Rural Water Resources Management
Professor Pennan Chinnasamy
Centre for Technology Alternatives for Rural Areas
Indian Institute of Technology, Bombay
Week 12 - Lecture 60
Rural water management models

Hello everyone, welcome to Rural Water Resource Management, week 12, lecture 5. In this week, we have been looking at the data that is needed for rural water resource management. We have looked at multiple data sets ranging from hydro metrological data like rainfall and then location of the recharge structures and also some other data on government plans, crop type area, groundwater, everything we have been saying. Now, what do we do with so much information? We need to process it into some kind of an algorithm. So, that we know what is the water available in the rural areas and what can be done about it.

The one issue we have here this that the model that we developed using the budget, water budget equation may not hold always good, why, because the water budget is in one timestamp. For example, you write your storage is equal to precipitation minus soil moisture minus groundwater discharge, etc. That is for one-time stamp. But there is a need to automate it so that you have a longer time series of what is happening and where the water is going because just one-time stamp will not be enough to do a successful management scenario.

In that respect, there is a need for a model that can capture these changes and then automated behind in the model software per day or per timestamp. So, it collects the data, it evolves from one-time stamp to another timestamp. Normally it is a day so from one day to the next day, and then it predicts or gives the outer.

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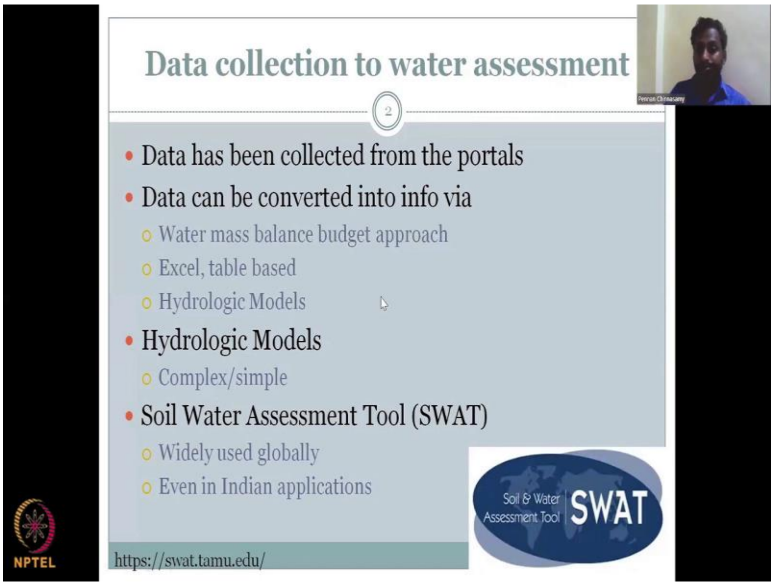

Let us take what we have done so far. So, data correction to water assessment this is what we are aiming to do. We have collected a lot of data. Now, we need to focus on the water assessment part. How do you do that? Data has been collected from different portals. As I said, we use WRIs, we use remote sensing is through women, we have seen a data from reports, both NGO and public reports and government reports. In fact, there are there is some data from World Bank and other agencies also that can be protected.

This data has to be converted to information. So, that is the lag. How do you convert numbers and values into information which is how do you get information from these kinds of data? There is a conversion process involved because just numbers does not make anything. Only when it becomes an information, it becomes useful for the policymakers, stakeholders and general public. Let us take the first example of water mass balance budget approach, we use the water balance. However, as I said, when you do not automate it into an information, it does have no value, all you get is plus minus your budgets and then you get a net storage.

How is that storage changing? The change is very important. And how is that storage reacting to a good rainfall, to a good management scenario in the village is important, so, most of the water balance approaches that we saw were Excel based. As I said it does not fit into a larger scale or a larger type series. So, there is a need for hydrological models. And these hydrological models use the same data that you input in the Excel sheet or the water budget. Here what happens is there is more sophisticated ways of integrating this data into information.

Hydrological models can be complex and simple. So, I am just going to go through some definitions of a hydrological model. So, it is basically what type of water balance does it use, what type of equations does it use, is it a physically based model which means it is driven by physics in terms of mass, energy conservation, a momentum and your water coming in, going out those kinds of analogies, whereas your empirical models are models where it is based on statistical approach for example, every year we have rainfall in June in Maharashtra, so, that we do not need a model to tell that the climate circulation is happening.

So, you will get rainfall in June, this is based on statistics, the 100 years rainfall says you get rainfall in June and you do get rainfall in June. So, based on these kinds of methods of how the model is at the end of the day, you want an information about the rainfall, how the rainfall converts into storage. So, this if it comes quickly through your empirical models, then you do not need a very complex physical driven model. So, it is based on your need and your location and data, what type of model you want.

So, hydrological models can be both complex and simple based on the equations they use based on the data they use. And one such kind of semi complex model I would say is a SWAT, a soil water assessment tool, which has been widely used globally everyone every country has been using this model for their government reports and also in Indian applications there are a lot of references to the SWAT model. In fact, the ministries of water and other agencies do use modeling tools and SWAT occupies a very dominant position most agencies.

Now, what SWAT differs from other models is first it is open source. So, you do not need to pay a lot of money to use it and learn it. There is no need of special capacity built for SWAT because a lot of learners in the world and there is an explicit forum where you go and put your question and people will answer to it. So, these all these resources are available at swat.tamu.edu, it is from Texas A&M University in the US. So, there is a model which has been supported widely in academic development. So, which means it will be very strong, because they do evolve in academic institutions.

The other aspect about SWAT it is a kind of a semi lumped model, which means you take the area of interest and the SWAT model would break it into smaller components. For example, if you take a sub basin or a basin, it will break it into HR use, hydrological response units and within the hydrological response unit, the water balance equation holds the same. For example, when you have a different geology or a land cover, the hydrological balance will change, the infiltration rate will come down, the percolation will be different, storage will be different, etc.

But that requires a very complex, more complex model. And sometimes that high level of accuracy is not necessary. So, what you would do is you would use somewhere in the middle a model, which can be free open source to learn, and also has a high level of complexity, thereby letting you understand the physically driven processes. So, it is a physical driven model. And it has different routing mechanisms for water hydrology, and etc. And it has its own limitations when it comes to data, and groundwater, etc. It is not a groundwater model, so it just does infiltration.

What happens after the infiltration, it does not care, it just goes down or goes as base flow, it does not put it very accurately. The other part I would like to tell is that there is also an active forum and developer's conference happening for SWAT those who are interested in check the website and learn it through these models and exercises. So, the entire approach, what I said is you have an Excel where you could put all these data that you collected and then estimator net storage or change, and that could be cumbersome that it is not real time updating, etc., whereas your models can be run on real time and also it can quickly convert the data into an information and give decisions.

In addition, SWAT has all the data you need to at least set up a model for Indian situation, all the data is kept at swat.tamu under the Indian data tab for India. So, just for India, they have very good data source, including your climate data, which is your rainfall, temperature, wind speed, etc. And your land use land cover data etc. As I was saying that is this model is a very sophisticated model in terms of it is a lot of data. And sometimes if you do not give the data, it will have the default assumptions. And those assumptions might kind of pull down your result.

So, please understand that it is also good to have a sophisticated model, but you need to give a lot of data. Rather than that you can have a simple model with less data. So, all this depends on your location, and the availability of data. So, now I have showed you where to collect data. But sometimes you also need more data for your models like SWAT for which you can get from government agencies in those times you just put it as a assumption in the model.

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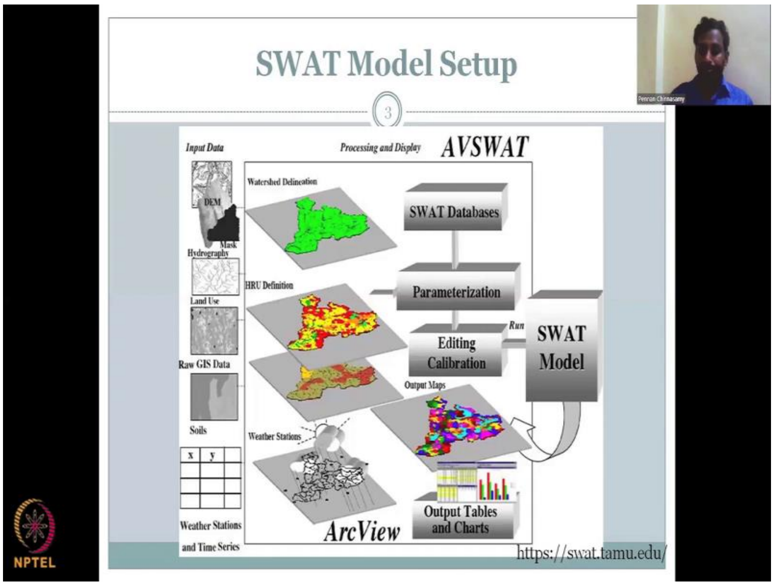

Let us see how the model is set up as I said, you do have all your data on your left-hand side which is collected and kept in separate folders or data bins and then that is mixed into the SWAT database. So, for example, you have your input data from your DEM, which is your digital elevation model, basically the elevation of the land, and that data can be taken as a remote sensing data as a raster as an image. And that can go into the SWAT framework, which is here. Then you have your hydrograph of the river discharge, which we already gave from WRIS and the river networks if you have you can use it.

The land use land cover can be taken from Google website I have mentioned or your own site, you could go and collect data for your region and then put it in as a good colorful map. Then you have your soil database and weather stations, the soil is very tricky system because not all high-level soil maps are available. However, the coarse resolution is there in the FAO database. And in the SWAT database that you could use. You could also take it from Google, which has a kind of similar scale soil database.

But throughout the world, people normally use the FAO harmonic harmonized soil database which has a combination of data to make these soil databases. Then you have the weather stations, the location x, y and the weather station and the parameters like temperature, rainfall, humidity, wind speed, as lot of data on these hydrological parameters, weather stations that is needed and the long time series, so what is a minimum timestamp of daily and then it can do monthly annual, etc.

So, you cannot capture the sub daily events, for example, you have a flood and the flood happens only in one or two hours, you cannot capture that in SWAT. It can be accumulated as a per day rainfall and then per day flood not as a sub daily level. So, that is the only time scaling issue that the SWAT has otherwise it has been widely used in many countries. So, then we have the other processes that run in the SWAT, which actually as I said, it takes the watershed boundary, it defines the boundary.

So, we had a class where we made sure we drew the watershed boundary. Here in this model setup, it will do it for you, it will just do the watershed boundary based on the elevation data you gave and also based on the outlet point you are interested in. Next, it goes to the definition of the sub basins at the small units which is called HRU and in the weather, data is actually mixed to it. And the databases are used calibrations that run the models rerun after validation and calibration. And at that last you get the output tables and charts.

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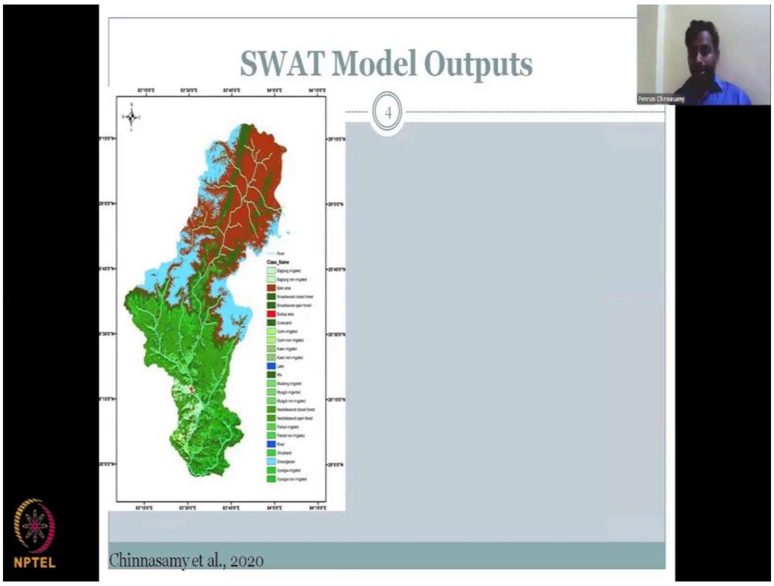

So, the output tables have as a chart as I said in Excel format down, you could see it, but then you need to convert it into maps and other information visuals on a GIS platform or very sophisticated mapping platform. So, I am going to show you some results and tell you how walk you through how this helps in accumulating data and then rural development for water. So, the first thing I would like to show you is a study basin in Nepal, where you see the land use land cover has been made at a very high resolution, this is your satellite data, ground data which has been useful for a mapping and that is an input data.

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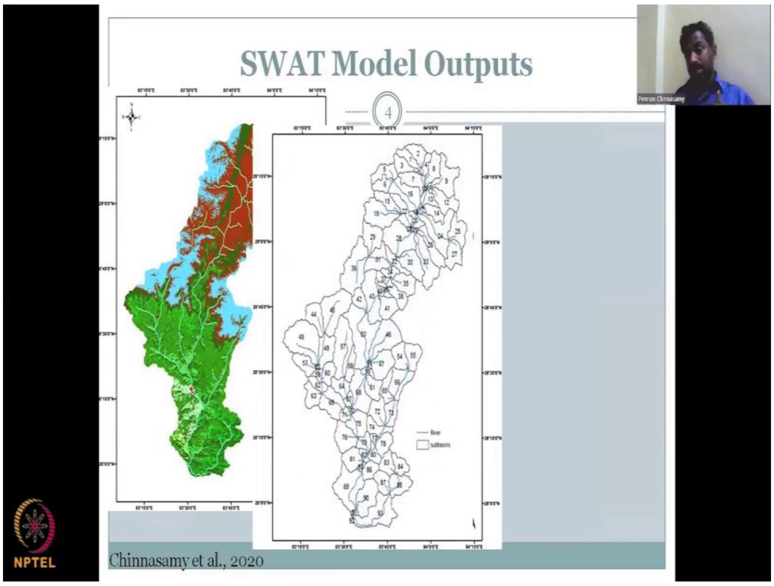

Now, then the sub basins being created, the HRU's are being created by this SWAT model, you do not have to give these boundaries it will make it based on the elevations and where the stream emerges or starts and then where it joins the other streams. So, you could see here all the small sub basins will have a small small river network coming and so which means that each one is on by its own a basin, but when it is in a bigger framework, it becomes a sub basin in a bigger frame.

So, all these sub bases will have to drain and then bring the water down to the outlet point which is in the sub. The north, the water comes, the streams start to emerge and then the time of concentration rainfall moving into runoff and then comes down as discharge. So, again if you can see that each one sub basin you do an Excel water balance equation, but can you do that for every location is the question which is not possible. So, you cannot do one equation here, one equation here, one equation on Excel or a table and then give the output. So, for that, you need a sophisticated model like SWAT.

So, what it does is SWAT would take this water this sub basin and then rainfall is occurring, it converts into runoff and puts it into the river stream network you could see here. Now, this stream number two basin did not have any other sub basins giving water into it, so the issues are very less is a very straightforward.

But now 2 would lead into number 7, so, number 2, in a state 45 because it is bigger to see. So, 45 does not have any other water coming into the sub basin. However, whatever water is created into the streams push into the streams at sub basin 45 is going to go to 49 and then 49 goes to 50 and then it goes on and on. So, this cannot be captured on a hand or a Excel model you need a very sophisticated model that captures waits for that river to come understands at time zero where the water is located and time t one how much water is moving across a base.

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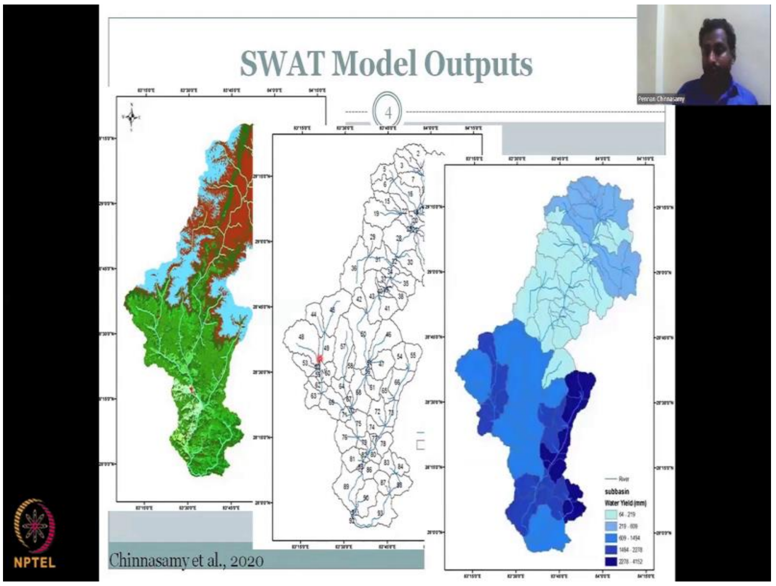

So, with this kind of understanding an analogy at the end you get a sub basin water yield map. So, water yield is the net water that comes out of these locations, sub bases annually or monthly however you have done as I said it comes as a daily timestamp. Now, the daily timestamp is converted to monthly or annual based on you in the table and charts that the output gives, so this is very similar to any other model. What I am trying to say here is you need a model to do these exercises. And the model outputs will vary depending on the model. But you could use the output to get more information based on your research questions.

Look at this example, you could see that even though rainfall happens across the sub basin at the whole area, some areas get more yield and that could be because of less groundwater recharge, more water coming in or more flashy floods. Suppose rainfall is the same across the basin. Then why is the these sub basins 55, now 66 getting more water yet and that could be because of the sloppy nature or less water extraction less water losses et, less et or a groundwater recharge. So, you see how we could make these connections come through.

The other connections that come through is these smaller basins would yield to a larger basin because the water comes in when you are here, there is no water from the outer basin coming inside because it is a lot system of watershed boundary is already there. But within the watershed, you have some basins contributing between each other, and that helps in increasing the water yield in the downstream locations. Let us look, so now we have done the basic baseline scenario, how much water is there and how it is distributed across the sub basins, now, once one baseline here.

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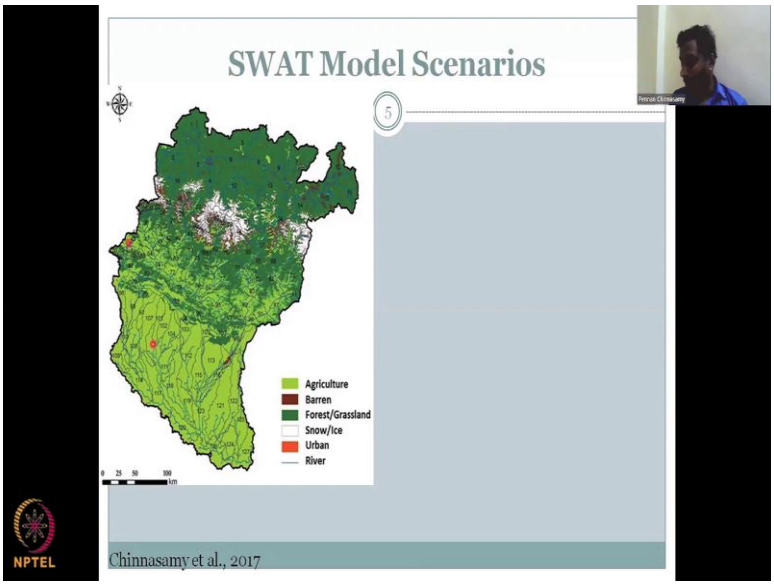

You can run scenarios, so that is the beauty of models. Once you set up a model to capture the current scenario, you can use the same model to add different scenarios and wishes. But one scenario is for sure the climate change. If I know 5 years later, this is the rainfall I am going to get. I can put that rainfall in the model today and understand how the yield would be distributed. And also, the land use land cover.

So, let us take one example like that, before we close this class, we have for example, the Koshi basin which I have been telling that it is a transboundary basin which starts somewhere in Tibet, China flows through Nepal, and then comes down to India and feeds into the Ganges basin. Koshi is one of the biggest contributors of a water to the Ganges basin.

And you could see here that the land use land cover is Forest grasslands on the northern part with some snow and ice, the Himalayan range and then down it is a lot of agriculture which is the Indian side, sloping land is less, more fertile plains are there, the aluminum has been deposited and this plane gets more agricultural activities.

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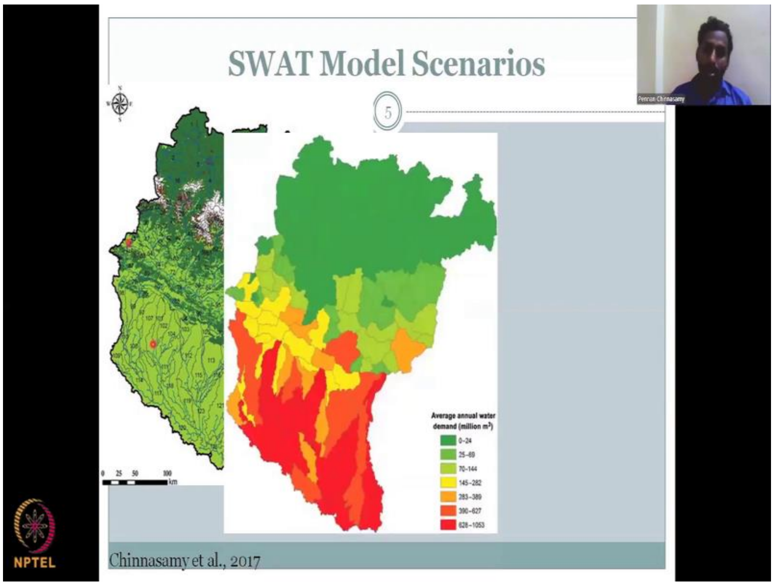

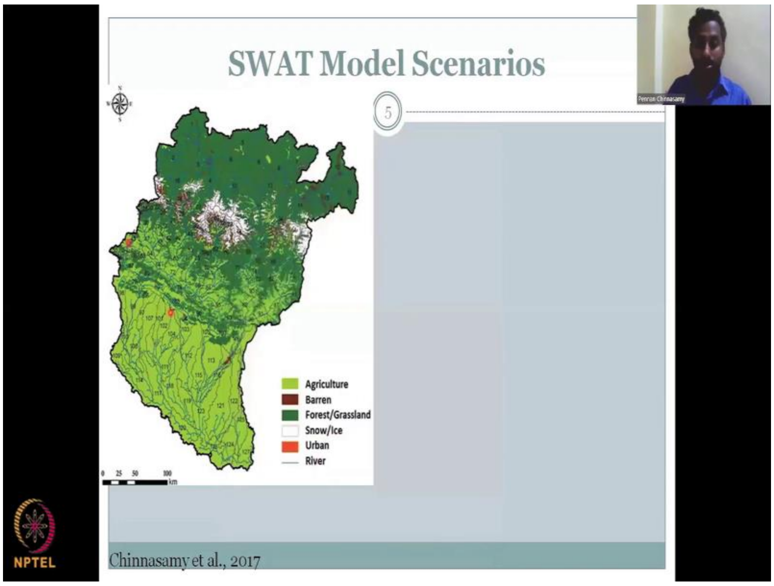

So, what has we have done is once you set up the baseline model, we were able to look at the annual average annual water demand. So, once the water yield is put now I could put the different demands that is inside the basin. So, one could be agricultural demand, domestic demand, industrial demand, etc. So, once you put that demand, you could actually visualize where the whole activities are happening. For example, you can look at the first image I will go back to the first image again, you see here is where agriculture is happening, here is this forest and grasslands and snow.

So, most of the ground water or rural water uptake is going to happen here but demand is going to happen here. And that is well captured in this location. Within that location, you do have some less demands. And that could be because of the variations in cultivation of crops and or the variation in land holding the water. For example, if there is a big flow coming into these smaller locations, mostly you are not going to know any agriculture inside the river, only around the river you will took. So, those lands are given up saying that it is not a you cannot do any agriculture. But near the river, there is a lot of land that is used for agricultural activities. So, now you could see a good understanding of these green, light green is a person's agriculture and that also represents red in the annual water demand.

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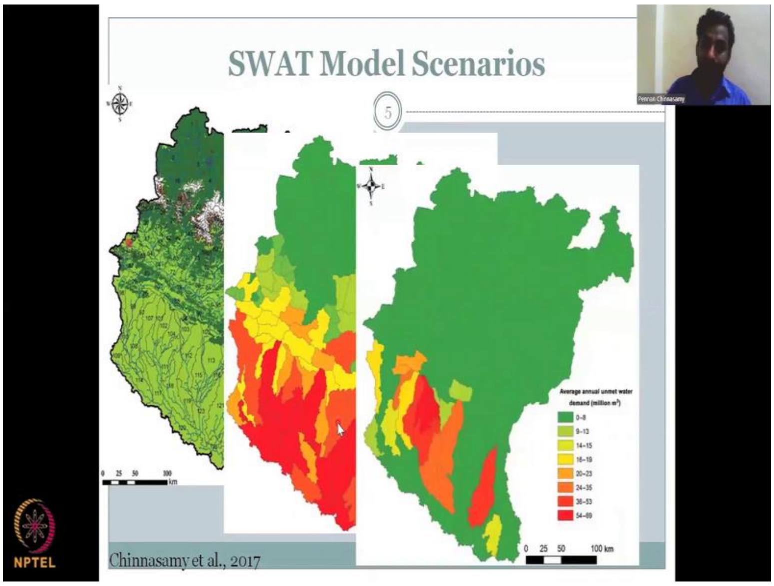

So, now we have run the model we've taken the water yield per sub basin. So, now the only thing to do is how much water is coming, what the water demand is, are they meeting each other. If they meet each other, then the unmet demand is 0 which is green color 0 to 8, which means I do have water coming into the basin to rainfall water yield and I know there is a water demand. If the demand and the water yield cancel each other then it is a healthy basin you are good like in terms of water managing, but that is not the case. Mostly it is negative which means you are using or demanding more than the actual water available, clean surface water, so, we are dealing about this as only surface water.

But then once the demand is high and the supply is low, what do you do? We look for other supplies to augment your demand. For example, you have a demand of petrol. So, nowadays you do see that petrol is mixed with other additives to increase the volume and the demand is high and so, what you do is you cannot just say people use less, you will have to match their consumption in the industrial sectors. So, for that they have given a mixture of petrol, which can be used for transportation. So, here that is the understanding here.

So, if I know the water yield and lot of water is lost out of the system and I know that there is a region where there is a water demand scenario unmet demand, then I could save the water and then reroute to the station. For example, in this excess water, in the central and the southern regions here, you could end here also.

So, you could save that water routed back to these red zones where the unmet demand is high, which means, they need the water, the industry is set up, however, the demand is not met because the water is not available. So, these are typically the scenarios that you could work with only if you set up the model and do these calculations.

And you could be creative on these calculations and explore more and more of these model intricacies because a lot of models are being developed. However, have they been valid on the ground is a question. So, you need to validate it on the ground, use it well. So, SWAT has been multiple times used in Indian scenarios.

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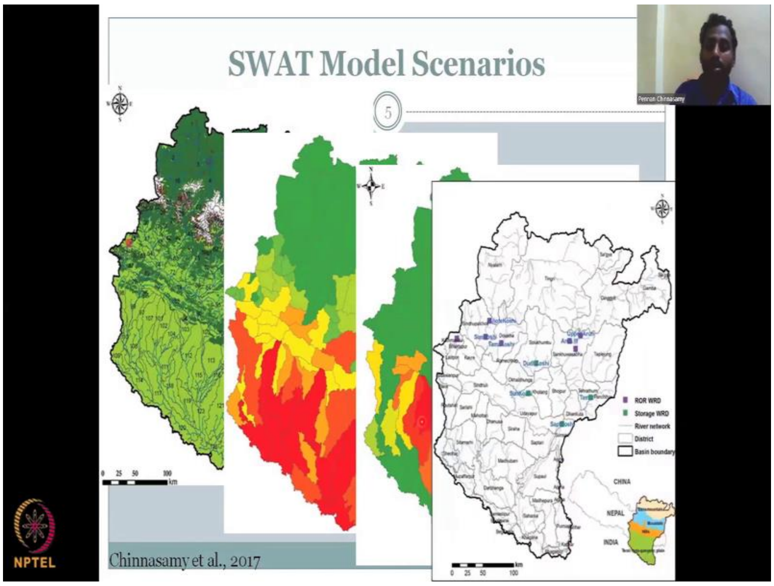

And then finally, where to put your recharge structures, check dams, large dams, etc. So, now, as I said you have unmet demand downstream, there is no point of stopping the water at the downstream location, but upstream where the yield is high excess water is there only when there is excess you have less demand, demand is always met.

So, hopefully the other regions have excess water and they are storing with you through the canals because gravity is there or pump transfer which a lot of southern states have also looked at in India, like which means you supply energy and then transport water from one end to the other. All these are good scenarios that can help especially the investment side of the government, where they can invest and bring people in to put these systems in place. And also, most importantly, it gives a clarity of where the water flows and how it flows for development.

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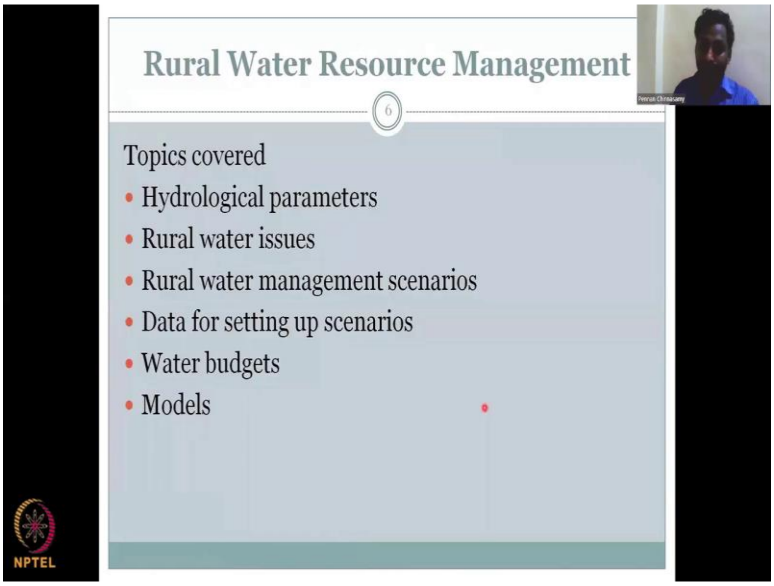

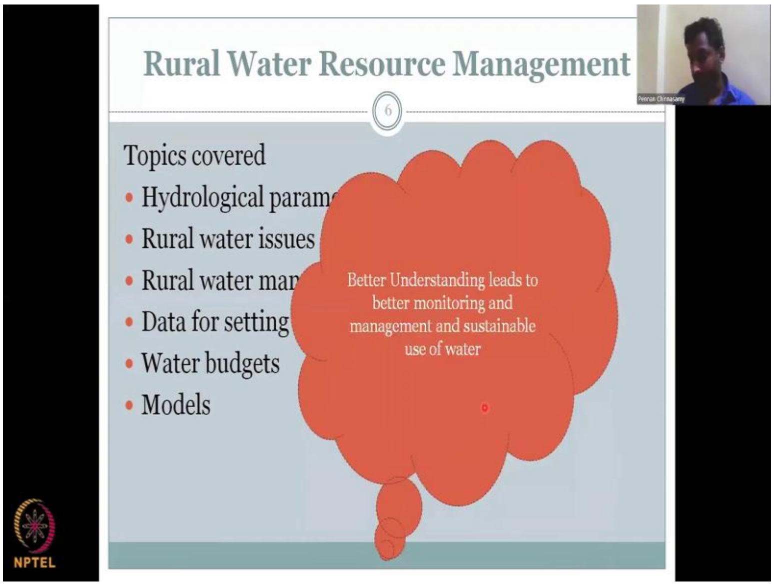

So, that it can be used further. So, we are coming to the close of this wonderful NPTEL course on rural water resource management. I really hope you had enjoyed this course as much as I enjoyed presenting it and I hope I have been able to sensitize you on the rural water issues and what are the ways have, so mostly we discussed about a hydrological parameters, what makes the rural water system and where is the data, etc. We looked at rural water issues, why rural India is facing so much water issues. And then which led to the different management scenarios both nature based and engineering based and different different scenarios where you could actually slow down the water and use it within your villages and stuff.

Then the last two weeks, we were extensively focusing on the data for rural water assessments. And as I said, a lot of people have come to a stage to talk about rural water development, but the data is lacking. So, that should not happen to you. And that is where I made sure I would spend 2 weeks on the data collection and showing the data portals. Once you have the data you can establish your water budgets. And since the water budgets may not be able to automate by self or have full vision of the watershed or holistic linking everything into the watershed, you need models and models can do that work for you.

All you have to do is give the data, make sure the model is correctly validated and evaluated before it runs fully into the system. So, all these topics we checked through and in the data section, we carefully pick only the major data that you would need. However, there are other data that could be possible, or could be needed based on the model you select. In those kinds of scenarios, I would recommend you to read some papers that have used these models and where they got the data. Mostly they will give the data. If it is a private data collection, which just means that they collected the data, they use the data, it might be hard to get the data, but I have taught you how to use report to cite it, and then use the data indirectly.

And the models, there are a lot of costly models, there are a lot of open source models. So, you are free to choose whatever model you would like and work on for sustainable rural water development, and rural water resource management. So, I hope this course led to a better understanding, because you the key is understanding these concepts, understanding the water balance, where the water goes, why it froze in a particular way. And I hope that better understanding leads to better monitoring and management situation because a lot of these monitoring and evaluation is not available.

But a lot of structures have been without knowing if they work. So, there is a lot of money and so, it is better to understand the global issues, understand the science behind the rural water issues, and then work on better management and monitoring solutions. This would lead a new wave of sustainable use of water, which is very much needed for the coming years because with climate change and ever-increasing population we are in the great need to manage water and save as much as water we can. With this note, I would like to thank everyone for coming to my course. I hope to see you in the future courses and I hope all of you do well in the exam. Thank you. Namaste.