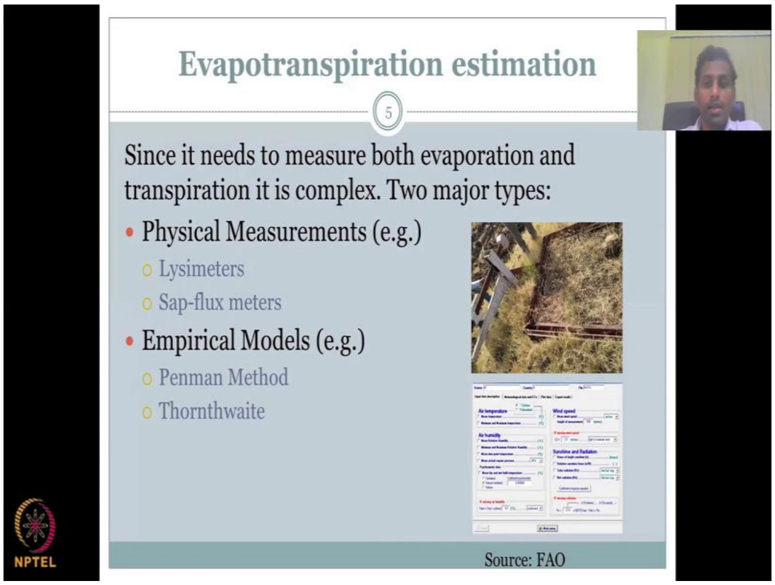

So, this is a cross section of the lysimeter. What you see here is a farmland. So, first we visual a farmland and you are cutting a cross section in the farm land. So, you are looking at the side view, not on the top, this is your top, you have a crops growing and I am looking in the side, this is your cross section. What you see is crops growing. So, crops growing on the top, and you have two places where you have some micro lysimeters.

We can ignore that for now, but it is a piece of land, can you see, this piece of land is first evacuated out, and then a mass balance scale is put in. So, big measuring, weight measuring device is put in here so as a weighing facility. Just like if you see a truck going and standing on a weighing scale, truck full of load, that is how they estimate how much load of truck.

So, they will take the truck, they stand on the scale, they weigh the scale with the truck before or before emptying, and then they go, after emptying they come back and then they estimate very load. So, it is a large scale land mass, which is taken out. Look at it, its weight at 15 tons, and the area is 1.5 to 2 meter square and then depth at 2.5 meters, so that is 2.5 meters, approximately 15 tons of land is evacuated.

You have to be careful, you should not disturb the soil. It is evacuated and then you put the mass balance inside. Once you put your, then you put back the land. So, this is your land, you take a piece out, you put your scale underneath, your scale to measure the weight, then you put back your land and in the land you start growing. How do you grow crops, you apply water.

So, when you apply water, the mass would be increased because you are adding weight through water and the next day the water would have evaporated or transpired. So, the water is lost and your weight would decrease. So, now you have a weight of your water which has been taken up or decrease and from the weight you can estimate the thickness of water that is being taken out.

So, this is how Lysimeter in real life looks at. I have taken this picture from the Parbhani University in Maharashtra. See that this is the land piece that was taken out and the mass, scale, which is put in, you should be have grass growing, it is the same crop on both sides. So, when we apply water the scale, here you could see the scale would accurately measure the land with the water and next day I come back and take a measurement.

All the water has been either evaporated or transpired. Knowing the soil I can estimate how much evaporation happens. So, most probably will come back to transpiration versus ET is one term.

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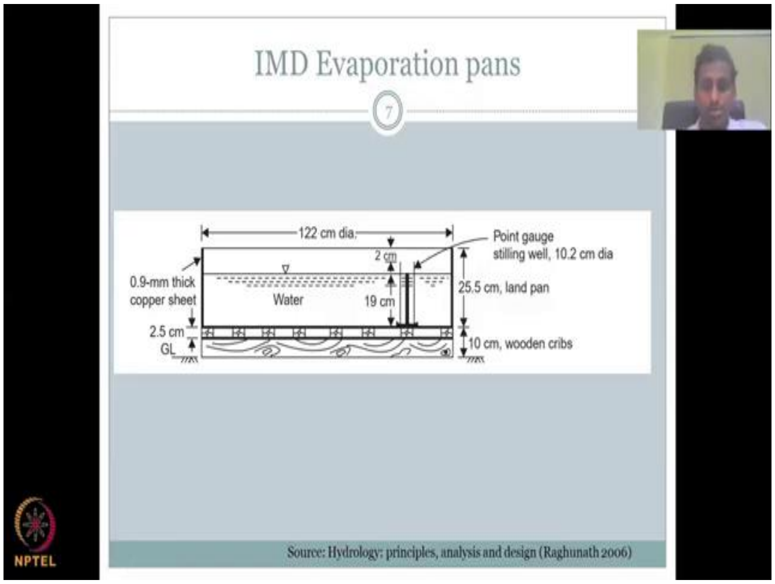

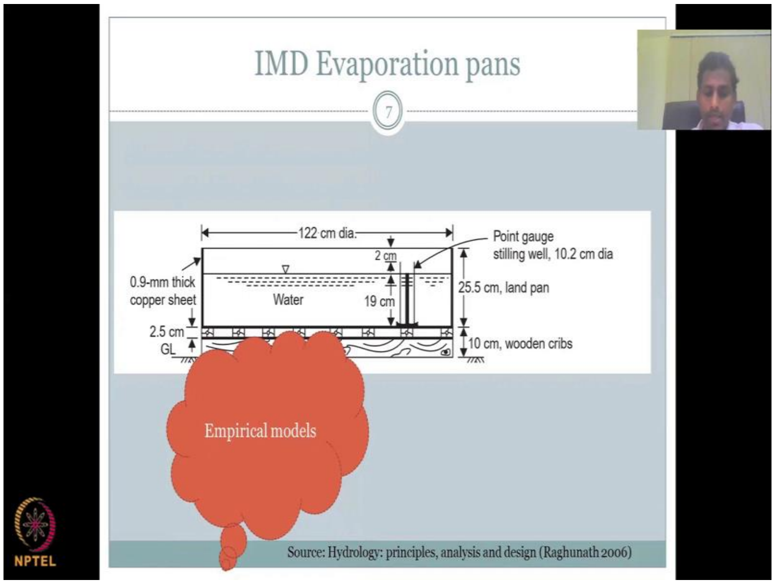

So, now we have estimated evapotranspiration, what about the open bodies, water bodies, et cetera, there is no crop, there is no land there. How do you measure transpiration? So, transpiration is 0. So, in open water bodies evapotranspiration is only from evaporation. So, we can label it as evaporation. To measure ET, IMD has a evaporation pan technique which is basically a aluminum pan you could see.

There are multiple dimensions for it, which is given in the figure, but most importantly think about visualize a pan. So, this is a pan with water and a scale, a scale to measure the height of the water. So, the first day at 9 o'clock in the morning, I would measure the water or 6 o'clock before sunrise or at sunrise I would measure the water level and then the next day I would come back and measure 6 o'clock or in the evening after the sun has set I can measure the volume.

So, what has happened in the whole day is when there is no rainfall and these are done only when there is no rainfall. When there is no rainfall the water level would decrease because of evaporation from the top and that decrease is the rate of evaporation per day. So, if you are doing it per day, analysis per day. So, it is very important to not have data taken on rain rainy days.

So, most probably it is done on a wet, not wet day or dry day when there is no rainfall. So, you would estimate your water loss as a thickness which directly goes into your water budget. So, this is IMD evaporation pan technique. So, now we have looked into the major physical methods by measuring evaporation, for evaporation and transpiration or ET together. Let us look at regions where if you do not have these, how do you estimate?

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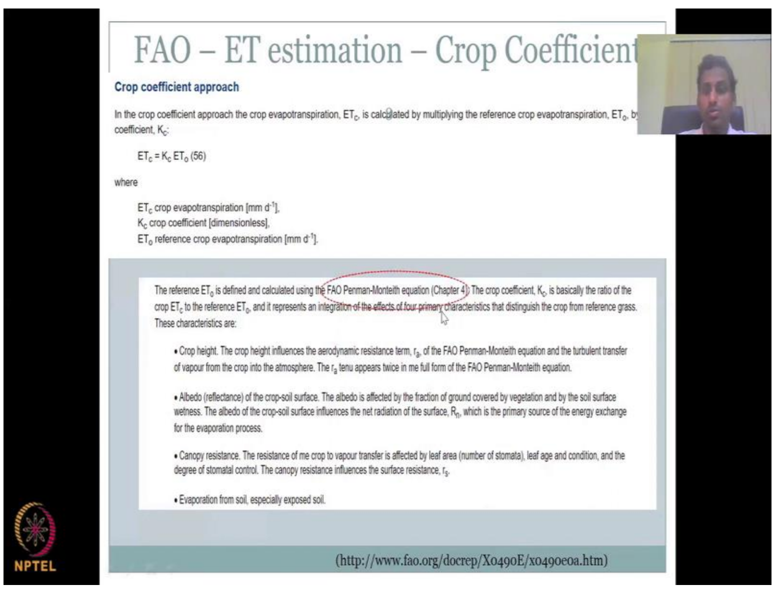

You have empirical models. Empirical models are developed by understanding between variables and how ET is a function. Let us take an example. The crop coefficient approach is a simplest and most widely used because it is promoted by the FAO. You could see that the simple equations Etc, which is Evapotranspiration of crop is equal to Kc which is your crop coefficient times ET0. ET0 is the reference ET.

So, if you have the definitions here and what is your Kc is, it is a function of your plant. And it is a function of your crop height, Albedo, reflectance of the crop soil surface. So, it is both the function of the soil and the crop of that particular location Kc, Canopy resistance, how much the leaf area resist the water loss and evaporation from soil.

All this is a function which is already built and given by FAO and different Kc values are given for different crop types and different regions; for equatorial regions, tropical regions, humid, semi-humid all those things, so if you can go to this website, I have given on the bottom, you can easily get Kc. And what is ET naught? ET naught is a reference crop evapotranspiration for that particular area. So, both if you see are units of millimeters per day.

And if you are going to report it your hydrological cycle as per days, if the per day unit goes off, it is just millimeters and then your ET naught is a reference crop. Most probably it is grass, alfalfa crop or any other reference crop for that particular region and all the ET value, ET naught values are given in a FAO. We use alfalfa crop for our region also.

So, ET naught would be a higher value whereas Kc would be a smaller or much, more or less closer value. So, ETc is a multiplication of this. So, it is a function value, because ETc is related to ET naught and Kc could be the proportionality constant. So, reference ET naught is defined and calculated using FAO Penman Monteith equation.

As I said, it is a function of multiple variables, wind speed, temperature, radiation coming in, tradition going on, so very complex equation, which the FAO has done for you. So, you can take the ET naught from chapter four, and you can estimate ETc by knowing the Kc and the Kc is also given to you by FAO.

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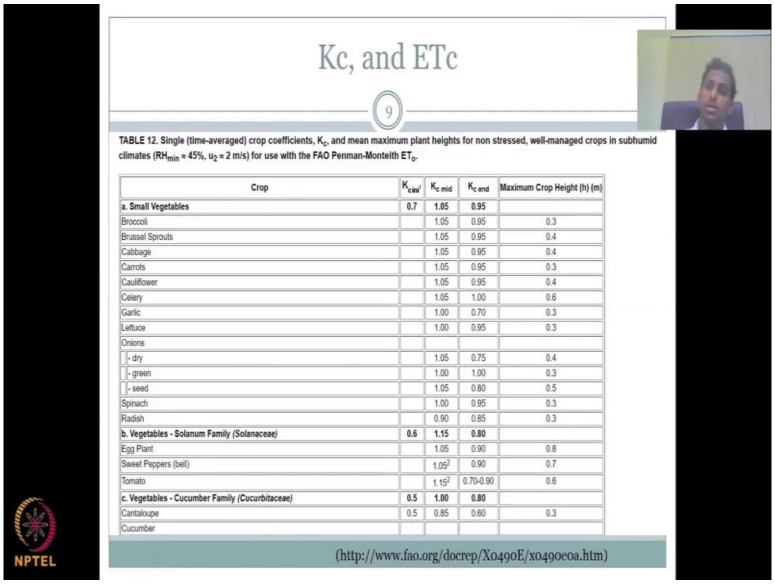

Let us look at some case Kc values. So, these are the Kc values and as I said the plant grows and then the initial period is Kc initial and then the mid range is when the plant almost matures and then the end is when the plant is dying off or ready for harvest. So, you could see that initial stage the plant does not take, consume much water because it is having less area of leaf or other aspects. The Kc mid is when it matures.

So, that is the max, you can see all the max values are in the case Kc mid, and Kc and is when it is ready for harvest, dice down, et cetera. So, if you look at these for a particular crop height and a particular crop, the FAO has given you the data for Kc. Let us take cauliflower, carrots, so you have 1.05, 0.95, there is no Kc initial because it is under the ground and Kc mid is there. But for small vegetables like you have your brinjal, et cetera, you have some Kc values, eggplant here.

So, you do have some 0.61, 0.15, 08, et cetera. So, from this exercise, you could calculate your Kc. From the previous ET naught from chapter four, you can take your ET naught and you can estimate your evapotranspiration. You can see how it is a very mathematically empirical based model. So, these are the two methods widely used. One is physical method and then you have your Empirical Method.

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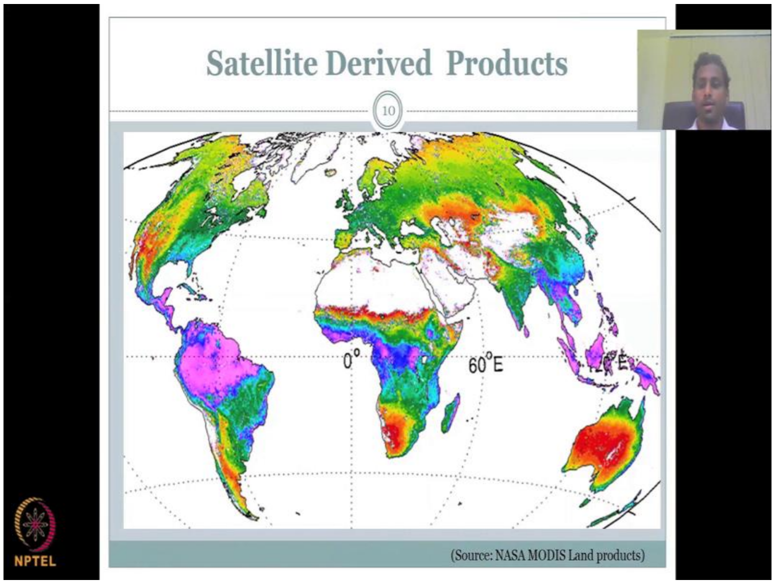

On top of that, we also have satellite remote sensing derived products. So, satellites which are on the top we have already said that it has been used for measuring precipitation, it can also measure indirectly your evapotranspiration. So, they have some capturing devices, image capturing devices, which are related to your evapotranspiration, an amount of water vapor that accumulates in the atmosphere. So, you could see here an image taken by NASA MODIS platform, it is open source, anyone can take it, and you could use it widely.

And many of the Indian data products you can find in ISRO and also are derived from satellite products. The one issue is the scale; the scale might not be as a small village or even a plot scale, so that is hard to get that values. But for a village or a district boundary you can still get good ET values from the satellite products and more importantly, it is open source, free to use and cost effective. So, these are multiple methods.

So, we have discussed today about evaporation, transpiration, one of the process, we have combined them together as evapotranspiration. We have looked at why it is important in the hydrological cycle. We have looked at what are the methods to measure physically and empirical method and if these two method are kind of costly and not available readily you could get into your satellite products. With this we have conclude the evaporation part of the seminar or lecture. Let us meet in the next lecture.