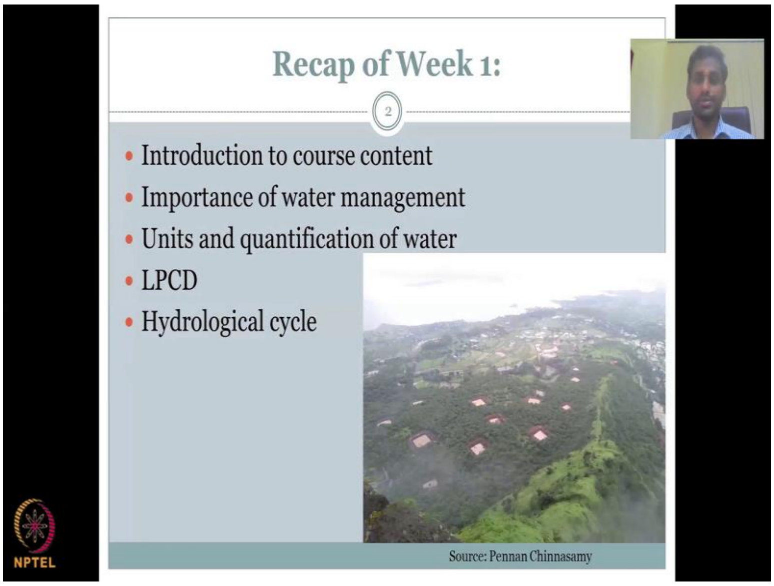
Rural Water Resources Management
Professor. Pennan Chinnasamy
Centre for Technology Alternatives for Rural Areas
Indian Institute of Technology, Bombay
Week 01 Lecture 05
Hydrological Cycle and Course recap

Hello everybody, welcome back to Rural Water Resource Management, week 1 lecture 5. This is the last lecture for the first week. And normally what I would prefer is to go back through the weeks course lecture notes, and then reiterate how they combine together for every week. So, that would actually put you in the right track to understand why we went through these different lectures all the 4 lectures for this week, and then how it all gels together for the common interest, which is Rural Water Resource Management.

(Refer Slide Time: 00:56)



Let us do the recap of week one, what did we see and this is a small example, the image I show here, what you see here is lot of farm ponds or Rural Water Resource Management in Maharashtra region, right next to a Mumbai from there. And you could see that a lot of land has been used to segregate water to store the water and then use it for agricultural purposes because for drinking you do not need this many number of stacks.

So, what did we see? First, we introduced the course content, what is Rural Water Resource Management, we looked into concepts of differences between urban water resource management and rural and we focused more our discussions on the rural aspect. Then we looked into the hydrological cycle, where the water is available, how much water is available, I will go again one more time today, because now after going through the hydrological cycle, the different compartments of water you will be in a better position to now relate back to the availability of water, that actually drives the drives the force on why we need to learn and focus on water management for rural regions.

And we used a lot of units and quantification of water, we looked at different units, how they should be used to quantify water. And we also looked at footprints, we looked at water stress indicators, we saw how and why a particular region in the world is going to be water stressed especially Indian regions, and within Indian regions, a lot of rural regions are going to be water stress by 2030. We looked at what are the driving forces etcetera.

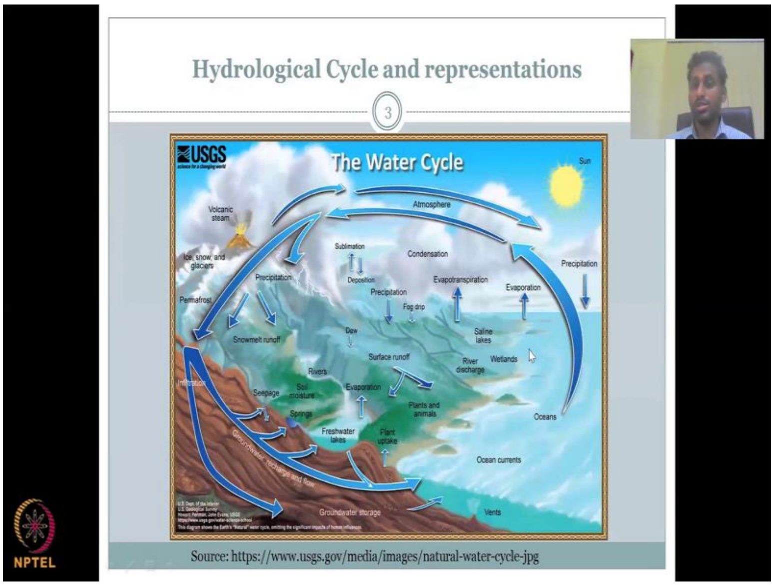
So, at first we looked at when we looked at LPCD, which is the litres per capita per day. So, how much water is used by a person per day in a household and we also went through different values and different volumes of water that has been promised ranging from 40 to 70 LPCD in the rural regions, and for urban regions, we saw that it is 200 LPCD.

So, we had a discussion on why 40 to 60 LPCD has to be increased for better livelihood options for better sanitation in rural regions, because initially there was no toilet facilities. But thanks to Swachh Bharat Mission and other missions by the government. There is toilets there is funds set up for toilets, but the water that is need to clean the toilets and for the drainage is still needs to be accounted for. And that is where the LPCD rates may have to be pushed up.

So, the government norms we discussed by 2030 by 2027, the government wants to push it to at least 70 LPCD that will be enough water for people to avoid open defecation and then use the latrines through the Swachh Bharat Mission. So, once we define the course content, we understood why we need to study Rural Water Resource Management, then we looked at the units and different parameters to calculate the volumes of water needed and water used. Then we went into the hydrological cycle.

So, even till the last lecture, we looked at how the hydrological cycle is being spanned out. What are the key variables? What The key drivers of hydrological cycle we explain the fact that if the Sun is not there the hydrological cycle would stop and it will stop evaporation, transpiration. So, they would not be any complete loop. So, all these factors we looked into the hydrological cycle.

(Refer Slide Time: 05:19)



So, today I would go from the atmosphere into precipitation sublimation. So, the other aspects because I want to close the hydrological cycle here. So, some might maybe tell me telling me that why I was not discussing how the other parameters are important. So, I will go through some of the parameters that I skipped in the rural part because now we are going to close the hydrological cycle.

So, we have volcanic stream. So, let us start with the atmosphere. So, we have clouds, I am going to follow through this arrow and then go back. So, we have clouds in the atmosphere, which is nothing but water vapour, condensed water vapour and then after condensation it becomes precipitation, there are multiple types of precipitation, there isiIce, snow and glacier deposits and there is rainfall. So, there is thunders and rainfall you could see. So, water comes down, condenses and comes down.

Once it comes down there is some rivers and surface flow, surface flow we looked at what constitutes surface flow lakes, streams, rivers etcetera. But there is also snow and some of the snow can start to melt because of the sun. So, the sun drives everything as I said so, because of the sun's radiation and the warmth some of the snow which is deposit on top of your high-altitude mountains start to melt and that water is called snowmelt.

So, like your rainfall which is your condense water from clouds into precipitation and rain, you can have precipitation into snow and snow into water and that water also comes back to the rivers. So, you can clearly see here that the snow which is the deposited on the top elevations are melted by the radiations and comes down as snowmelt runoff. So, this runoff and your rainfall runoff combined together in rivers and open water bodies.

Then, some of the water let us say surface water goes into the soil I told you in the previous example that part of the water gets captured by the trees but then goes down and as soon as it hits the earth's surface it converts to runoff which is your rivers oceans etcetera but then also it has soil moisture. So, it goes into the soil after plant uptake etcetera. So, we felt this part then let us come to this part.

So, some of the precipitation is also as permafrost and dew, dew is a form of precipitation very very small droplets of water and all of that can and fog drip etcetera. All of that can convert to surface runoff. So, we are drawing a line here all the parameters have been discussed for sublimation and the deposition is just conversion of water from one face without going to going through a intermediate phase.

For example, straight from snow it can without converting into water it can be evaporated, so same thing what water vapour instead of coming back to liquid and then freezing to snow, you can also have sublimation and deposition, so that is what this cycle is. It is a very very small part but still let us get through all the important things.

So, we have this dew sublimation, snow, permafrost all of them convert to surface runoff and the surface runoff goes into rivers and lakes and oceans surface discharge, etcetera etcetera. So, once the water gets into the river body and a stagnant water body, there is a lot of evaporation again driven by your sun. So, it is because of the sun's heat and radiation you do have a lot of evaporation. So, what will evaporates from the top surface.

So, from freshwater lakes from oceans, you see these arrows big big arrows showing that water is moving back into the atmosphere. So, water started as a vapour condensed into condensed into clouds then condensed into precipitation as liquid phase and from the liquid phase it goes back into vapour through the evaporation cycle. And then, evaporation can cool down once the vapour cools down it becomes clouds.

So, after the surface runoff and soil moisture, what happens some part some part of what it guesses as seepage and once it seeps in, infiltrates into the earth. So, this is where I said surface above and surface below. So, below the surface the water can infiltrate into the earth and come down as deep groundwater.

So, this is the deep groundwater, which is taking sometimes millennia 1000 years to reach to a point. We will get through that when we discuss more on groundwater for rural regions, but mostly, you see this cycle, which is the shallow aquifer, water infiltrates comes down into the ground, and then seeps out some of the water can come out as seepage, what is it called in Indian terms, it is springs.

So, if you go to the Himalayan regions, or mountainous regions, you see waterfalls springs, which is suddenly in a hill or mountain, you have seen water seeping out. So, that is seepage, that is water which has gone into the ground and coming back out. So, that seepage can be a spring, it can be a waterfall, anything that comes out of the ground.

Then some of the water can also get directly into a water body. So, we do not know how much this is because you cannot see it. So, when you see a river or a lake, some of the water can also come from underground the lake, so that part is your groundwater, saying how water can come from the groundwater to the lake, part of the lake water can also get down into groundwater.

So, that is the groundwater recharge. And this is the groundwater discharge, all these arrows which are going from the groundwater into the earth is called above the Earth is called your discharge, whereas here it is recharged, it goes into a ground water. This does not happen that quickly and easily. So, that is why we have wells, we have wells and farmers put in pumps in rural villages to pull it the water out.

So, as I say, this particular face these particular drivers are very limited as much as you have this one. So, recharge happens a lot. This does not happen that much. Why? Because groundwater gravity forces there. So, water by default wants to move down only when there is a pressure difference, there is some constructions to flow it moves out like this mostly by pressure difference, when the water is… water always moves from high potential to low potential.

So, these are high potential energy, when it down to low potential energy. And same thing, high pressure to low pressure. So, then it finds a weak spot in the earth in breaks the part and then comes out. And that is where you have springs, waterfall, etcetera etcetera, you will see water gushing out. So, when you see a waterfall, it is not water coming slowly, so like gushing out with such a force. And that is because of the pressure difference.

So, as I said a lot of recharge happens, but not much of groundwater discharge. And that is why people force it or we force it by using pumps, industry or rural pumps for irrigation, anything that pulls the water out against gravity, and by spending a lot of energy, so then groundwater also gets stored here, which is the groundwater storage.

So, there is a tank, just imagine like a tank which is under the ground, it stays there, because there is a void there is a space water that takes a long long time to get in would not easily come out. So, that is the groundwater storage, there is deep and then shallow groundwater storage. And if you hit it right by the pump and bore holes, then you can take it out and that is what is happening in most villages.

So, you had all these precipitation converting into rivers and lakes and discharge and then all of the water if you see goes back to the ocean; the groundwater, your river water, your lake water. So, there is a very philosophical saying of this too, right all streams all water comes to one point so that is this point, oceans. So, you it goes to the seas, seas are smaller, and oceans are big. Pacific Ocean is big, Arabian Sea is small. So, it goes to the seas Bay of Bengal, all of it and then goes back to the Indian Ocean for Indian context, I am saying.

So, ocean is the place where it finally ends, all the water movement stops going into the earth side, and then goes back up. And that going back up is driven by your sun. So, as I said, you have your sun and this cycle is not complete until it brings it back to the cloud. So, it may not be you do not have to start from the cloud. You can even start from the ocean. The same cycle will happen. Water converse from ocean to clouds, clouds to rainfall, rainfall to groundwater, groundwater to freshwater, freshwater to oceans.

So, you could see here that the salinity is remaining back in the oceans. It is the same water. The oceans have water plus salinity, but when it evaporates and comes out and rainfall it is called freshwater which is it is not saline, there is no salt in it, you can comparatively it to a much, much lower. And this is what they force it in a desalination plant they heat the water, pull it down and then do all those things for remove the salt out.

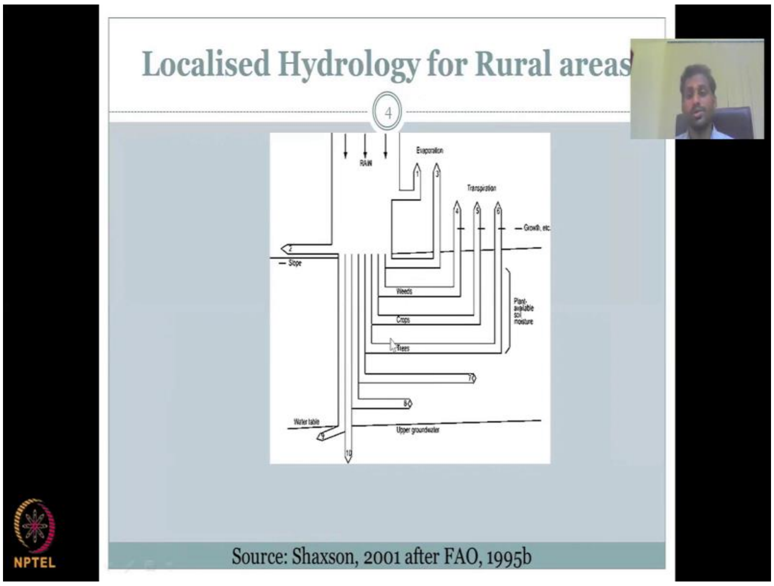
So, this has done naturally without any cost to the system by the sun. But if you disrupt the system, if you change any of these factors, then nature gets violent that is what climate change is happening. So, if you change all these some of these parameters over evaporation, then big big clouds come and sudden condensation comes, sun convection comes. So, all these things happen when you disrupt these cycles in a particular fashion.

That would be discussed more in a climate change kind of lecture, but here for Rural Water Management, please understand that it is not the different waters that are going back to the atmosphere and oceans it is the same water. What, whatever water you do not hold, it gets back to the oceans, and from there it goes back the cycle. There are some water which gets stored in the groundwater, lakes, rivers, dams, etcetera. Those are different but again, it eventually evaporates or transpires so that part I missed.

So, let us look at it here, which is your plant and animal uptake. Even humans we transfer when we jog, when we run, we have sweat, and then the sweat evaporates. So, there is sort of transportation when we say sweat, it is transpiration and transpiring, that is what we say. So, what you have your plants, your plants take up the water and transpire. So, all this transpiration would go back into your atmosphere.

And if it is just the water bodies is called evaporation. If it is with a plant, it is called evapotranspiration. So, that is a big big factor look at the arrow size, it is big the all the other arrows are smaller compared to your up gradient of evaporation and the evaporation from water bodies is also big, the evaporation from smaller bodies is small, because the volume of water is small, but oceans is really really big. So, that is why these big big arrows are coming.

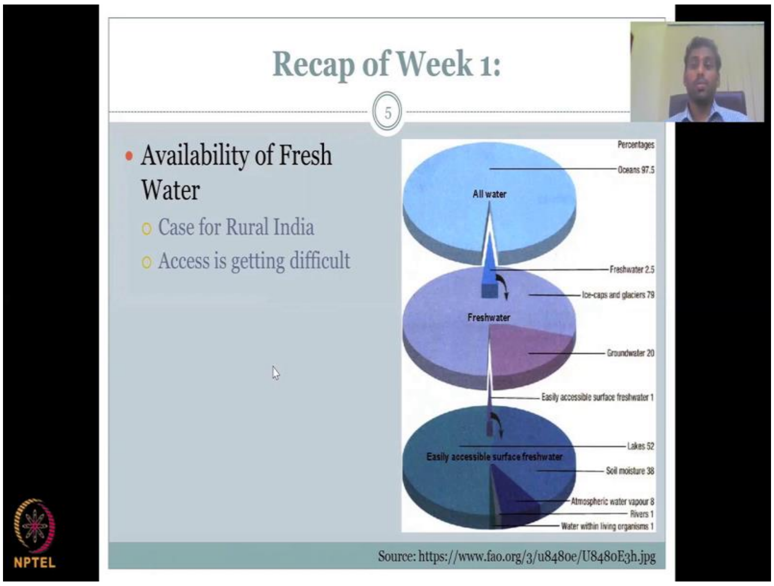
(Refer Slide Time: 17:16)



We also discussed the localised need for hydrology in rural areas, which is understanding not all these parameters are important, but very specific parameters for your research area. And most of the time, you will not have the hydrology of snow, snowmelt etcetera to discuss even the oceans you will not have it, you would not have a dam you have a channel but not a dam.

So, for rural water management you will be mostly looking into this part which is your weeds crop trees, how much water they take, how much water they transpire, evaporate etcetera. And the idea is this one how do you lessen, how do you lessen or reduce the conversion of rainfall into runoff so that if you can do this proportion of water you can save this water back into the cycle. So, understand that if you cut one of these, the other components can take the water up and use it for their respective purposes it gets divided for other purposes.

(Refer Slide Time: 18:18)



I would like also to stress the fact that for water management is really really necessary especially nowadays where you have climate change extremes of floods, droughts etcetera. So, the composition might change drastically and availability of freshwater is decreasing day by day. And for case of Rural India we looked at of the total water only 2.5 percent is freshwater and of the freshwater only 21 percent ground water 20 was easily accessible water is 1 percent is available and even that of all that only a part of the groundwater you could use.

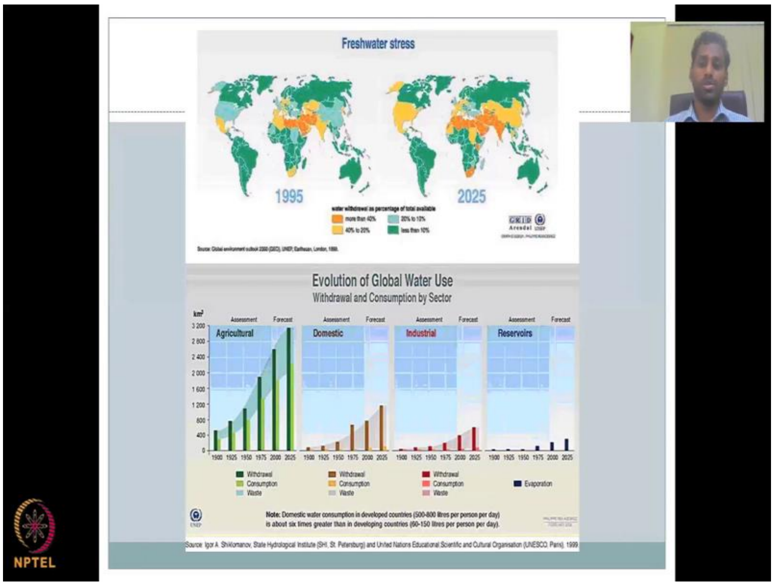
And what happens when there is no rainfall people go farmers go to groundwater to recharge or irrigate their fields or they look at dams and channels not everywhere we have irrigation command areas, but we do have wells almost everywhere in India, where you go and take the water for irrigation, even houses have groundwater.

So, understand that we will be driving more focus on water management, how (())(19:26) you conserve rainfall water and then use it for agriculture, but also we will be looking at this freshwater percentage. The access is getting very difficult. So, that is why a lot of people are putting more money on the engineering aspect of pumping, a lot of water is being pumped. But again, that is not sustainable. As I showed in my hydrological cycle some of the groundwater takes 1000s of years if not 100 years.

So, most of the time you would see water recharging even across the boundaries of India that we are pulling now. So, that is how much water you may be using. We do not know where the recharge happening for some regions, it might be within the boundary of India it may go out of the boundary of India.

So, it is very, very important to understand where the recharge is happening. And for that we need data which is really not available, so it is better to conserve the groundwater use it wisely. Just because you have water, do not just use it everything in one go. And that will for that a clearer understanding of the hydrological cycle is needed, where you use waters adequate.

(Refer Slide Time: 20:36)



Let us take a look at the freshwater stress as per UN body in 1995, we saw water withdrawal as percentage of total water available. For example, if I have 100 litres, what is the percentage how much flow water am I taking out? So, you could see that in the world, India was always taking more than 40 percent or around 40 to 20 percent of the total water, so you still save around 60 percent of the water in 1995.

But then, the case is slowly changing, the projections are really bad. And it is saying that you are going to use more than 50 to 60 percent of your water. So, that is what the positions are given by 2025. And even the countries which are in green, which means which are using less than 10 percent of the water they used, they are converting into orange and yellow.

The sad part here is you do not see anyone greening, which means you do not see from 1995 some countries which were in the yellows and greens, yellows and orange converting to green colour, which is a safe colour, you do not see that. So, what is happening is all the countries are being increasing their water use, or they are increasing the water withdrawal. And by that they might be breaching how much water they can use.

It may not affect no countries in green, because they just slightly increase like for example, Canada, or South America, you do not see how much water use Australia etcetera. But if you come to the Middle Eastern countries, India and China, you see a lot of water being used. And there is evidence of further increase of water use.

Where is the water use, now the first image shows you that a water has been used a lot? Let us see the evolution of global water use withdrawal and consumption by sector. They are given only four sectors, which is agriculture, domestic which is drinking water and water for evolution, bathing, etcetera. Industrial water for industries and reservoir, reservoir is just a storage.

You see that there is not much change you expect from 2000 to 2025 in reservoirs, which means that reservoirs are… new reservoirs are not coming in. If you go and look at the news articles, you do not see any big dams being proposed, maybe small dams a little bit the height has been increased. But the proposals are not as much as it was 10 years ago, 20 years ago, because people are slowly understanding that centralised approach for water storage may not be the solution.

So, reservoirs are coming down and the forecasts also saying that it is not going to be stagnant. You are not going to increase it. But strikingly you do see that the withdrawal, the withdrawal rate is going up, which is the dark green for agriculture exponentially high, but also the consumption is going on and the wastage, the wastage is the difference between how much water you take and how much you consume. So, the wastage is getting bigger and bigger that is the concern.

Initial days 1900s we did not waste that much. Because of withdrawal was less the consumption was almost there. We knew how much water we will do. But now because of everyone having access to pumps, everyone having access to decentralised water supply, which is your groundwater, you are seeing a lot of wastage, where water can be conserved. People may be using it for fallow irrigation flood irrigation rather than drip irrigation or other aspects and that is what this graph is showing.

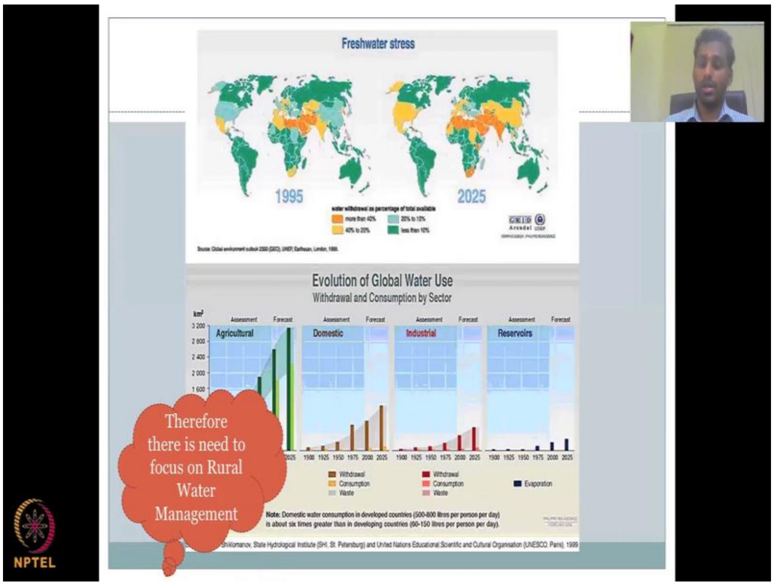
The forecast is not looking good. The agriculture consumption is going high, the withdrawals going high and the consumption is also going high, but the problem is between the withdrawal and the consumption, the wastage is going high. You also see that the withdrawal for domestic use is going high and the consumption is almost the same 40 litres per day 50 litres per day. So, there is a lot of wastage. So, a lot of wastage is happening.

Industries, they do consume a lot but they have the money and the technologies to conserve water. So, some of them may be putting in some systems to conserve water. So, in these volumes are all on the same scale. So, you could clearly see that compared to the water availability and use agriculture ranks the top followed by domestic industry and resorts across the globe.

So, this is a study by the UN and it clearly says that agriculture is where we first need to rescue or consult on what resources and then slowly to domestic industry and reservoirs. So, this is why this course is very important, because it happens in rural India and it is very important to go back to the roots and find where the water use is high. And is it possible to conserve the water because the farmers are still the same stage which is a economic stage, it is not like they use a lot of water and they convert it to money.

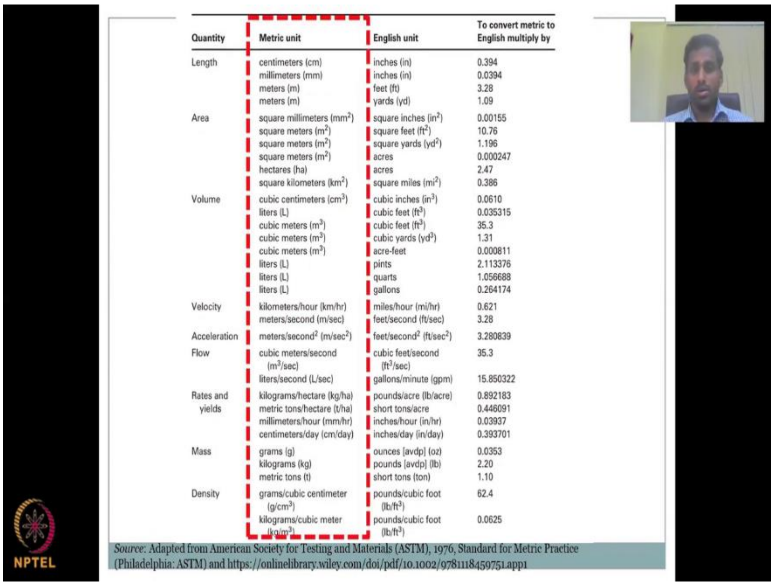
So, where is the gap why are they not becoming rich, why is the water being used at such an intensity so, that is what is very important for the future generations. So, this course will put you in track to understand where the withdrawals are high and how to conserve water.

(Refer Slide Time: 26:06)



Therefore, there is a need to focus on rural water management and again, I would like to propose that as the course that is the title of the course that you have signed up.

(Refer Slide Time: 26:16)



Quantity	Metric unit	English unit	To convert metric to English multiply by
Length	centimeters (cm)	inches (in)	0.394
	millimeters (mm)	inches (in)	0.0394
	meters (m)	feet (ft)	3.28
	meters (m)	yards (yd)	1.09
Area	square millimeters (mm^2)	square inches (in^2)	0.00155
	square meters (m^2)	square feet (ft^2)	10.76
	square meters (m^2)	square yards (yd^2)	1.196
	square meters (m^2)	acres	0.000247
	hectares (ha)	acres	2.47
	square kilometers (km^2)	square miles (mi^2)	0.386
Volume	cubic centimeters (cm^3)	cubic inches (in^3)	0.0610
	liters (L)	cubic feet (ft^3)	0.035315
	cubic meters (m^3)	cubic feet (ft^3)	35.3
	cubic meters (m^3)	cubic yards (yd^3)	1.31
	cubic meters (m^3)	acre-feet	0.000811
	liters (L)	pints	2.113376
	liters (L)	quarts	1.056688
	liters (L)	gallons	0.264174
Velocity	kilometers/hour (km/hr)	miles/hour (mi/hr)	0.621
	meters/second (m/sec)	feet/second (ft/sec)	3.28
Acceleration	meters/second² (m/sec^2)	feet/second² (ft/sec^2)	3.280839
Flow	cubic meters/second (m^3/sec)	cubic feet/second (ft^3/sec)	35.3
	liters/second (L/sec)	gallons/minute (gpm)	15.850322
Rates and yields	kilograms/hectare (kg/ha)	pounds/acre (lb/acre)	0.892183
	metric tons/hectare (t/ha)	short tons/acre	0.446091
	millimeters/hour (mm/hr)	inches/hour (in/hr)	0.03937
	centimeters/day (cm/day)	inches/day (in/day)	0.393701
Mass	grams (g)	ounces [avdp] (oz)	0.0353
	kilograms (kg)	pounds [avdp] (lb)	2.20
	metric tons (t)	short tons (ton)	1.10
Density	grams/cubic centimeter (g/cm^3)	pounds/cubic foot (lb/ft^3)	62.4
	kilograms/cubic meter (kg/m^3)	pounds/cubic foot (lb/ft^3)	0.0625

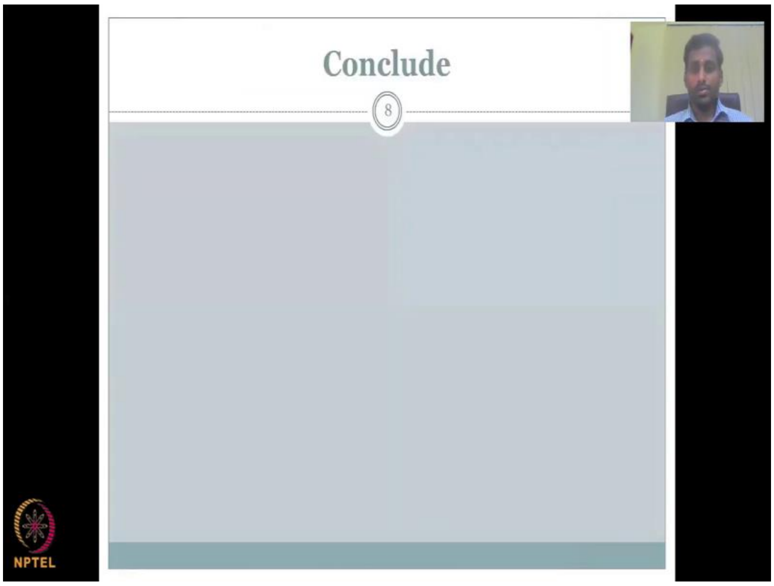
Source: Adapted from American Society for Testing and Materials (ASTM), 1976, Standard for Metric Practice (Philadelphia: ASTM) and https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118459751.app1

So, it is a very important study area and to wrap up, I will not get into the units again but please have a book of units understand that because we were ruled by the British earlier stage, we still have a lot of English units, but because of the science evolution and development, we do have metric units more.

So, metric units or SI units or centimetres, square may kilometres, volume in litres etcetera cubic metres, but then you also switch back and forth the English unit of inches feet, still cricket means yards. And you can also see velocities in cubic feet per second in discharge curves etcetera etcetera. The use of some properties are still okay globally, we are using the same terms like kilogrammes grams, metric tonnes all those things are okay but somewhere we also switched back and forth two inches or so acres for example for agricultural area.

So, it is always important to understand the conversion rule so easily you can have it on your mobile phones or you can have it done by heart but have it ready for reading through doing my exercises etcetera.

(Refer Slide Time: 27:35)



So, this I would like to conclude the first week of lectures. I hope you all enjoyed the introduction to the course and why this course is very important. It is not a traditional course. It is going to be a sensitization course, where you understand the need for rural water development, and hopefully understand where you could put their efforts in conserving water for India.