Soil and Water Conservation Engineering
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Lecture – 06
Soil Loss Estimation

Hello friends, welcome back to NPTEL online certification course in title Soil and Water Conservation Engineering. I am Rajendra Singh, Professor in Agriculture and Food Engineering Department, IIT Kharagpur. And we are studying week 2 today that is we are in lecture number 6 and the topic is Soil Loss Estimation.

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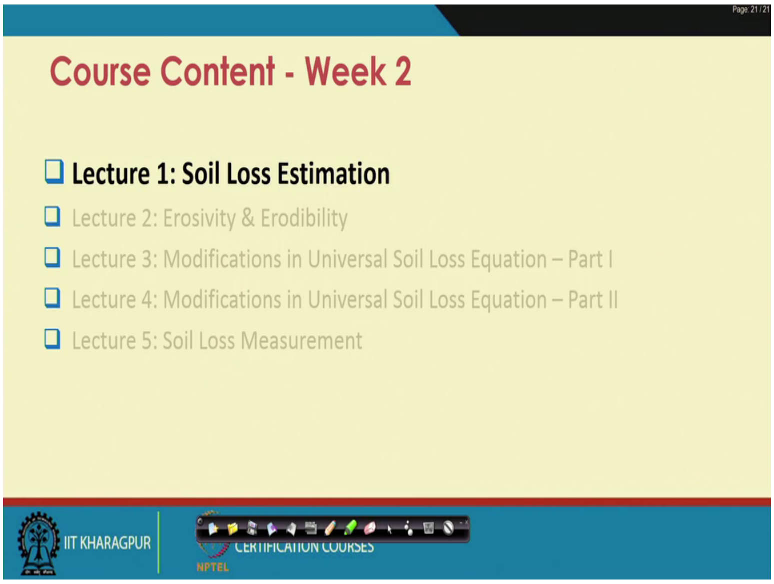

In this week this will be our course content; that is will today will start with soil loss estimation. In lecture 2 of this week that is lecture 7 will go into erosive and credibility and lecture 3 of this week; that means, overall lecture 8 will be covering modifications in universal soil loss equation part 1.

Lecture 4 that is cumulative lecture number 9 will be covering modification will be still maintaining modifications in universal soil loss equation part 2. And last lecture of this week which will be lecture number 10 of this course will see how to measure soil loss in field conditions.

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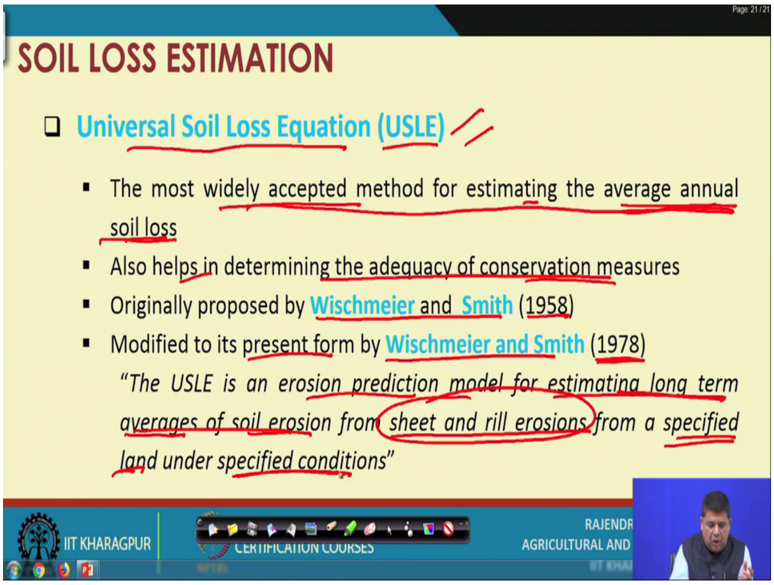

So, we start today with the soil loss estimation and what we cover is the most widely accepted method for estimating the average annual soil loss which is referred to as universal soil loss equation, very popularly known as USLE. So, USLE is a very popular component of soil and water conservation and as it says it is the most widely accepted method. Important thing to note here is that it is used for estimating the average annual soil loss that in a long term soil loss it gives, it means that for a single event this method cannot be used for estimating the soil loss. So, it gives us average annual soil loss. It also helps in determining the adequacy of conservation measures.

So obviously, if we know what are the soil losses, if you estimate soil loss when no conservation measure is taken using USLE and for another field condition where are certain conservation practices have been taken and again I use USLE. So, by relative or comparing these 2 estimates we can find out how effective these soil conservation measures are.

And this USLE was originally proposed by Wischmeier and Smith in 1958 and later on Wischmeier Smith itself they modified this equation to it is present form in 1978. And the definition of USLE is like this, the USLE is an erosion prediction model for estimating long term averages of soil erosion from sheet and rill erosions from a specified land under a specified condition.

So, they are certain important terminology here that is erosion prediction model for long term average of soil erosion, that already we have mention. And it only considers sheet and rill erosions; that means, the gully erosion process is not considered as far as a USLE is concerned. And it estimate soil loss from a specified type of land, where a particular type of crop is being grown and a specified condition or under if any kind of conservation measure had been taken or not.

So, all these under this specific conditions we use universal soil loss equation to measure soil loss or to estimate soil loss rather.

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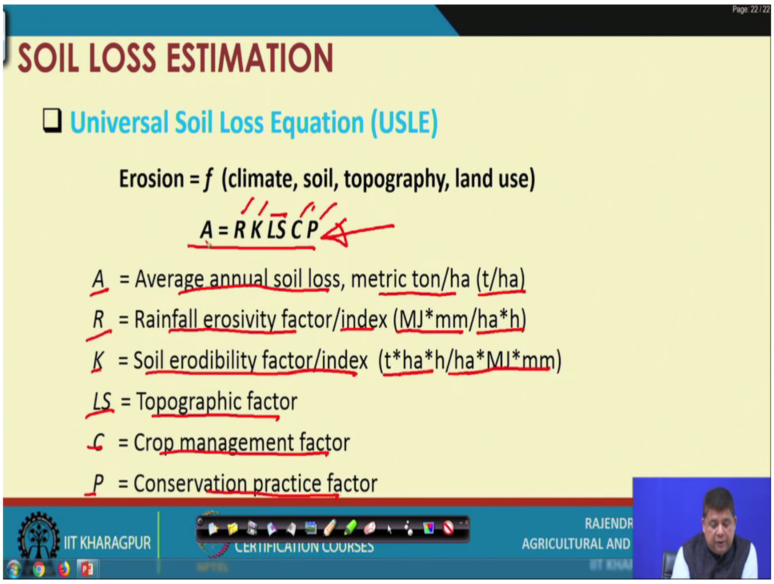

Now, continuing with universal soil loss equation USLE you remember that we in one of the classes where we were discussing about the factors affecting erosion and I gave equation that erosion is a function of in short term ctvs climate, topography, vegetation and soil. So, same equation is written here also that erosion is a function of climate c only thing is the terminology are little bit shuffled.

So, climate, t topography, v vegetation or land use and s soil all 4 are here, but they are written little differently. But, ultimately these are the factors which are responsible for erosion and that means, that universal soil loss equation also considers only these components.

So, the equation if you look at the equation universal soil loss equation this is the equation, that is A equals to RKLSCP used in just remember these terms R, K, LS they are taken kept together C and P.

So, these are the equation which is referred to as universal soil loss equation A equals to RKLSCP. And let me remind you that they are certain important things are certain fundamental things of a subject. So, USLE is that kind of a fundamental thing of soil and water conservation engineering. So, it is expected that if you say to somebody that you have read this course it is expected that you at least will know universal soil loss equation. So, that is why my request will be that please do remember and do understand this universal soil loss equation.

So, just to repeat A equals to RKLSCP is the universal soil loss equation. Coming to different terminologies A is the average annual soil loss and the unit used is metric tons per hectare or tons per hectare. This is how symbol we use, R is rainfall erosivity factor or index certain text used factors certain other text index.

So, that is why I have used both terms rainfall erosivity index or rainfall erosivity factor. The unit is used here is million joules millimeter per hectare hour. K is the soil erodibility factor or index and the unit is tons hectare hour per hectare mega joules millimeter and because of the interrelationship the terminologies that is why these kind of units are being used here. And LS taken together is topographic factor, C is the crop management factor and P referred to as conservation practice factor.

So, R is A is average annual soil loss transfer average annual soil loss transfer hectare, R is rainfall erosivity factor K is soil erodibility factor, LS is topographic factor, C is a crop management factor and P is conservation practice factors. So, these are the terms which are involved in universal soil loss equation.

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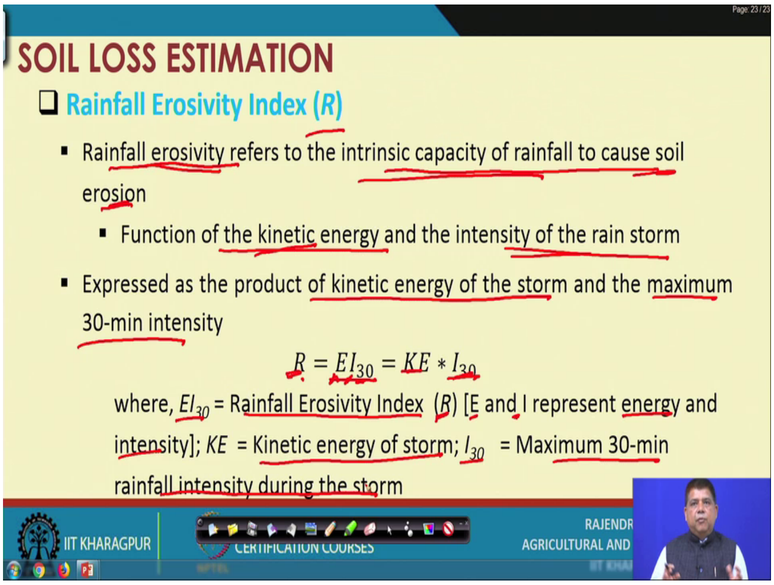

So, let us see these terms one by one, let us see the first term which is they are is Rainfall Erosivity Index or Rainfall Erosivity Factor which is designated by letter capital R. And rainfall erosivity refers to the intrinsic capacity of rainfall to cause soil erosion and it is the function of kinetic energy and intensity of rain storm.

Right from lecture number 1 when we started classifying soil erosion we always saw there, water erosion starts with raindrops splash erosion. And we also saw it is the raindrop impact which is the major factor behind the detachment process.

So, that that it is the raindrop impact which causes. So, that intrinsic capacity of the rainfall to cause soil erosion that simply means to start the detachment process which; obviously, depends on the kinetic energy and intensity of rainstorm that is referred in terms of rainfall erosivity.

And it is expressed as a product of kinetic energy of the storm and the maximum 30 minute intensity of the storm. That is R is EI 30 equal to KE times I 30, where EI 30 is Rainfall Erosivity Index R, where E and I represent energy and intensity.

So, Rainfall Erosivity Index R is also referred is EI 30th were E is energy, I is intensity 30 minutes refers to the 30 minute duration where the intensity is maximum. And then will also expresses KE times I 30, where K is the kinetic energy of the storm and I 30 is maximum 30 minute rainfall intensity during the storm; so in a given storm for which we want to estimate from; which we want to estimate the soil loss and that simply means first we have to estimate the rainfall erosivity.

So, during that particular storm we have to find the 30 minute duration where the rainfall intensity is maximum. And, we will see how to do, how to calculate, how to estimate all these term and terms when we come to later part of this particular class.

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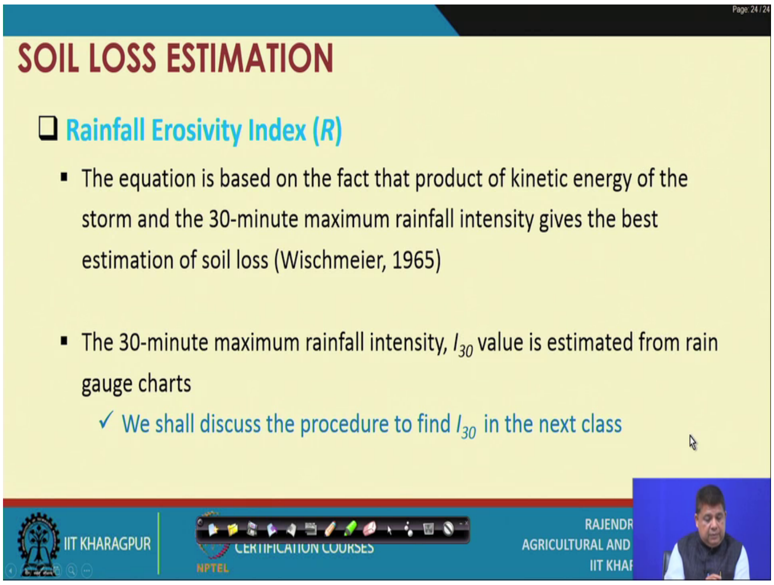

The equation just now we saw that is the equation which we saw that is EI R equal to EI 30 KE times I 30. That is basically based on the fact that product of kinetic energy of the storm and 30 minute maximum rainfall intensity gives the best estimation of soil loss. And that was given by Wischmeier in 1965 based on a large number of experimentation.

So, after conducting large number experimentation Wischmeier found that if the product of kinetic energy of the storm in 30 minute maximum rainfall intensity that gives the best estimation of the soil loss and that is how this rainfall erosivity was defined like that. And the 30 minutes maximum rainfall intensity either value is estimated from rain gauge charts. And we shall discuss the procedure to find I 30 probably the next class when we take up the next class.

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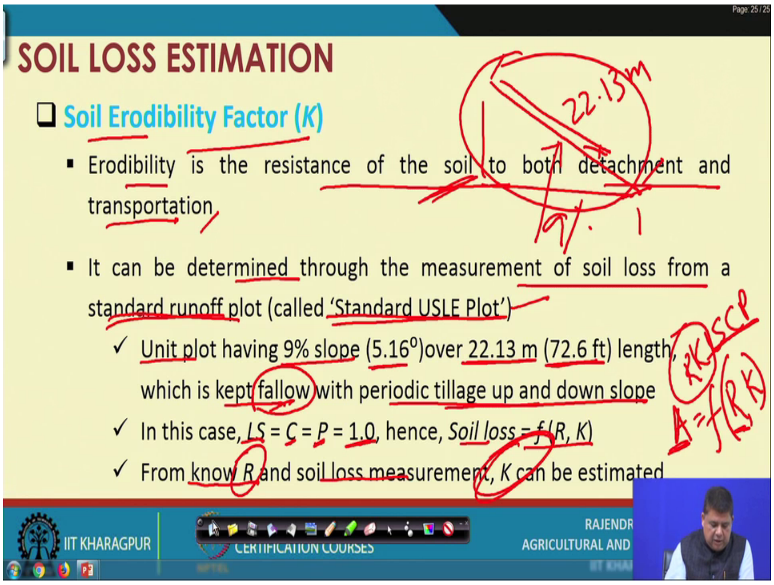

Then next term is soil erodibility factor K and erodibility we have we saw rainfall erosivity and now we are seeing soil erodibility. So, remember erosivity is the characteristics of the rainfall and erodibility is related to soil. So, erodibility is the resistance of the soil to both detachment and transportation.

So, if any particular soil which can resist detachment and transportation so; obviously, the erosion will be less. So, that is the measure of erosion so, erodibility represents that. And it can be determined through measurement of soil loss from a standard runoff plot. So, if you have to do some kind of experimentation in order to find out the value of applicable value of salt erodibility factor. And when we say standard runoff plot basically is also referred to as standard USLE plot and there are certain standards and that is why it is called standard.

That is it is a single plot having 9 percent slope or in degrees it is 5.16 degrees and length of the plot is 22.13 meters or 72.6 feet. And this plot is kept fallow with periodic tillage up and down slope. So, that simply means that it is a plot standard plot which is which has a slope of 9 percent.

So, slope is 9 percent length of the plot is 22.13 meters and this on this plot tillage up and down the slope tillage operations are done, but no cultivation is done. So, cultivation is not done that is why it is referred to as fallow lands. So, this plot is kept fallow and we if suits or if it is follows the standard dimensions that is slope is 9 percent length is 22.13

percent. And it is where it is kept fallow and periodic tillage up and down slope tillage operations are being done.

Then it is referred to as standard USLE plot and that is a plot which is measured for soil loss estimation or for that matter estimating the soil credibility factor, And if this is the condition these are the standard conditions of a standard U plot. Then the LS factor that is topographic factor, C that is a crop management factor and P that is the soil conservation factor or conservation practice factor. They are all taken is 1 and you remember equation RK LS CP. So, this is these 3 terms are gone. So, we are only left with RK so; that means, soil loss or A is a function of R and K.

So, that is what it is so, if we are using a standard USLE plot the soil loss becomes function of R and K and because for conducting experiments we can always use the rainfall simulators. So, we will always know the rainfall intensity or rainfall pattern basically under which we are measuring the soil loss. So, that simply means which will be possible for us to estimate the value of rainfall erosivity index.

So, if R is known and A is measured that is soil loss is measured from the standard plot then obviously we can find out or estimate the value of applicable K for a given condition. So, that is how soil loss erodibility factor for a given soil can be estimated using the standard runoff plots.

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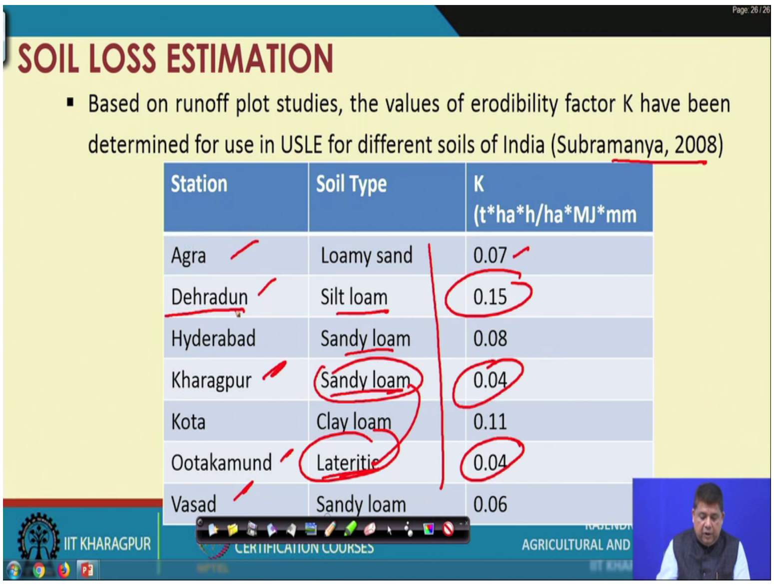

And based on the runoff plot studies certain values of erodibility factor have been recommended and for different soils of India and the references Subramanya in 2008. And the state different stations you can see Agra, Dehradun, Hyderabad, Kharagpur, Kota, oothi Vasad in Gujarat and these are the different types of soils.

And the K value vary from 0.07 so, minimum is 0.04 both in Kharagpur and Ootakamund where the soils are lateritic or sand sandy loam basically Kharagpur also soil is same lateritic soil. So, 0.4 value and highest value here we find is 0.15 that is how silt loam reported from Dehradun. So, these are the experimental values that have been reported which can be used for these kinds of soil types.

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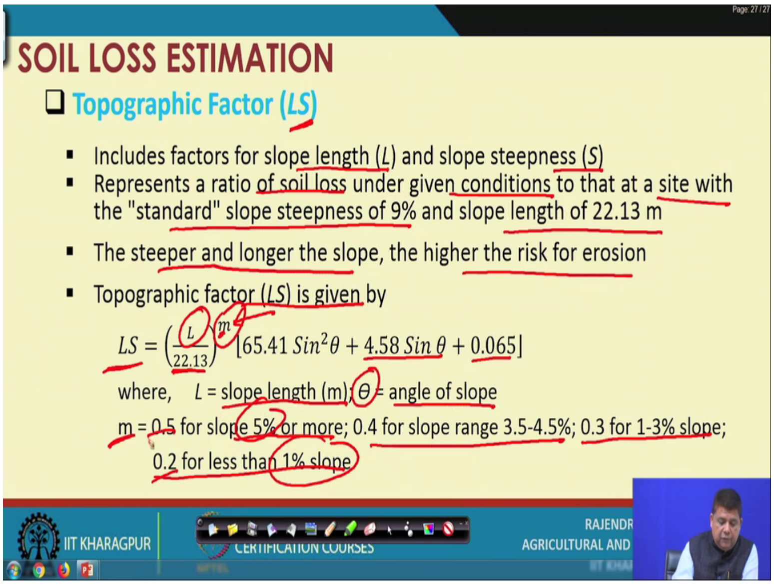

Then we come to the next factor that is topographic factor and the topographic factor it includes factor for slope length and slope steepness LS taken together we write LS, LS is to be consider where L is stands for slope length and S stand for slope steepness. And it represents a ratio of soil loss under given conditions to that at a site with standard slope steepness of 9 percent and slope length of 22.13 percent. So, basically here also is the USLE plot standard plot is use a reference.

So, they are you measure the soil loss and then you measure soil loss for another field where the slope length as well as slope steepness is different and then you can find out the applicant value of a LS like we saw in case of K and the steeper and longer the slope the higher the risk of erosion which is quite obvious, because we also saw when we discuss about the topographic factors.

So obviously, if the slope is more than; obviously, the velocity of flow will more will be more that means, the kinetic energy of the flowing water will be more. So that means, erogic capacity will be more erosion will take place and if that kind of slope continuous for a longer length obviously then more erosion will take place.

So, it is steeper and longer the slope higher will be the value of erosion. And topographic factor can be estimated using this equation that is LS is L by 22.13, remember this is the standard length of USLE plot to the power m 65.41 sin square theta plus 4.58 sin theta plus 0.065. Where L is the slope length in meters and theta is angle of slope. And this exponent m depends on the slope.

So, it is taken as point 5 for slope 5 percent or more 0.4 for slope range 3.5 to 4.5 percent, 0.3 for 1 to 3 percent and 0.2 for less than 1 percent. So, as you can see if m is more the this factor will be more; that means, the soil loss will be more so obviously if slope is less than this value is less slope is more this value is more which is quite obvious.

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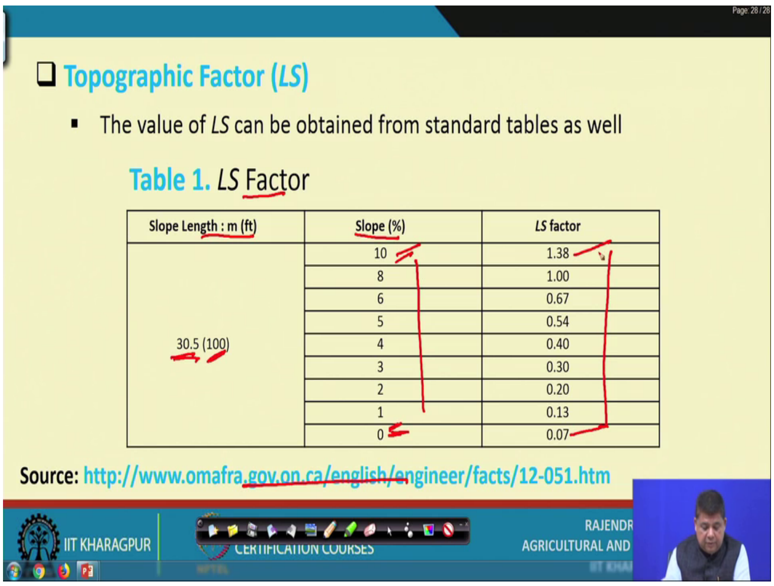

And topography factor values can also be obtained from standard tables. Here I have used this reference for tables where LS factor has been tabulated for different slope lengths and for different slope percentages and the recommended value.

So, if slope length is 30.5 meters or 100 feet then for different slopes starting from 0 to 10 percent these are the values. So, if the length is 30.5 meters and if slope is 0; that means, horizontal then LS value will be 0.07. Where in if it slope is 10 percent then this value will be 1.38. So, depending upon where the slope increases the value of LS factor also increases.

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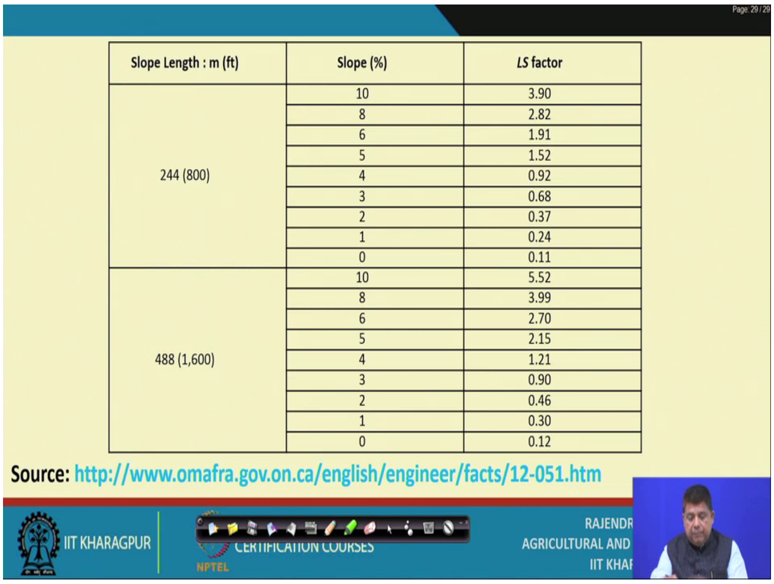

Slope Length : m (ft)	Slope (%)	*LS* factor
244 (800)	10	3.90
	8	2.82
	6	1.91
	5	1.52
	4	0.92
	3	0.68
	2	0.37
	1	0.24
	0	0.11
488 (1,600)	10	5.52
	8	3.99
	6	2.70
	5	2.15
	4	1.21
	3	0.90
	2	0.46
	1	0.30
	0	0.12

And similarly this sites produces tables for different slope length 61 meters, 122 meters and then 244 meters and 488 meter.

So, values can be the LS values can be referred from these tables.

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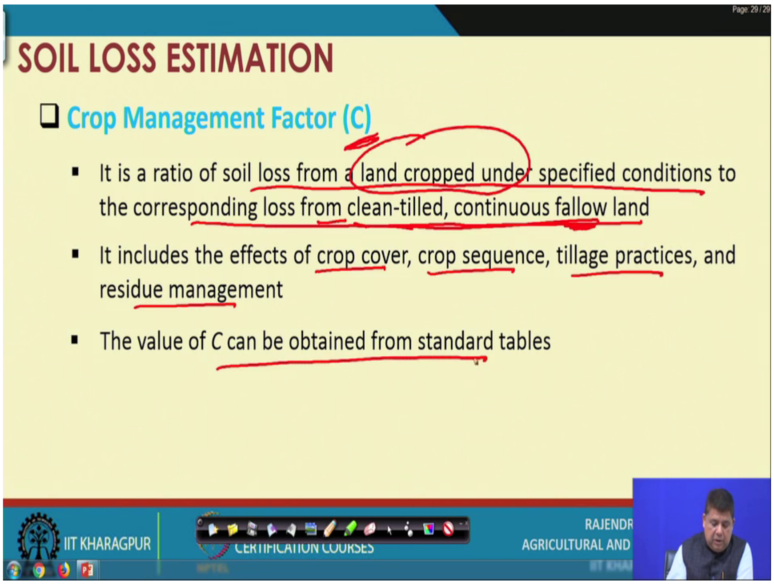

Now, coming to soil loss estimation and then continuing with the next factor the next factor is crop management factor. And it is the ratio of the soil loss from a land cropped under a specified conditions to corresponding loss from clean tilled continuous fallow land.

So, as again the difference is you can see is everywhere USLE plot standard USLE plot, where again it is fallow land continuous fallow, but clean tilled up and down slope some tilled is operation has taken place that is the difference value. And then if you measure soil loss from any other area which has been crop differently than the ratio of that soil loss will define the value of C.

And; obviously, it as we know under the various crops factors. So, crop cover, crop sequence, tillage practices and residue management how residual (Refer Time: 21:11) previous lecture.

So, all this will make impact and the value of C can be also obtained from standard tables and for example.

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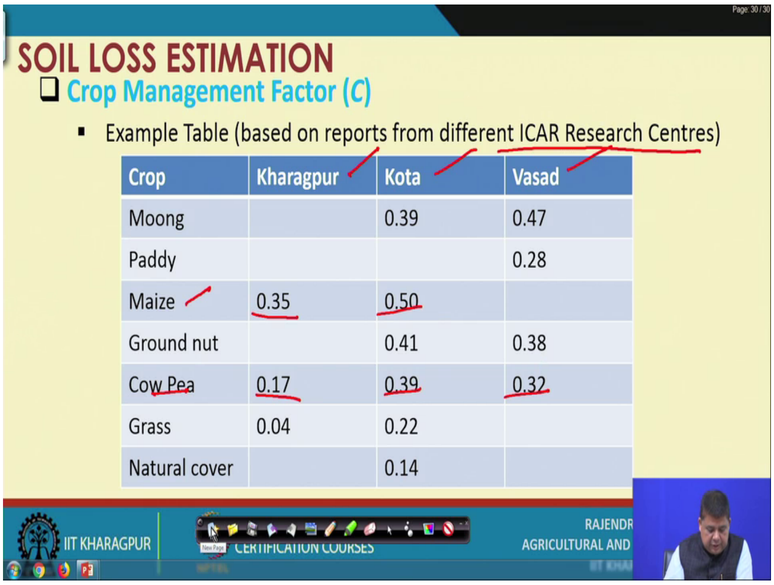

This is a table here which is based on reports from different ICAR research centers the values of C are there. For example, their Kharagpur research centre Kota and Vasad these are the values that is for Maize for example, value is 0.35 in Kharagpur 0.5 in Kota and Cow Pea if you take values are 0.17 and in Kharagpur, 0.39 in Kota and 0.32 in Vasad in Gujarat. So, that is way how you can refer the values of C from standard literature.

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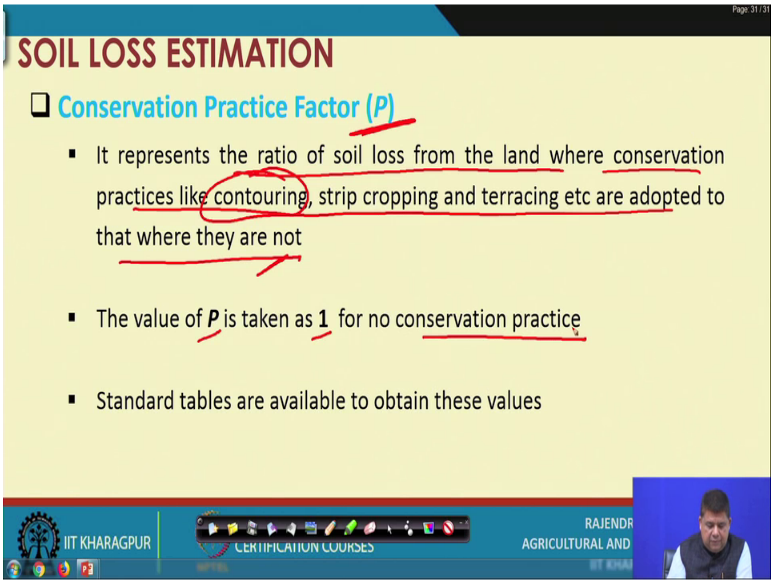

The last factor is so, conservation practice factor P which represents the ratio of soil loss from a land where conservation practices like contouring strip cropping and terracing etcetera are adopted to that where they are not that is. So, USLE standard USLE we know that no such practices adopted.

So, if you take the soil loss value from a field say for example, contouring has taken place then; obviously, with reference to USLE what is the soil loss that will defined the value of P. So, value of P is taken is 1 for no conservation practice. Similarly, the value of C is taken as 1 if no crop is the land is fallow and continuously being tilled. And for like LS and C for P also standard tables are available which can be referred.

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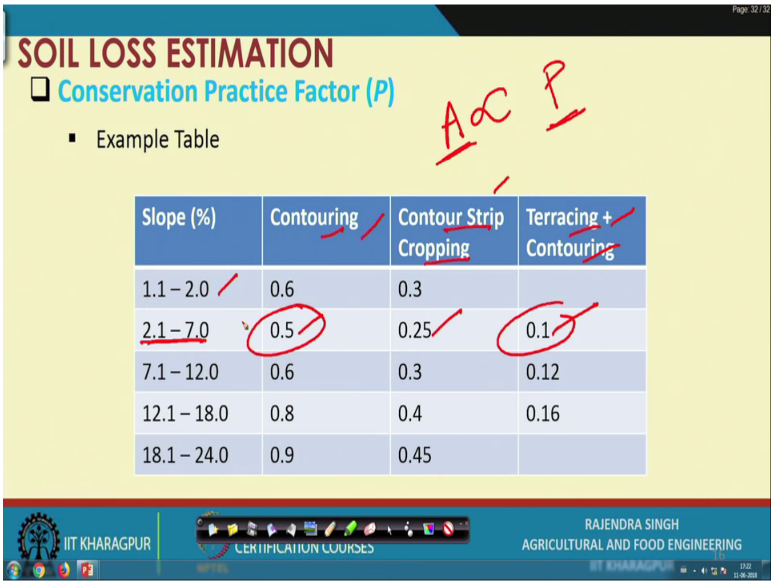

So, for example, this is a example table were for different slopes and different kinds of conservation practices that is contouring, contouring, contour strip cropping and terracing and contouring together the values are there. For example, if slope is between 2.1 to 7 percent for contouring the value is 0.5, for contour strip cropping the value is 0.2 and for terracing and contouring the value is 1. And from equation A is directly proportional to P. So, larger the value of P greater will be A.

So, from this relationship we can see that if we adopt combination of terracing and contouring over 2.1 to 7 percent. Then obviously the soil loss will be less as compared to when we only adopt contouring. So, that is quite obvious.

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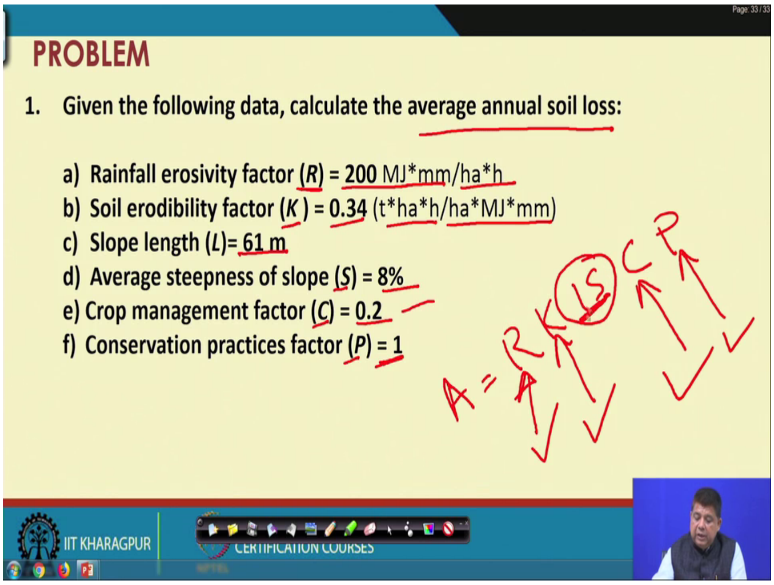

Now, let us come to a problem we try to see after seeing the universal soil loss equation, let us try to solve a problem. And the problem says that giving the following data calculate the average annual soil loss.

The rainfall erosivity factor R is given 200 mega joules mm per hectare hour, soil erodibility factor K is given as 0.35 tons hectare hour per hectare mega joules millimeter. Slope length is given L 61, average steepness of slope S is given as 8 percent, crop management factor C is given is O.2. Conservation practice factor P is given as 1 which implements that no conservation practice is taken. Just to see just to if we say A equals to RK LS CP this is what we have to use universal soil loss equation in order to be able to estimate the average annual soil loss.

So; obviously, here R is given, K value is given, C value is straightaway given and P value is given. So, and for LS factor; obviously, we have L and S known. So, as we saw either we have to use the relationship we saw in the LS factor we have a relationship or we can use the standard tables to obtain the LS. So, only thing which we have to determine knowing L and S, L and S what is the value of LS factor if we can obtain that will be able to solve this problem.

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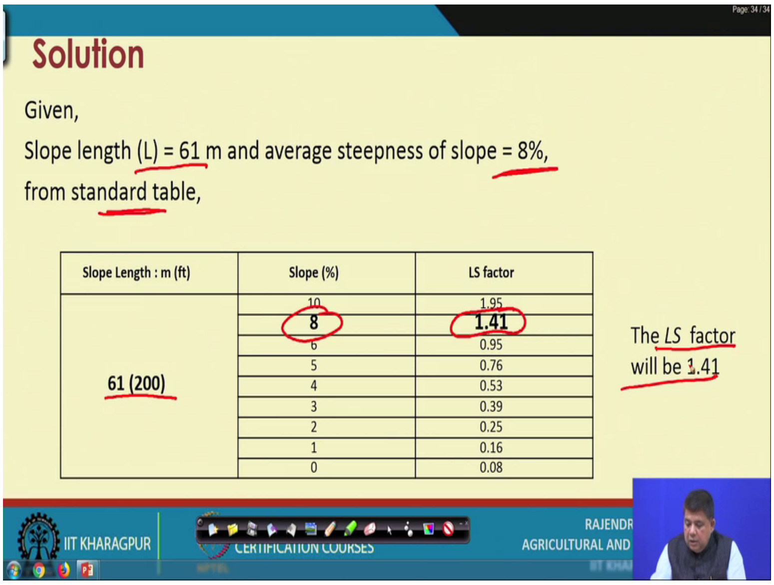

So, coming to the solution we can for finding L LS factor for L equals to 61 meters and average steepness slope of 8 percent we have gone to the standard table just now we saw earlier.

So, we have to refer the slope length equal to 61 meters or 200 feet and we have to refer the slope 8 percent and from the table we can read the value of LS is 1.41. So; that means, LS factor applicable in this particular problem will be 1.41 and thus knowing after knowing the value of LS we can continue.

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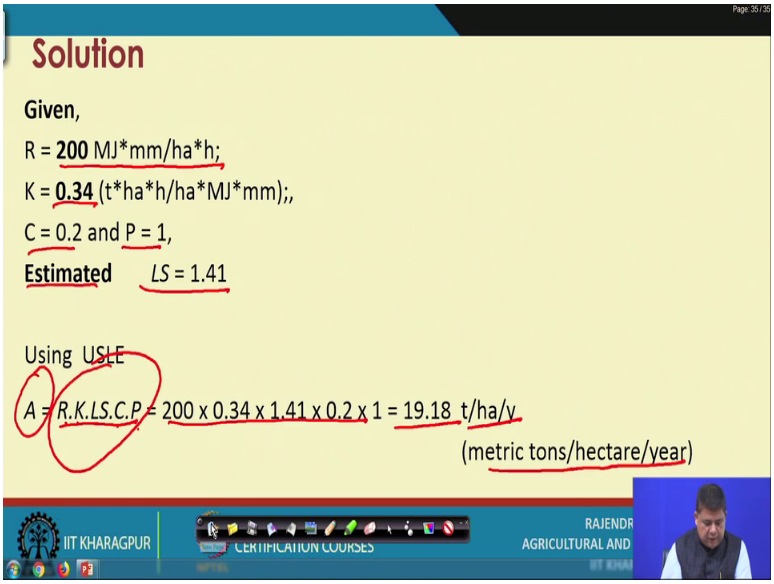

We have been given R equals to 200 mega joules 200 mega joules millimeter per hectare hour K is 0.34 in standard units C is 0.2, P is 0.1 and we already have estimated LS equal to 1.41.

So; obviously, we can we now know the values of all these factors and does putting in this equation and calculate. And we find that average annual soil loss A is 19.18 tons per hectare per year or 19.18 tons per hectare or metric tons per hectare per year that is the value of soil loss using this equation.

So, that simply means have you want to use the universal soil loss equation for estimating soil loss from a given conditions then we have to obviously obtain the values of all these factors RKLS C and P to be able to apply this equation.

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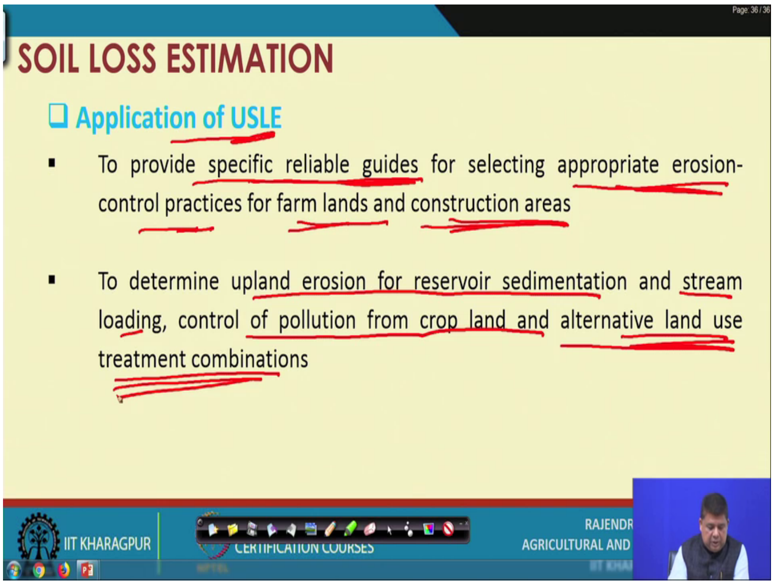

Now, for soil loss estimation; obviously, we apply USLE and what means that to provide specific reliable guide for selecting appropriate erosion control practices for farm lands and construction the areas that is the application of USLE.

So, for example, because we already know that if we adopt a particular crop management factor, if you adopt a particular conservation practice factor then what should be it is value? And under what treatment what kind of cropping pattern we should adopt? Or what kind of conservation practice we adopt, based on that the value of C and P will be affected.

So; obviously, USLE could be applied to provide reliable guides for selecting appropriate erosion control practices for farm lands and construction area. That means, we have to first the side how much erosion, we want to what is the soil tolerance soil loss tolerance for a given area on annual basis and based on that we can decide on what kind of erosion control practice should be adopted. Determine upland erosion for reservoir sedimentation in stream loading control of control of pollution from crop land and alternative land use treatment combinations.

So; obviously, we know one of the ill effects of erosion is also that it fills the reservoirs or storage structures or it stream beds also. Because, the ultimately whatever soil is eroded that reaches the streams are the storage structures like reservoir; so obviously, if you want to maintain the life of the reservoir or if you want to keep the reversed cross section free from sedimentation. So obviously, we have to control erosion on the upside, that is from were upland when we say it is that is means the catchment from where the water is reaching a particular reservoir at particular stream.

So, if we can control that so for that for controlling that what kind of land use treatment combinations we have to use that can be found applying universal soil loss equation. These are the important applications.

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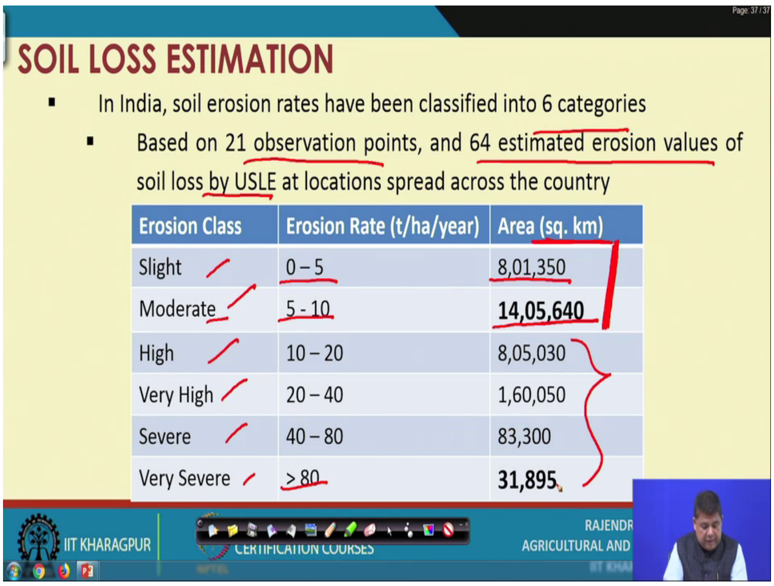

Now, in India soil loss rates have been classified into 6 categories that is based on 21 observation, 0.64 estimated erosion values by USLE a different it locations spread across the country. The erosion classes are slight, moderate, high, very high, severe, very severe. And erosion rates slight means 0 to 5 tons for hectare per year, moderate is 5 to 10 tons per hectare and very severe is greater than 80 tons per hectare and these are the areas affected. So, moderate erosion which is basically allowed up to what level we can allow.

If there are 14, 05, 640 square kilometer of the area is that falls under moderate erosion class. Where in 8, 01, 350 hectares falls under the slight erosion. And of course, as we know that we have to keep from when we are discussing salt tolerance we saw that we must keep soil loss within the moderate limit. That means, these many levels are unacceptable so; that means, we have to take various kinds of soil erosion measures in order to control the higher loss of soil erosion wherever it is occurring.

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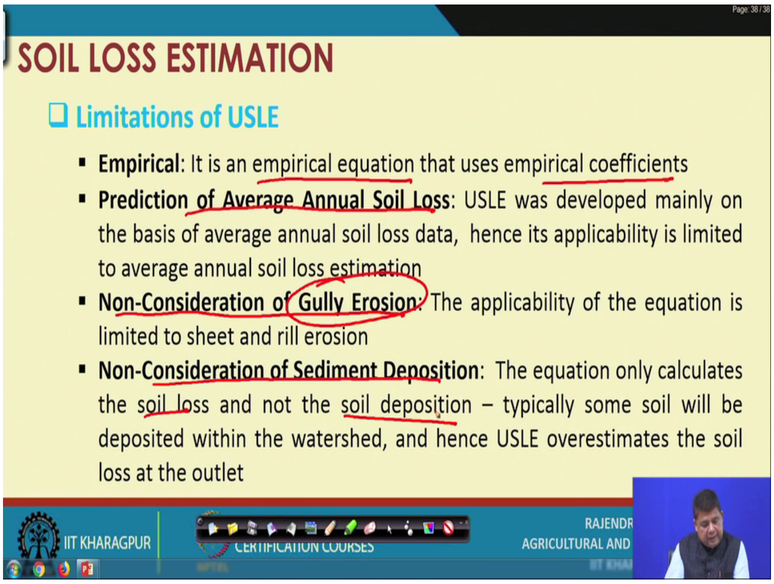

Then obviously, USLE has certain limitations as well it is empirical in nature that means all coefficients are empirical. So, that is one of the limitations. So, the values of R or K or LS or CP are applicable only for the areas for which we have estimated those values. Then next is the prediction of average annual soil loss it does predict only average annual soil loss.

So, if you want to use a find out the soil loss from a particular event then USLE cannot be used. Then; obviously, we when we define USLE it is we saw that is only limited to sheet and rill erosion. That means Gully erosion which is one of the primary or major erosion concerned that is not taken into account; then non consideration of sediment deposition.

So, here it only talks about the sediment loss, but as we know that we have already seen the process that when erosion detachment and transportation take place in deposition also occurs. But, there is no consideration of soil deposition in USLE. So, that is one of the major limitations of USLE.

So, with this we have seen USLE that how to use universal soil loss equation, what are what are the factors involved in the universal soil loss equation, what are the applications, what are the limitations of universal soil loss equation. That we have seen in this first lecture of this week, that is week lecture number 6. And in following lectures we will see how to estimate erosivity, erodibility, what are the various modifications available for USLE and how to apply that in coming weeks.

Thank you very much.