Soil and Water Conservation Engineering
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Lecture - 07
Erosivity and Erodibility

Hello friends. Welcome back to NPTEL online certification course entitled Soil and Water Conservation Engineering. I am Rajendra Singh, professor in Agriculture and Food Engineering department of IIT, Kharagpur. We are in lecture 7, week number 2 and the topic today is Erosivity and Erodibility.

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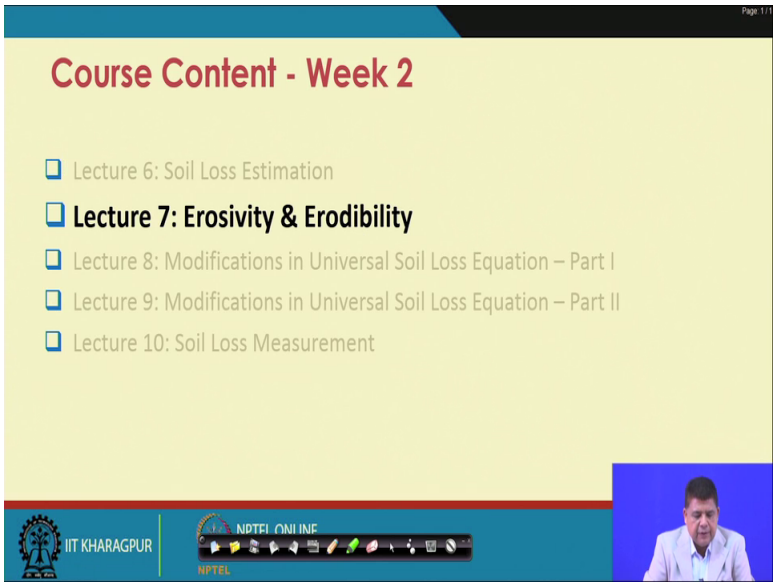

Just to give you a background up of what we are covering this week, in previous lecturer we saw how to estimates soil loss.

And during the process, we went through universal soil loss equation where we saw that rainfall erosivity index and soil erodibility index are two important factors and in lecture 7 today, we will be covering erosivity and eodibility. Lecture 8 we will see modifications in universal soil loss equation that will be part 1 of the lecture and in lecture 9, we will continue with that same modification in universal soil loss equation that is part 2 and in last lecture of the week that is lecture 10, we will go through soil loss measurements.

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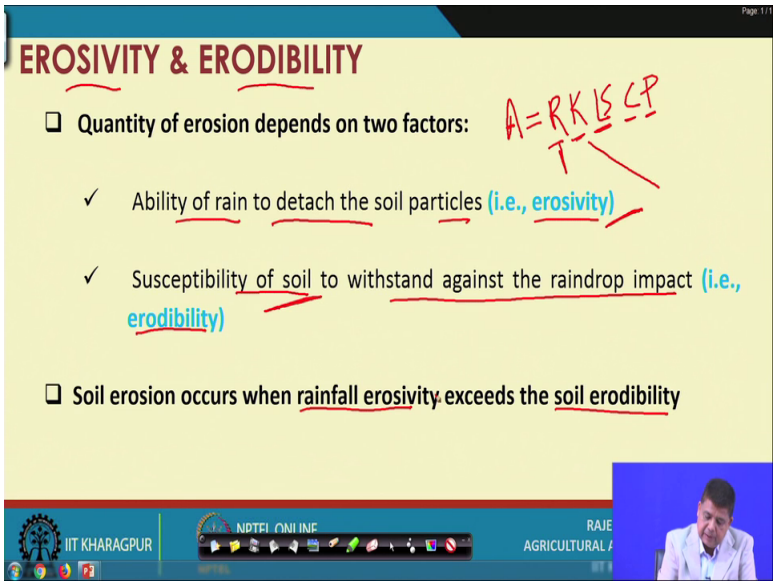

So, coming to erosivity and erodibility now just to remind you, I would like to write the equation which we saw for universal soil loss equation that is this is what it will be saw a equal to R K L S C and P and we defined R is real for erosivity index and K is soil erodibility index and that is what erosivity and erodibility is our topic today. So, basically if you remember, the process of a soil erosion, we know that there are 3 processes water erosion; it basically if we talk about detachment transportation and deposition, these are the 3 processes.

So, the first one is detachment, of course, and we are also saw that it is the raindrop impact that is responsible for detachment ah in a measure way. So, that ability of rain to detach; the soil particles is referred to as erosivity where and on the other hand, the susceptibility of soil to withstand against the raindrop impact that is referred to as erodibility. So, that simply makes it clear that erosivity is a rainfall characteristic.

And that is while R is the fined as rainfall erosivity index where erodibility is a soil characteristics and that is why when we define K means right soil erodibility index or soil erodibility factor and soil erosion; obviously, occurs when rainfall erosivity exceeds the soil erodibility whenever erosivity will be greater than the erodibility soil erosion will take place.

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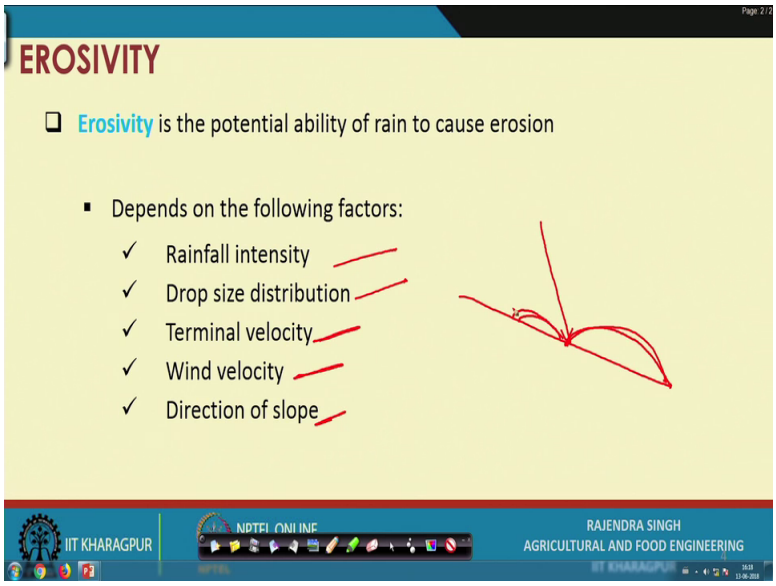

Now, erosivity is the potential ability of rain to cause erosion and it depends on several rainfall characteristics that is rainfall intensity drop size distribution that that we know that it is the kinetic energy is which is responsible for raindrop impact. So obviously, if the drop size is larger than the impact will be much higher, then terminal velocity which again depends on the drop size higher the velocity more will the kinetic energy wind velocity.

Because we know that we saw that when we saw the impact of wind, we saw the wind could change the direction of direction at which the ah raindrops hit the soil surface and that could make a angle which might make erosion process or detachment process more severe, then of course, direction of slope will have the same impact.

So, if the direction of slope, we saw if the soil is like this if rainfall is vertical, then; obviously, this will be I means in the details soil particles will move much larger down, the slope is compared to in the after directions. So, these are some of the factors on which erosivity primarily depends.

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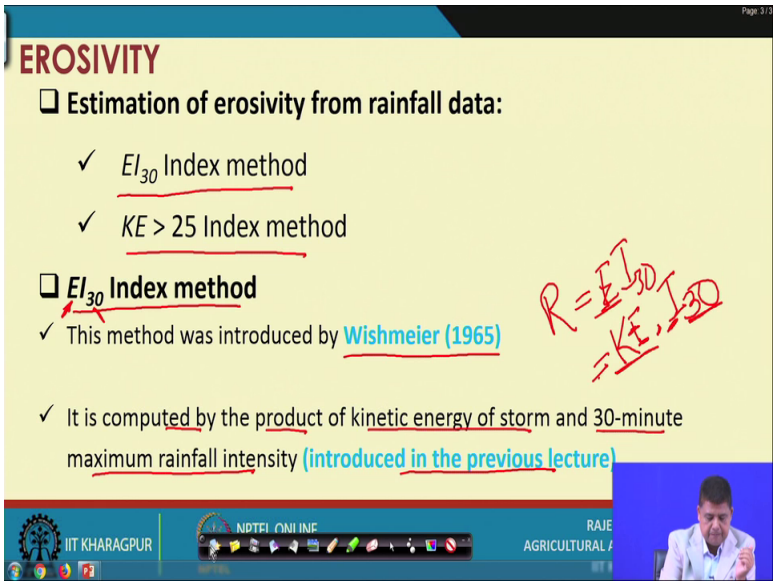

Now, estimation of erosivity from rainfall data is basically could be done by 2 methods; EI 30 index method or KE greater than 25 index method and we will see all both these methods one by one.

So, coming to EI 30 index method, this method was given by Wishmeier in 1965, you remember Wishmeier and Wishsmith; they were responsible for giving the universal soil loss equation and it was the Wishmeier that who gave the EI 30 index method and; obviously,.

As the name itself suggest, it is computed by the product of kinetic energy of storm and 30 minute maximum rainfall intensity that is E represent kinetic energy of the storm and I E 30 represents the 30 minute maximum rainfall intensity and introduce this in previous lecture also, we say we saw that when we discuss R we say R is EI 30 or we also said is that it is K E times I E 30.

So; that means, E or K is the kinetic energy and I is the rainfall intensity suffix, 30 represents the 30; 30 minutes duration during the storm where the rainfall intensity is maximum. So, it is referred to as defined as 30 minute maximum rainfall intensity.

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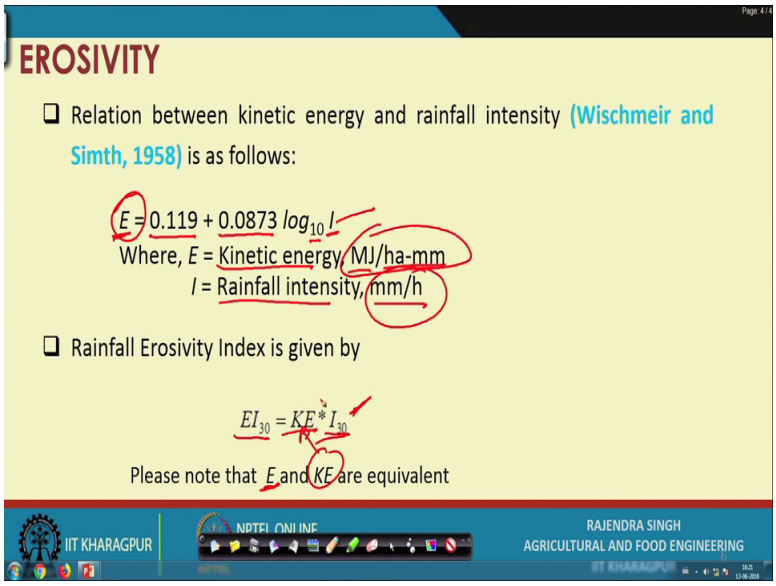

Now, relation between kinetic energy and rainfall intensity as given by Wischmeir and Smith in 1958 is given by this equation that is E equals to 0.119 plus 0.0873 log base 10 I where I is the E is the kinetic energy in Mega Joules per hectare millimeter and I is the rainfall intensity in millimeter per hour.

And like any other empirical equation is dimension also that we have to be careful about the units, if you want to use the equation and in its represent former is given form because the coefficients or constants which are there they are because of the units which are being used for a variables.

So that means, if you want to use this Wischmeir and Whsmith question, I has to be put in millimeter per hour and E will always be the output will always been Mega Joules for hectare millimeter. So, we have to remember the formula now rainfall erosivity index is I already said that is given by EI 30 equals to kinetic energy times I 30 and please note here that E which is given in which is used in Wischmeier and Smith question and KE which is being used here, they are equivalent they are same.

So, E or KE when we are writing we are talking about the kinetic energy and I 30 remains I 30. So, that is a R is EI 30 or KE I 30.

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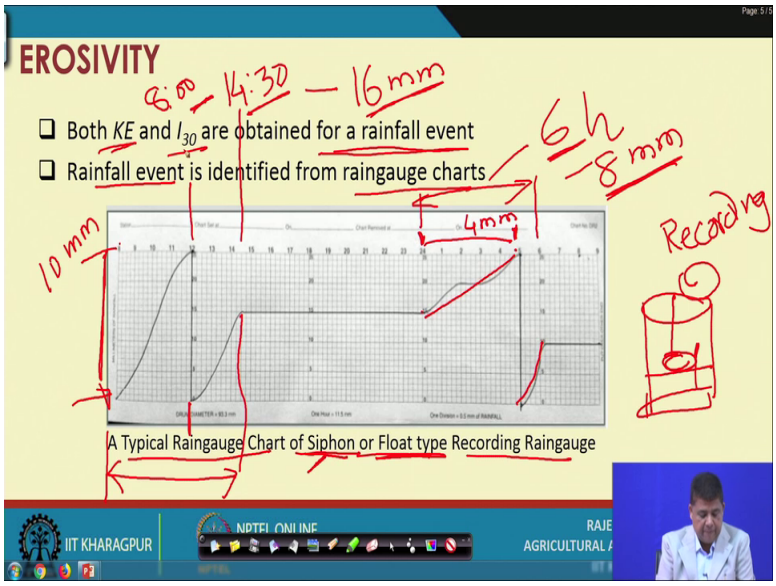

And both kinetic energy and I 30 are obtained for rainfall events because the rainfall characteristics so; obviously, we have to obtain for a particular rainfall event and for identifying a particular rainfall event we use the raingauge chart. So, this is basically the raingauge chart which is which comes from a recording type raingauge that is used for finding out the both kinetic energy as well as I 30.

So, this example here, you see, this chat here you see is a typical raingauge chart which is obtain from siphon or float type of recording rain gauge I am sure that you have read various kinds of raingauges non recording recording and within the recording you probably have heard that there is a tipping bucket, there is a weighing bucket and there is a float or siphon type of raingauge. So, we have this is the siphon upload type of raingauge that is basically the standard recording type rain gauge adopted in India and that is why I am showing the chat here.

So, in this case ah as you can guess that is a float type in siphon type the terminology are used because there is a float chamber in vista rainfall guess collected and as in the chamber itself it is a cylindrical chamber basically. So, as the water level goes up there is a float here that, float rises and this float is connected to a some kind of recording mechanism here and in this recording magnesium, there is a chart place. So, that is why in you see that this is the maximum 10 millimeter of rainfall that is the capacity of the float chamber.

So, here this chart shows this is starts at 8 o' clock because typically in India, 8 o' clock, 8 AM is the time where the rainfall is recorded, it is supposed to be recorded by as per IAMD. So, that is why this chat also start from 8 o' clock. So, here if this line shows that the raingauge event, the rainfall event with starting on 8 8 8 o' clock and then this continuous recording is there at this point you see it is around 12 o' clock that is the noon time, they total rainfall is becoming 10 millimeters, this is this is 10 millimeter, this scale is 10 millimeter.

So, this is becoming 10 millimeter; that means, the capacity of the float chamber is completely filled and then the second part of the name come that is siphoning siphoning takes place and; that means, this recording mechanism comes back off float comes back to 0 level and then again recording starts. So, that simply means here you can see that here siphoning has taken place, but immediately there is a continuous record that this simply shows that there is a rainfall event over this period of time.

So, 8 o' clock till all most two third is this is 14:30 actually 14:30. So, from 8:00 hours to 14:30 hours that is a continuous rainfall and then from this raingauge chart, we can also read what is the magnitude of rainfall. So, this is 10; 10 mm and here as we see this is 6 mm so; that means, during this period total 16 mm of rainfall occurs.

So, that is one rainfall event and then after this 14:30 hours till 24 hours, we see a horizontal line which shows that there is no rainfall occurring and then again this pen is starts rising or the float rises and because of that there is chain so; that means, you see here from 24 hours till 5; 5 in the morning, there is a this reaches the capacity that is 10 mm, this is 6 mm, this is 10 mm.

So; that means, from this to this place, it represents in this period, 4 mm of rain fall and then siphoning takes place and then again the pen is starts up and goes here so; that means, in this is the second event and it is continuing till 6 am so; that means, the total duration of the storm here is 6 hours and the total rainfall which is a occurring here is 4 and 4; 8 mm of rainfall.

So, in this particular day or on this on this particular day for which this chart is taken, there are 2 rainfall events; one is continuing from 8 o' clock in the morning till 2:30 in the afternoon and having 16 mm of rainfall, when the second event is starting at 12 mid night, continuing till 6 o' clock in the morning and total rainfall is 8 mm. So, this is how

we can identify a particular rainfall event and this is how we can calculate both kinetic energy as well I 30 from a given raingauge chart.

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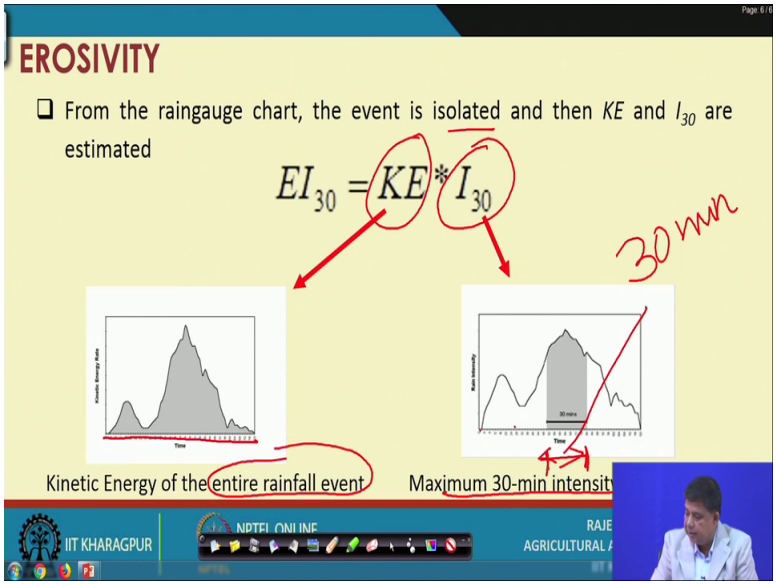

So, from the raingauge chart is just now saw, we identify the event ah. So, basically we isolate the event and then kinetic energy in I 30 are estimated. So, here you see while estimating the kinetic energy the entire rainfall event is being use. So, entire rainfall event is being used here for calculating the kinetic energy, where in for estimating the I 30 is the name itself suggest, we have to really look into the entire is storm and look for the slot where 30 minutes slot or 30 minute duration where the rainfall intensity is maximum and that is why it is refined is maximum 30 minute intensity due in the event.

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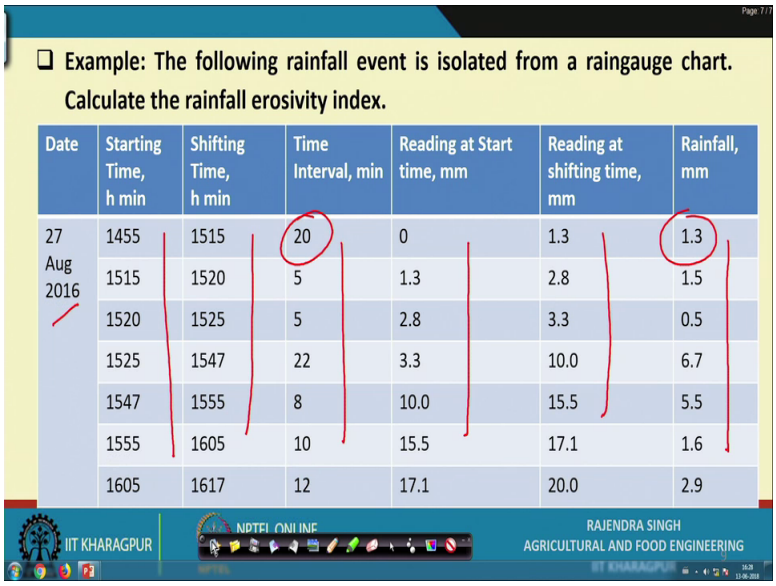

Date	Starting Time, h min	Shifting Time, h min	Time Interval, min	Reading at Start time, mm	Reading at shifting time, mm	Rainfall, mm
27 Aug 2016	1455	1515	20	0	1.3	1.3
	1515	1520	5	1.3	2.8	1.5
	1520	1525	5	2.8	3.3	0.5
	1525	1547	22	3.3	10.0	6.7
	1547	1555	8	10.0	15.5	5.5
	1555	1605	10	15.5	17.1	1.6
	1605	1617	12	17.1	20.0	2.9

So, let us take an example. So, this particular example following rainfall element is isolated from a raingauge chart, calculate the rainfall erosivity index. So, here you see a particular date is given different is starting time shifting times is given, time interval is given, reading at the start is given, reading shifting time is given and rainfall magnitude we and so, from here, for different intervals, we know what is the rainfall taking place; so, basically this data has come from a raingauge chart.

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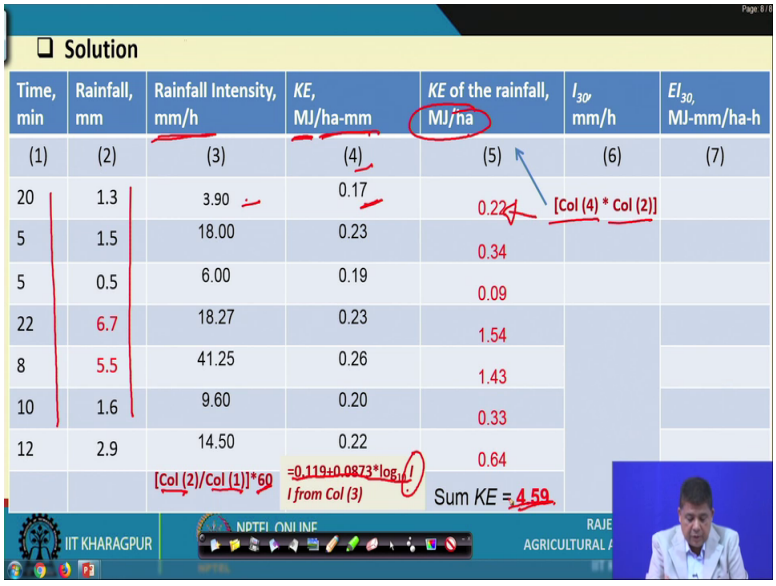

Time, min	Rainfall, mm	Rainfall Intensity, mm/h	*KE*, MJ/ha-mm	*KE* of the rainfall, MJ/ha	I_{30}, mm/h	EI_{30}, MJ-mm/ha-h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
20	1.3	3.90	0.17	0.22		
5	1.5	18.00	0.23	0.34		
5	0.5	6.00	0.19	0.09		
22	6.7	18.27	0.23	1.54		
8	5.5	41.25	0.26	1.43		
10	1.6	9.60	0.20	0.33		
12	2.9	14.50	0.22	0.64		
		[Col (2)/Col (1)]*60	=0.119+0.0873*log(I) I from Col (3)	Sum *KE* = 4.59		

[Col (4) * Col (2)]

So, using this data, we can really go an estimate the EI 30 or rainfall erosivity index. So, what is done here; as you can see that we have rainfall in millimeters duration rainfall in millimeters given? So, we can calculate for each duration rainfall intensity. So, that is column 2; that is the rainfall divided by column 1; that is the duration 20 minutes multiplied by 60. So, that we can get in units desired unit of millimeter per hour and once we know the intensity, then we can use the Wischmeir and smith equation with which is the function of I.

So, knowing I using this equation, we can calculate the kinetic energy in million joules per hectare millimeter quite easily. So, that is what we have done here. So, for each for this I this is the kinetic energy in mega joules per hectare millimeter, but in this equation, you remember the EI 30 unit is mega joules millimeter per hectare per hour that simply means E is being used in mega joules per hectare and I 30 is in millimeter per hour.

So, that simply means the kinetic energy which is there in mega joules per hectare millimeter that has to be converted into these unit mega joules per hectare. So, for that we multiply column 4 with column 2; which is column 2 is nothing, but the magnitude of the rainfall in different durations in order to get the kinetic energy of rainfall in desired unit that is mega joules per hectare for different intervals.

And then the total sum is obtained by adding these values which is 4.59. In this case which is basically which has to be used in this equation and then; that means, kinetic energy we have calculated the next important thing is to calculate the I 30.

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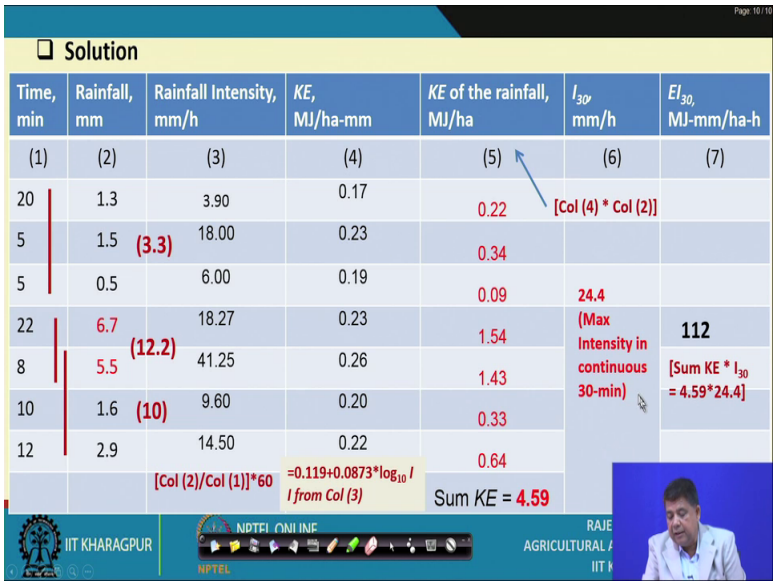

And for I 30, first thing is that we have to within the time frame, we have to identify 30 minute durations.

So, here if we analyze one by one, we see that there are see you see here that there are three different events, we can identify of 30 minute duration; 22 plus 8 is 30; 8, 10 and 12 is 30 and in each of these 30 minutes, we can calculate; what is the total rain falls. 3.3 mm here, 12.2 mm and here 10 mm; so, from this, we see that this duration is that is the 30 minute durations where the intensity will be maximum that is because 30 minute duration rainfall is 12.2.

So; that means, the maximum intensity is continuous 30 minute duration is 2 times of that that is 24.4 that is; so, I 30 maximum for this particular problem is 24.4 millimeters per hour and once we know K I and once we know when we know the KE and once we know I 30 then; obviously, the multiplication of this sum value we are the sum value here and the I 30 value here will give us the total rainfall erosivity index EI 30 for this particular event or for that particular problems. So, that is the, that is how we estimate the EI 30 for a given event.

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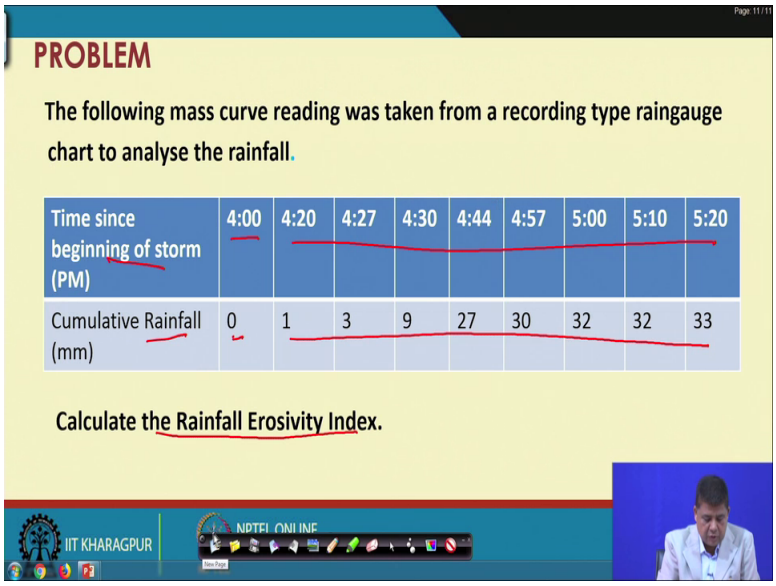

We can take its get another problem. Let us say for example, the following mass curve reading was taken from a recording type raingauge to analyze the rainfall time. Since beginning of storm is given in here that is different; 4, 4:20, 4 to 5:20 that is the duration and cumulative rainfall values are given here 0 here; that means, here the rainfall event is starts and the total rainfall is 33 during this period and we have to calculate the rainfall erosivity index. So, just following the procedure we saw earlier in the earlier example we can do that.

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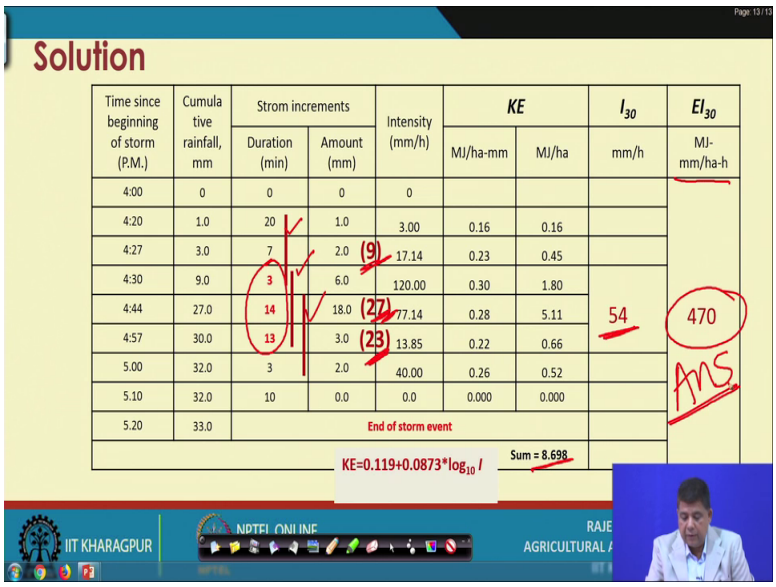

So, here; obviously, for different times, time, different time intervals, we know; what are the cumulative rainfall values. So, for different durations; so, here 4 to 4:20; that means, 20 minute duration, the magnitude of rainfall is 1 mm. So, for different durations, we can find out; what is the total amount of rainfall and thus we can calculate the intensity of rainfall and once we know the intensity of rainfall by using the Wischmeir and Smith equations.

We can calculate kinetic energy in mega joules per hectare millimeter and then again by multiplying this with the total magnitude of rainfall we can get in the kinetic energy in mega joules per hectare that is what we want and then next part of this problem is to be able to estimate the I 30; that means, we have to again find out different continuous 30 minute durations and here again we see that there are three different events.

So, these events are as you can see here 1 1 2 3 3 different events are there; that means, 30 minutes continuous duration and if rainfall in these 30 minutes, we know 9 mm, 27 mm and 23 mm. So, again this one is 30 minute duration where the intensity is maximum and total magnitude of rainfall is 27 mm so; that means, intensity I 30 maximum is 54 millimeters per hour and once we know the kinetic energy, the sum and I 30 multiplication of these 2 will give us the I EI 30 hour rainfall erosivity in mega joules millimeter per hectare per hour. So, that is the answer which we are looking for this particular problem.

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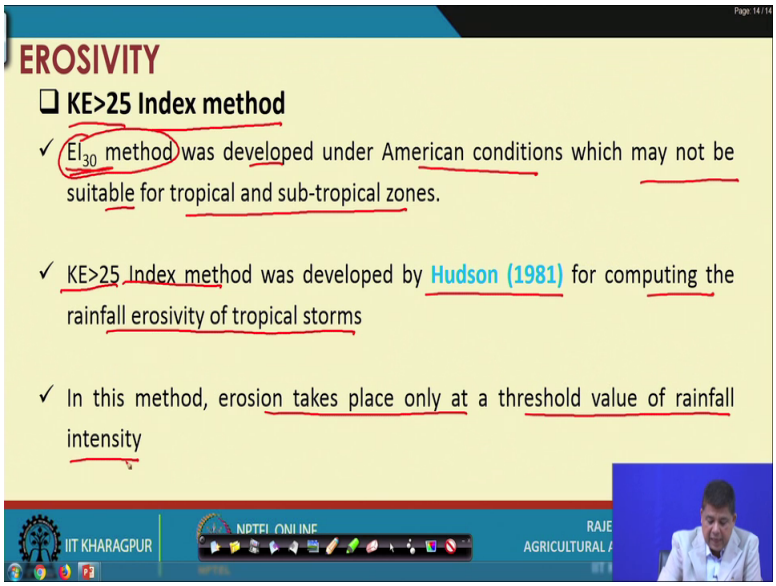

Now, we will come to continue with erosivity further and here we are going into the next method that is K I greater than 25 index method KI greater than 25 index method. So, the EI 30 method, just now we saw we saw how to calculate the rainfall erosivity. By using the method, this was basically developed under American conditions which may not be suitable for tropical and sub tropical zones. So, that is the drawback of EI 30 method, as far as its development conditions are concerned. So, to overcome that drawback, Hudson in 1981; he develop KE greater than 25 index method and this was bent for computing the rainfall erosivity of tropical storms.

So, the first method which was given by Wischmeir and Smith that was from ambassador on American data and that was it was said that, it may not be may not be suitable may not be suitable for tropical and subtropical zones and that is how this new method came K greater than 25 came and in this method erosion take place only at a threshold value of rainfall intensity.

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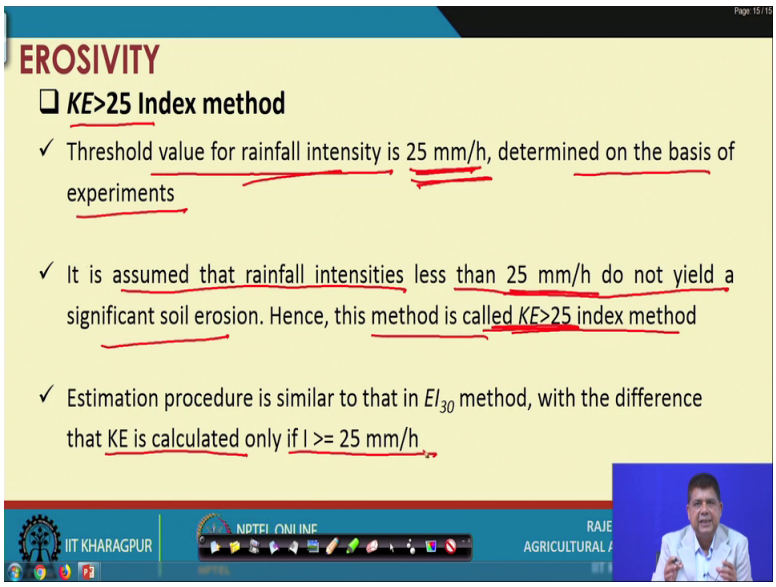

And the logic is given in the as follow that is the threshold value first which is use of rainfall intensity is 25 millimeters per hour which is determined based on experiments.

So, based on a large many experiments the threshold value of rainfall intensity is obtained is 25 mm per hour and that is why the name of the method KE 25 index method that is it is assume that rainfall intensity is which are less than 25 millimeter per hour do

not yield a significant soil erosion hence this method is called KE greater than 25 index method.

So, in the experiment which were conducted in tropical conditions they showed that if the rainfall intensity is less than 25 mm per hour, then the soil erosion was not significant and that is why it was said that the threshold value of rainfall intensity is 25 mm per hour for causing erosion and that is why this method KE is greater than 25 index method.

The estimation procedure of this method in EI 30 is very similar only difference is that in EI 30 method, we calculate kinetic energy for all intensities of rainfall where in this case, KI calculate K E is calculated that kinetic energy calculated only if I is greater than 25 mm per hour.

So, any rainfall intensity in any duration weather rainfall intensity is less than 25 mm per hour that is neglected basically in this particular method.

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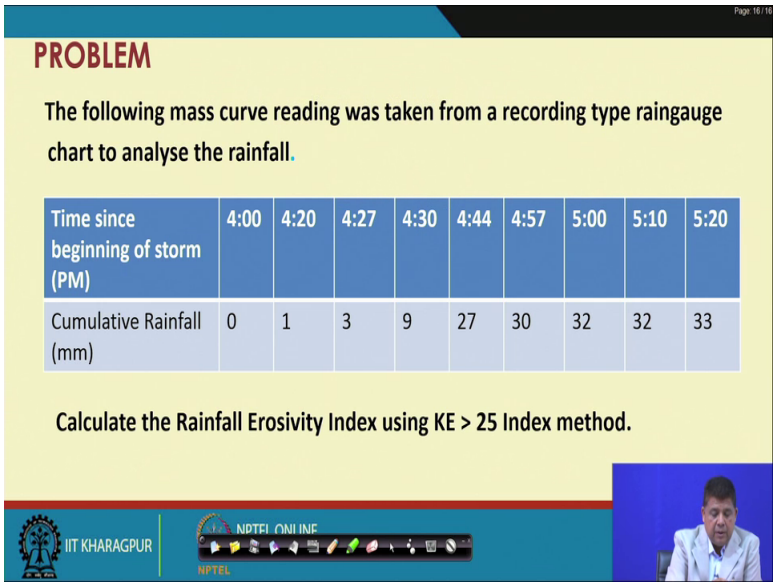

So, let us take problem through to really see how to use this. So, the mall; it is the same problem which was used for used for applying the EI 30 method. So, now, in the in the same problem where is the following mass curve reading was taken from a recording type raingauge chart to analyze the rainfall where the rainfall begins at 4 o' clock continues to still 5:20 and the cumulative rainfall during the event is 33 mm that same event is being used and we have to calculate the rainfall is erosiovity index using the KE

greater than 25 index method earlier we used EI 30 method. So, now, we are using KE greater than 25 index method.

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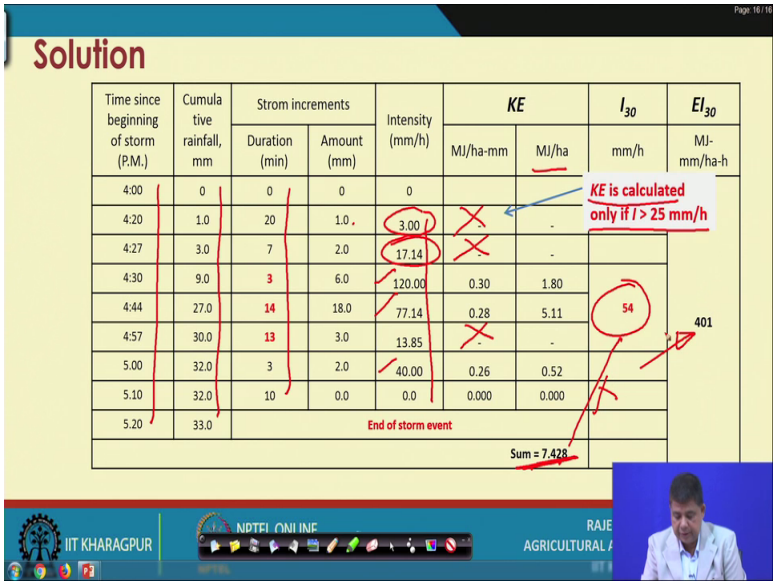

Time since beginning of storm (P.M.)	Cumulative rainfall, mm	Strom increments: Duration (min)	Strom increments: Amount (mm)	Intensity (mm/h)	KE: MJ/ha-mm	KE: MJ/ha	I_{30} mm/h	EI_{30} MJ-mm/ha-h
4:00	0	0	0	0				
4:20	1.0	20	1.0	3.00	-	-		
4:27	3.0	7	2.0	17.14	-	-		
4:30	9.0	3	6.0	120.00	0.30	1.80		
4:44	27.0	14	18.0	77.14	0.28	5.11	54	401
4:57	30.0	13	3.0	13.85	-	-		
5.00	32.0	3	2.0	40.00	0.26	0.52		
5.10	32.0	10	0.0	0.0	0.000	0.000		
5.20	33.0	End of storm event						
						Sum = 7.428		

So, here is the solution. So, here again the time since beginning will be there cumulative rainfall will be written as it is and duration of course, remains the same there is no change there is 4 to 4:20, 20 minutes, then rainfall is 0 to 1; that is 1 mm, then in 20-27; 7 minutes rainfall is 2 mm and so on. So, all those calculations remain the same the data extraction from the raingauge chart or raingauge data which is given in tabular form remains the same intensity value calculation is also same.

So, we calculate till intensity, there is no change is the procedure remains the same as it was in EI 30 method, but this difference start from here in any duration if rainfall intensity is less than 25 mm per hour, then kinetic energy is not calculated; that means, kinetic energy is calculated only if I is greater than 25 mm per hour. So, in this event you see which is less than 25 mm per hour, we are not calculating kinetic energy. Similarly, here it is 17.14; it is less than 25 mm per hour. So, we are not calculating the kinetic energy.

So, only those events or those durations where the intensity is more than 25; so, 1, 2; only 3 durations where intensity is greater than 25, we are calculating rest of the places we are not calculating. So, that is how you see only 3 values in the kinetic energy that is mega joules per hectare millimeter which comes from the Wischmeir and Smith is same

equation is Wischmeir and Smith equation is use here also for calculating the kinetic energy and; obviously, then mega it will be express in mega joules per hectare also only for these durations. So, that simply means that only, these intense kinetic energy will be multiplied by the rainfall amount and that is how these values will come.

So, the total sum will be 7.428 remember in EI 30 method, we use or you calculate kinetic energy for each of these durations so; obviously, this sum was larger I 30 calculations remains the same. So, that is why we in this case also will get 54 mm of rainfall intense in mm per hour and; obviously, EI 30 value will be then multiplication of these 2; 2 obtain this.

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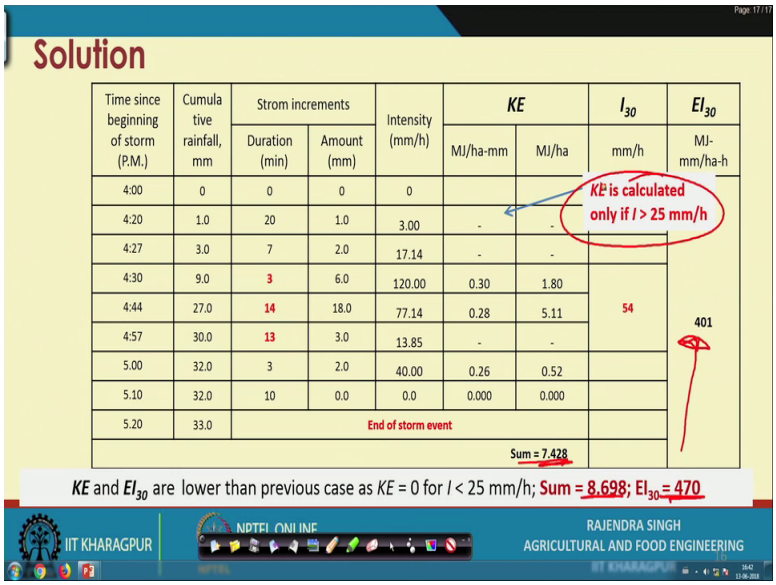

So, in this case, the difference is that in the previous case, the sum was the kinetic energy sum was 8.698 here it is 7.428 and that is why EI 30 will which was 470 mega joules millimeter per hectare hour that is now getting reduced to 401 because we are only considering I greater than 25 mm per hour for calculating the kinetic energy.

So, that is the only difference here. So, 2 methods; one is this method is say that is more suitable for tropical storms or tropical regions, here we neglect the rainfall intensity is the durations with rainfall intensity is less than 25 mm per hour for calculating the rainfall erosivity that is only difference otherwise. So, the processing we saw more or less both methods in similar fashion.

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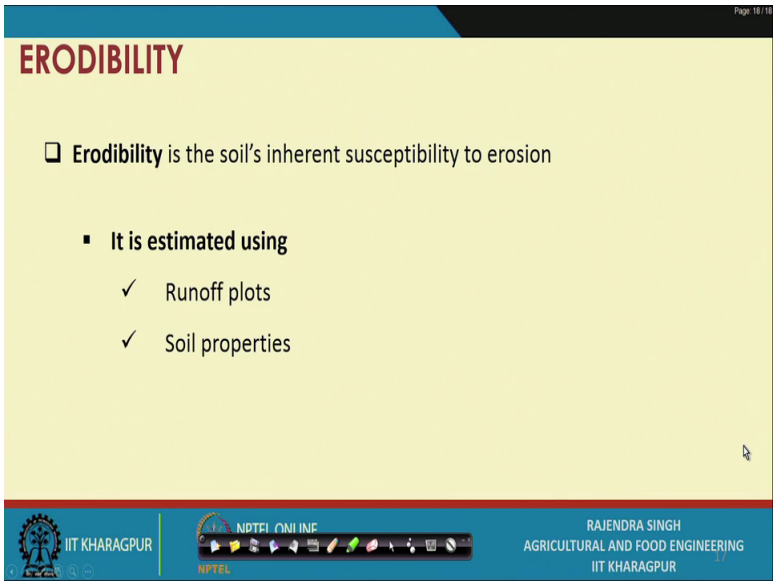

Then next thing is erodibility which is the soils inherent susceptible to erosion and this can be estimated using runoff plots or soil properties.

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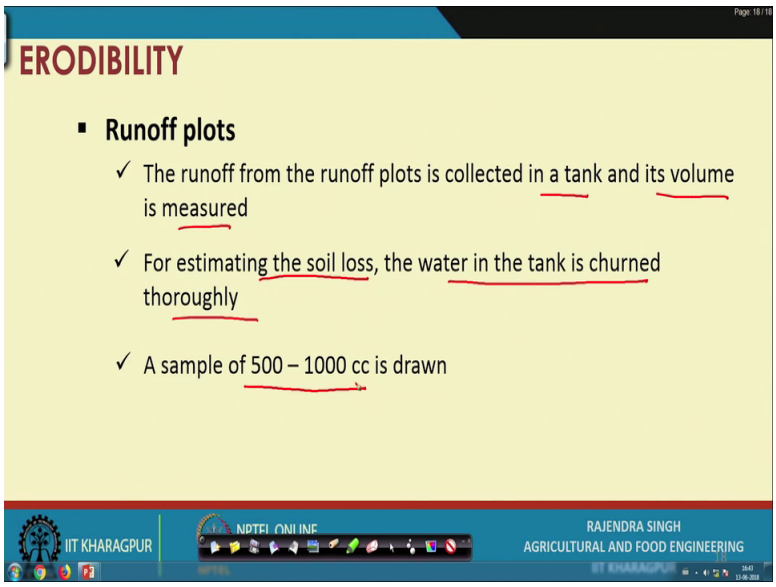

So, as per as runoff plot is concerned runoff from runoff plots is collected in a tank and its volume is measured and from for estimating the soil loss the water in tank is churned thoroughly. So, that the soil water mix is complete and then from this tank we take out a sample of 500 to 1000 cc that is half liter to one liter sample is taken and this.

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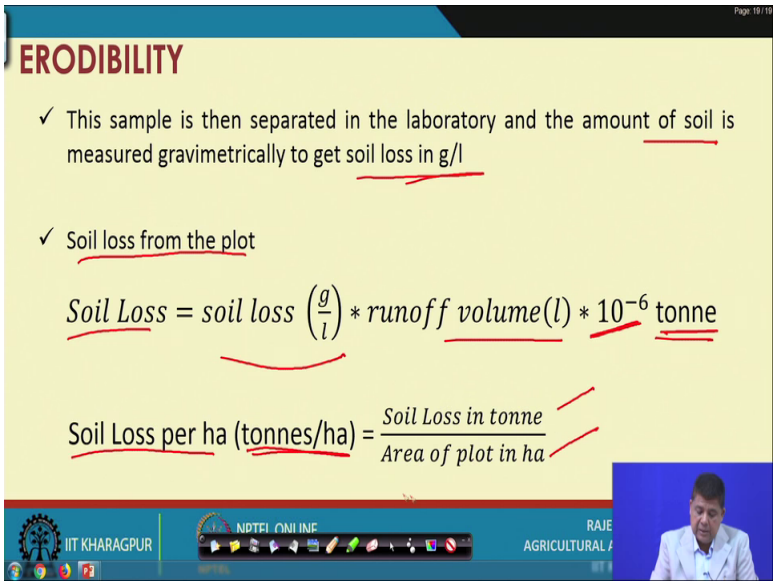

Then this sample is taken to laboratory where which we find out the amount of soil in the in the in the sample in grams per liter that is 1 liter. So, what how much grams of soil was there.

So, that gives us the total soil loss in grams per liter and then for soil loss from the plot soil loss grams per liter that we have obtained laboratory total runoff volume we have already calculator in liters. So, this will give us soil loss in grams to convert that in tone which is normally unit we multiply that with 10 to a minus 6.

So, if this way we get soil loss in tones and then soil loss per hectare which is usually unit is transfer hectare soil loss in tones divided by area of the plot in hectare that is from where the sample has come; that will tell us give us soil loss per hectare in tones per hectare and that is how erodibility can be found out experimentally, basically, this is experimental determination using the now plots.

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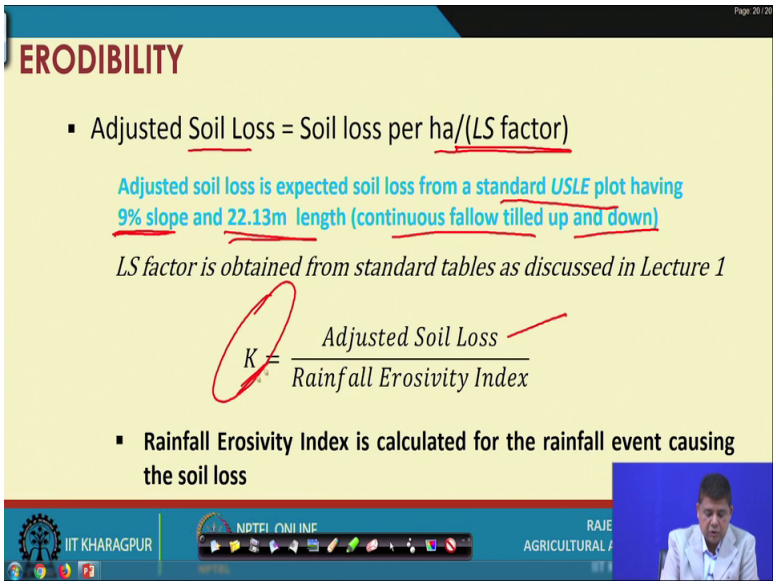

In the second case, we basically find out erodibility or rather we can still at just this for soil loss for LS factor because we have used we might have used non standard plot. So, for that we convert that to standard USLE plot where we knew that the, we know that the slope 9 percent and length of 22.13 meters is used and this plot is continuously fallow tilled up and down. So, for that; we adjust a soil loss which is soil loss per hectare, which we calculated earlier divided by LS factor. So, divided by rainfall erosivity index that will give us the soil erodibility value and rainfall erosivity index calculation already we have seen how to estimate that.

So, from using this soil loss values and the rainfall erosivity values, we can find out what is the soil erodibility for a given experimental data.

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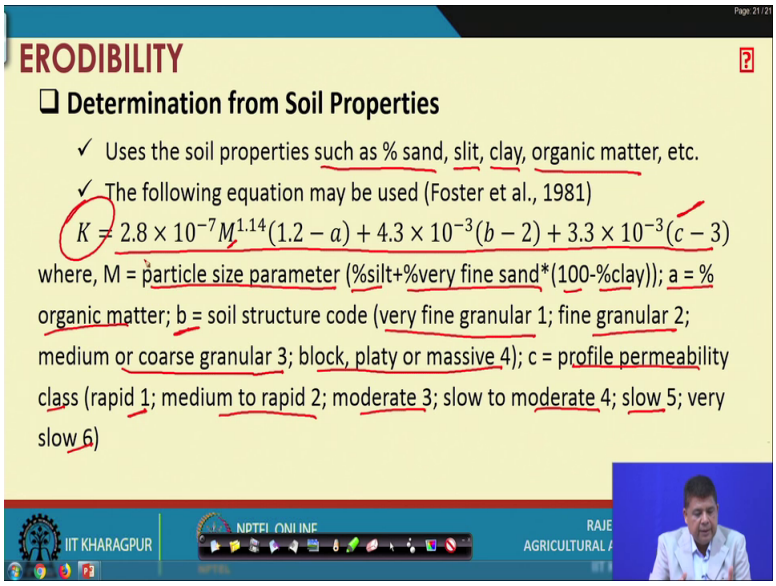

Alternatively, we can also use the soil properties for estimating the erodibility and basically, we use the soil properties likes percent sand percent slit clay and organic matter and then this empirical equation is used here where you see that capital M is particle size parameters that is percent silt plus percent very fine sand multiplied by hundred minus percent clay.

And this when we do the soil texture analysis all these values, we can get from laboratory a is percent of organic matter which can also we obtained from laboratory b is the soil structure code and this code is very fine granular for one fine granular for two medium or code course granular three block platy and massive 4 and see which is used here in this equation is profile permeability class.

So, if the permeability is rapid then which is one medium to rapid 2 moderate 3 slow to moderate 4, slow 5 and very slow 6; so, using b and c course here and knowing the percent sand slit clay and organic matter which can be obtained from experiment from the laboratory, we can also determine K using this empirical equation.

So, erodibility can be estimated by 2 methods are using design runoff plot for experiments and all also by using the soil properties using the empirical relationship. Similarly, we saw for rainfall erosivity, we have 2 methods; one is EI 30 method and one is K greater than 25 index method. So, with this we come to end of this class where we have seen how to estimate rainfall erosivity as well as soil erodibility.

Thank you very much.