Irrigation and Drainage
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Lecture - 59
Irrigation Economics

Lectures we have talked about economics of drainage project and now I mean the Irrigation Economics we are going to cover in this lecture; so the basically the Irrigation Economics.

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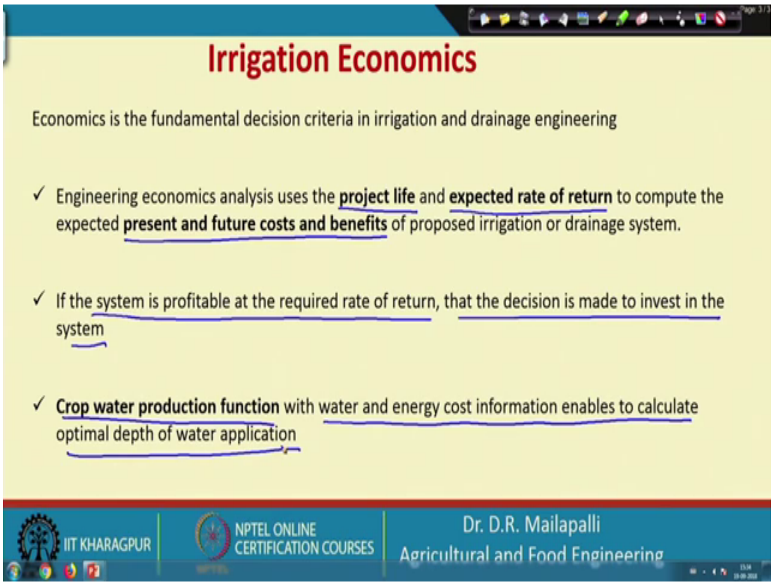

So, economics is the fundamental no decision criteria of irrigation drainage engineering. So, engineering economics analysis uses basically the project life, we have explained the project life into three basic types: one is actual life, economic life and financial life. So that is project life and expected rate of returns and to compute the expected present and future cost and benefits of a proposed irrigation and drainage system.

So, in this what happens so, knowing the project period and rate of return and you are going to bring both cost and benefits to the present value and compare. And, see whether it is beneficial to invest in this particular irrigation project or not and we are going to compute the cost benefit ratio and also net present value. So, these two were two indicators we are going to compute in irrigation economics as well as the drainage economics. So, if the system is profitable at the required rate of return that the decision is made to invest in the system.

So, this is a common sense if you are getting the profits, you know in the particular system or then definitely it is worth to invest in the particular project. So, this is the overall project, but individually or seasonally if you want to know or if you want to estimate the cost of production. So, we need the crop water production functions with water and energy cost information enables to calculate optimum depth of water applications. This is not only to estimate the production cost, but also estimate economic and I mean depth of water to be applied. So, that the yield will be maximum right and the profit will be maximum ok.

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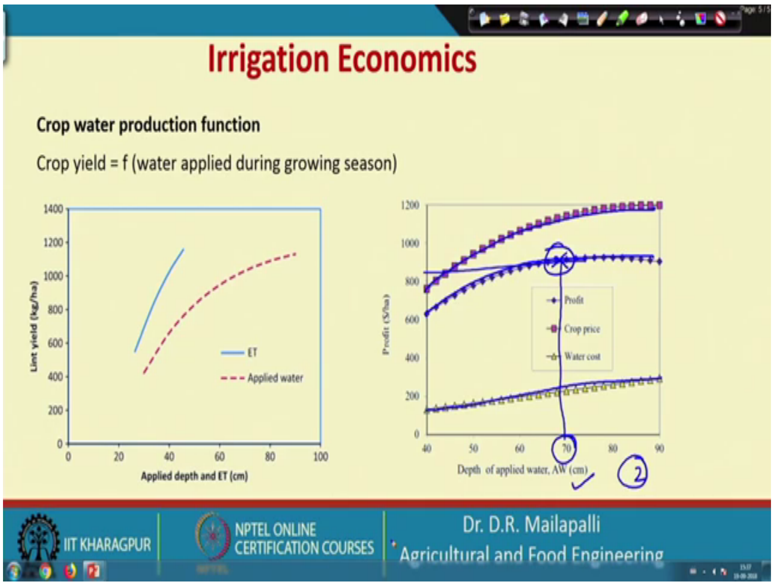

So, and then the next is so, the crop water production functions here for example, the crop yield is a function of water applied during the cropping season. So, here for example, in the figure 1 in figure 1, if you see the applied depth of water which is in iron and ET; so depth of water as well as ET on x axis and then the cotton yield that is called lint yield, that is in kg per hectare and y axis. This is the graphs there are two graphs: one represents the ET and the other one is you know applied water.

So, here for a particular applied depth of water right; so, the ET results ET based irrigation that results the maximum lint yield compared to you know the water you applied right in the field. Now that means, it has some losses this is the total water or the grass water applied in the field. So, that includes you know pre-irrigation and then all other losses like runoff, where de-percolation all other losses ok. So, definitely so, this is one and then the in the figure 2 you see this is the profit on y axis and depth of water applied on x axis.

So, if you see this, the crop price so it contains two components. So, this is a crop price and then water price and when you subtract the water price from the crop price and you get the profit ok. This is the profit graph and if you clearly see a at what depth definitely the profit is maximum. So, look at this maybe you know at about 70, now this point in the profit is maximum. So that means, the 70 centimeter of water needs to be applied to get the economic yield and also the maximum profit.

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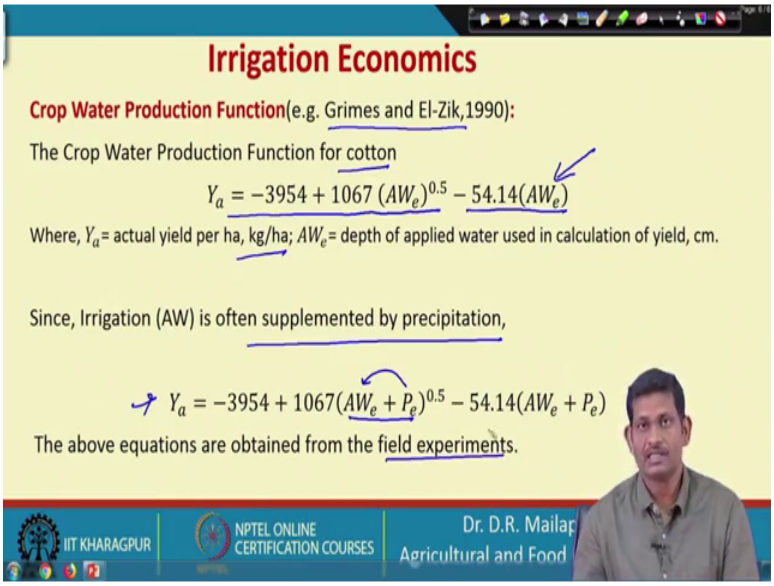

And then so, the next is we are going to see the crop production functions, here Grimes and El-Zik, 1990. So, he gave a crop production function especially for the cotton. So, here Y a this is the yield in you know actual yield and kg per hectare is equal minus 3954 plus 1067 into AW e. This is experimentally given water depth 0.5 54.14 into applied water. So, this is these relationships basically obtained from the experiments. So, AW e represents the applied water in experiments field experiments.

So, since irrigation often supplemented by precipitation, so sometimes you know you have to you know sometimes they are there are some precipitations during the irrigation or if there is precipitation you do not give to irrigation. So, you need to add that the precipitation or effective precipitation in applied water ok. So, then the production function looks like this Y a. So, this is the total water applied and then AW e P e ok. The above equation obtained of course, the field experiments.

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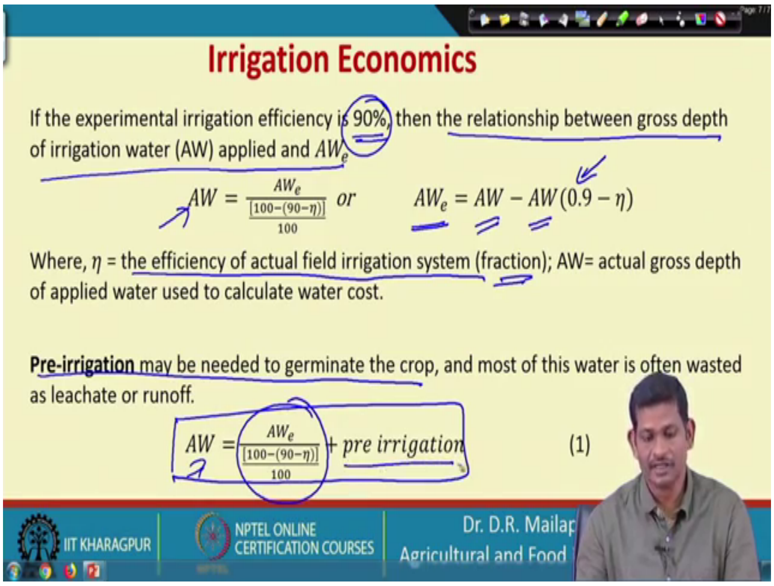

So, and then the next is so, if the experimental irrigation efficiency is 90 percent ok. So, these production function what we have obtained is based on 90 percent irrigation efficiency. So, then the relationship between the gross depth of irrigation water applied and AW e. So, this is AW this is gross applied gross depth of water applied which is equal to a depth of water applied in field experiments divided by 100 minus 90 minus the irrigation system efficiency divided by 100 ok.

Or the experimental depth of water applied water is equal to gross depth of water minus gross depth of water into 0.9 minus n. So, n refers to this 90 percent, we assume that the experimentally determined AW is related to 90 percent irrigation efficiency ok. So, n is the irrigation efficiency the field irrigation system which is in fraction and the other one is this and pre-irrigation may be needed to germinate the crop.

So, you know in not only the AW e so, you also have to apply you know this is the pre-irrigation that is that is comes under gross. So, the most of this water is often wasted as leachate or runoff. So, then the adjusted gross water depth applied to the field is equal to so, this we have already computed plus pre-irrigation ok. So, this is the gross water depth applied to the field for a particular crop, whereas, AW e is the depth of water or actual depth of water applied to the crop during the experiments.

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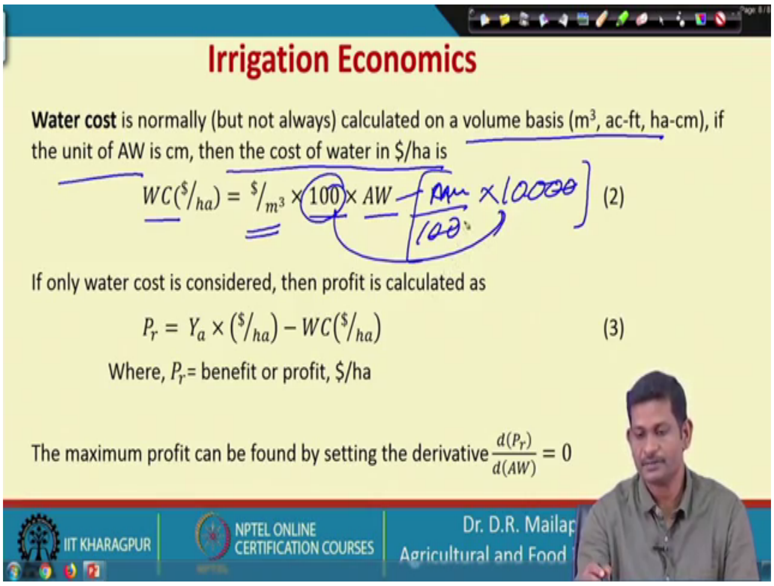

So, then the cost here so, irrigation cost here water cost is normally calculated on volume basis right, that is meter cube or acre foot and hectare centimeter, if the unit of applied watery centimeter then the cost of water in dollar per hectare is equal to water cost is dollar per hectare which is equal to this is, this is the cost of water right in dollars into 100 into AW this is in centimeters.

So, since we are looking for you know computing for 1 hectare. So, the centimeter is been converted into meters that is you know there is a meter by 100 and since it is you know 1 hectare this is 10,000 ok. So, then this gets so, 100 ok; so, this 100 is from this. So, if only water cost is considered then profit is calculated as.

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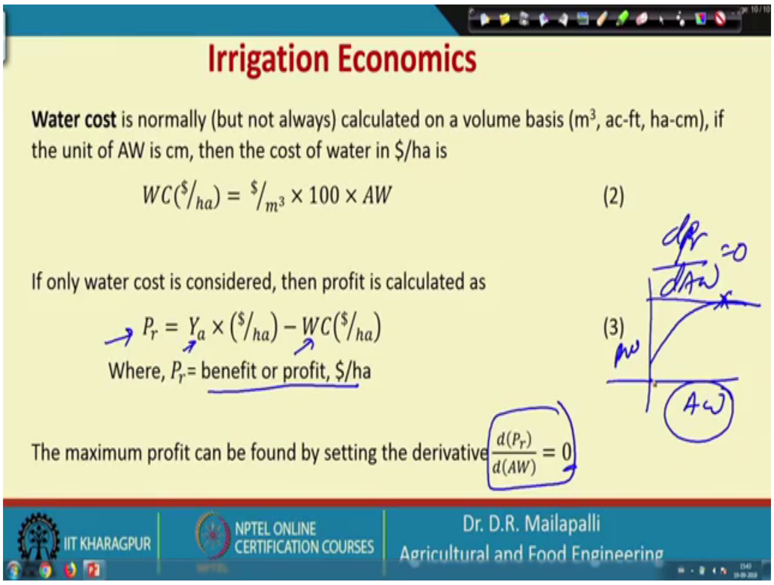

So, generally profit is equal to so, production cost minus water cost so right so, that is the profit. So, during the season this is the product once you get the yield and the resale value of the yield or value of the yield minus the cost of water that will give the profit only, if you are considering the water as the cost. And, P r is the benefit or profit in dollar per hectare.

So, the maximum profit can be found by setting the derivative. So, this we know because, the graph which is going like you know AW and the profit so, this goes in this. So, there is one place is the maximum; so that means d P r divided by d AW which will be 0 at one point. So, that will be 0 and you get the AW right. So, economic AW for which the profit will be maximum.

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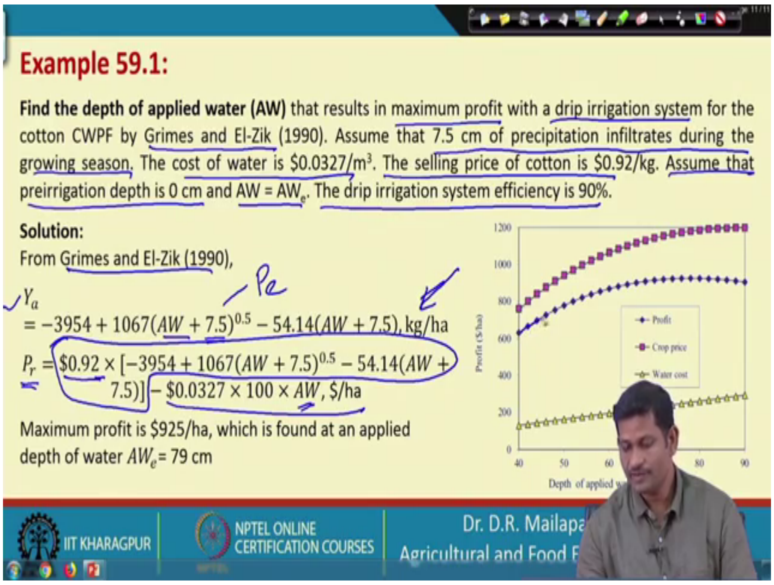

Here is the example, let us see find the depth of water applied that results in maximum profit with drip irrigation system for the cotton CW Crop Water Production Function by Grimes and El-Zik. So, that is already given in the previous slides. Assume that 7.5 centimeter of precipitation infiltrates during the growing season. The cost of water is 0.0327 per meter cube dollars. The selling price of the cotton is 0.92 dollar per kg. Assume that the pre-irrigation depth is 0 centimeter and AW e which is equal to the experimentally determined AW e. The drip irrigation system efficiency is 90 percent ok. Since, it is 90 percent and AW definitely will be equal to AW e ok.

So, as per the formula is concerned. So, from Grimes and El-Zik 1990 so, this is the previous equation minus 3954 plus AW, this is a you know P e right precipitation excessive or precipitation excess and AW e. So, this is the kg per hectare this is what production ok, this is the production and now profit which is equal to so, Y a multiplied by 0.92 right. So, this will give the selling price right up to this from here to here the selling price of the crop and then this is the water cost.

So, water cost this is the price of water into applied water ok. So, the maximum profit so, with using this equation; so, the profit function is being drawn right. And, from the graph so, the maximum profit you get at you know at about 79 AW is a 79 right 79 centimeter and you get the maximum. So, that will be equal to your 925 dollar per hectare ok. So, this is 925 dollar and you get this is 79 centimeter ok. So, using this graph you can estimate the maximum profit for which for which the applied water will be terminated.

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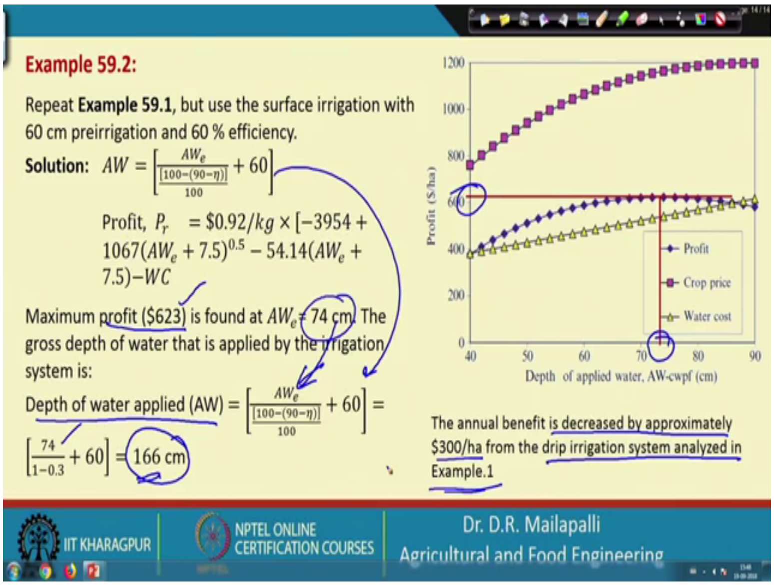

And then there is a second example. So, in this repeat the same example; that means, you have drip irrigation system ok. And only, but use the surface irrigation system here instead of drip irrigation system change it to surface irrigation system. And, see how it is profitable with the 60 centimeter pre-irrigation and 60 percent efficiency. So, there it is 90 percent efficiency. So, since it is 60 percent efficiency. Therefore, the field applied or experimentally applied water will be different from field applied water.

So, here AW e this is gross water which is equal to AW e experimenter divided by 100 minus 90 minus n by 100 plus 60, 60 is the pre-irrigation where, here n for surface irrigation it is given 60 percent ok; so then using the profit function using the same profit function. So, this is for surface irrigation this is for surface irrigation. So, for surface irrigation you are going to get the maximum you know you are going to get the maximum profit at 623 here and AW e here you get 74 centimeter. So, for 74 centimeter AW e you get 623 in dollar as a profit in case of surface irrigation.

So, now depth of water applied AW gross depth of water applied in case of surface irrigation is equal to so, this is applied water AW d AW e the 74 plus 90 minus so, the same equation you can repeat it. And, then substitute the value 74 1 minus 0.3 because, 90 minus 60 is 30 that is 0.3 plus 60; there is a 166 centimeter ok. 166 centimeter you need to apply in case of surface irrigation, huge amount of water you need to apply.

So, the annual benefit is decreased by approximately 300 dollar per hectare. If you see this is 623 and in case of drip irrigation it is 900 923 something like that. So, around you get 300 dollar you know difference from the drip irrigation system right, in case of example the previous example ok. And not only that, if you see the gross water depth so, that is increased 166 centimeter compared to I mean the previous example if you see. So, that will be around 74 centimeter something like that.

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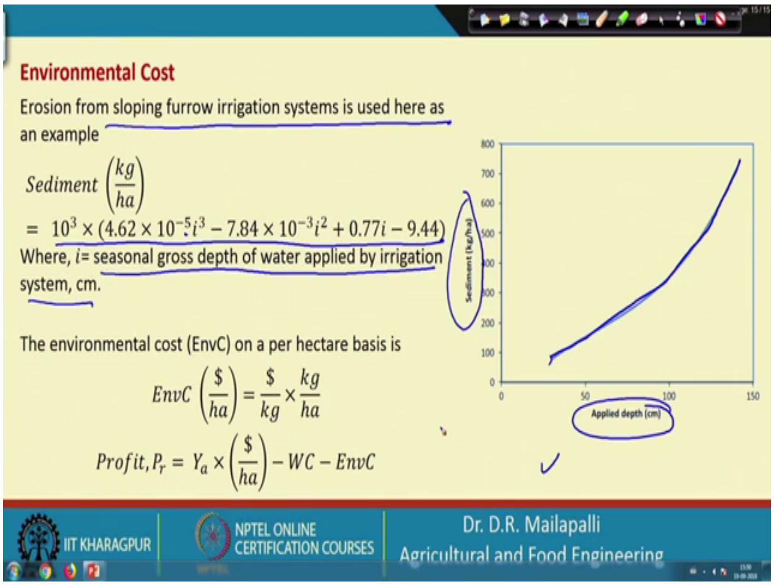

So, this way you can analyze if you shifting to one irrigation into another irrigation whether it is profitable or not and then environmental cost. So, previously we have only accounted for water cost, now for example, environmental cost also very important. Suppose in case of surface irrigation there is a lot of runoff and that carries lot of sediments from the field and definitely that pollutes the near water bodies ok. So, that involves the cost because, you are dumping you know non points or sub pollution pollutants into the fresh water bodies.

So, if you consider that definitely the profits will reduce. So, the erosion here erosion from the sloping furrow irrigation system used here an example, sediment kg per hectare is computed with this empirical equation that is 10 power 3 4.62 into 10 power minus 3 into i power 3. So, where i is the seasonal gross depth of water applied by irrigation system centimeter ok. So, the 7.84 into i square 0.77 i minus 9.44 here is the here is a graph it is applied depth on you know x axis and then sediment on y axis ok. So, definitely so increasing the water depth that yields you know more sediment and that runoff from the field to the nearest water bodies.

So, the environmental cost EnvC suppose on per hectare basis is equal to it is computed as dollar per hectare. So, dollar per kg so, this is the cost of for sediment which is been added to the fresh water and kg per hectare is the yield of sediment from the particular watershed or the irrigation system. So, the profit here is this is called this is a production, this is the total you know income you get in the end of the season, then this is a water cost and this is an environmental cost. So, the crop income minus water cost minus environmental cost will be profit.

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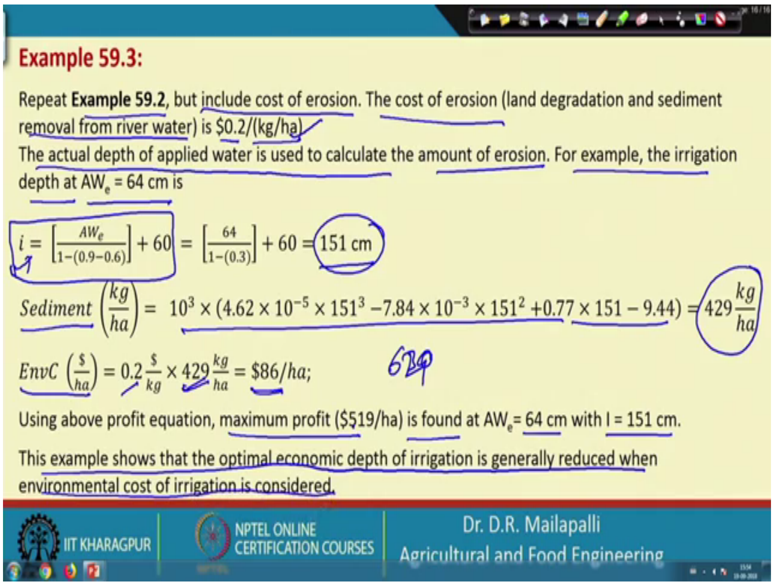

So, then for example, including the environmental cost. So, here repeat example of 59.2 where that is the surface irrigation system remember, but include cost of erosion. The cost of erosion land degradation and sediment removal from the river water is 0.2 dollar per kg per hectare. So, because of I mean suppose the removal cost the sediment removal cost is 0.2 from kg per hectare from the I mean water body, where I mean the sediment from the nearby fields are being added to the system. So, the actual depth of applied water is used to calculate the amount of erosion. For example, the erosion depth AW e which is experimentally determined applied water which is 64 centimeter.

So, that is i; this is a grass depth of water AW e 1 minus 0.9 minus 0.6 plus 60. So, this is from surface irrigation system the previous example 64 1 minus 0.3 plus 60 this is 151 centimeter ok. So, this is a gross depth of water and sediment. So, with this gross depth of water using this gross depth of water estimating the sediment, sediment will be 429 kg per hectare; using the you know empirical equation we defined before. Now, the environmental cost is you know 1 kg per hectare for 1 kg per hectare you have 0.2 dollars. So, 0.2 dollar for 1 kg per hectare in 429 is the kg per hectare is the sediment yield and total cost of sediment is 80 dollar 86 dollar per hectare.

So, using the above profit equation the maximum profit 519 per hectare is found at AW e 64 centimeter with I equal to 151 centimeter. So, using the previous you know, if you can subtract in 86 dollar from the previous thing. Then you get 519 right, which is because that is around 630 minus 86 9 it seems 29, when it is 6 you get 19. So, with this example shows that the optimal economic depth of irrigation is generally reduced; the environmental cost of irrigation is considered. So, if you are considering the environmental cost. So, the irrigation depth is going to reduce 151 and there it is 171 something like that right.

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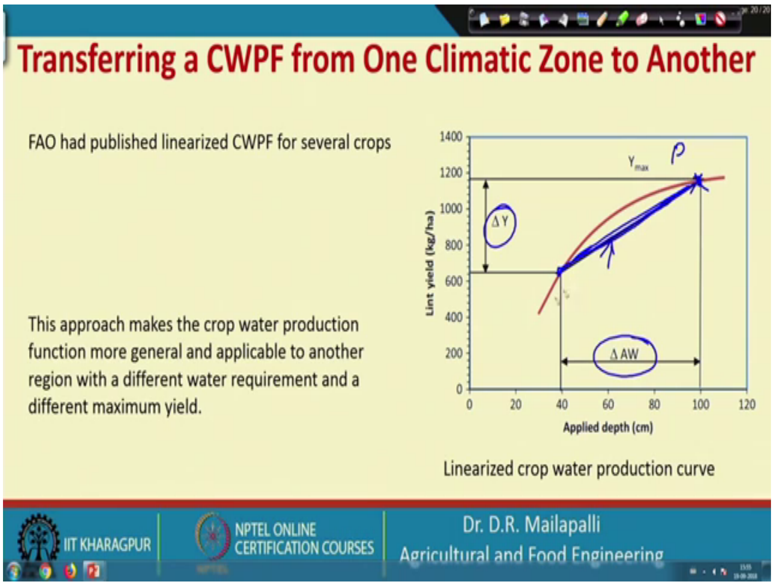

So, now whatever the production functions defined this is experimented for a particular region. So, if you want to translate that to the different region, if someone wants to use the same production functions in another region. So, FAO that the food and Food and

Agriculture Organization has, I am given a procedure or linearized the actual production function. So, that anybody can use the production function. So, here for example so, the actual the applied depth on x axis lint yield on y axis.

So, this is the actual curve right actual curve and in order to linearize that so, this is the linear curve ok. So, how to translate this particular curve into linear curve? So, this is called a linearization of this particular curve. So, it has a slope in the sense so, this is a wide X difference and Y difference. And, definitely delta Y by delta AW will be the slope of this particular curve, I mean line ok. And, knowing this point right knowing this point or at any at this point and knowing the slope you can find out the; I mean line equation. So, let us see that.

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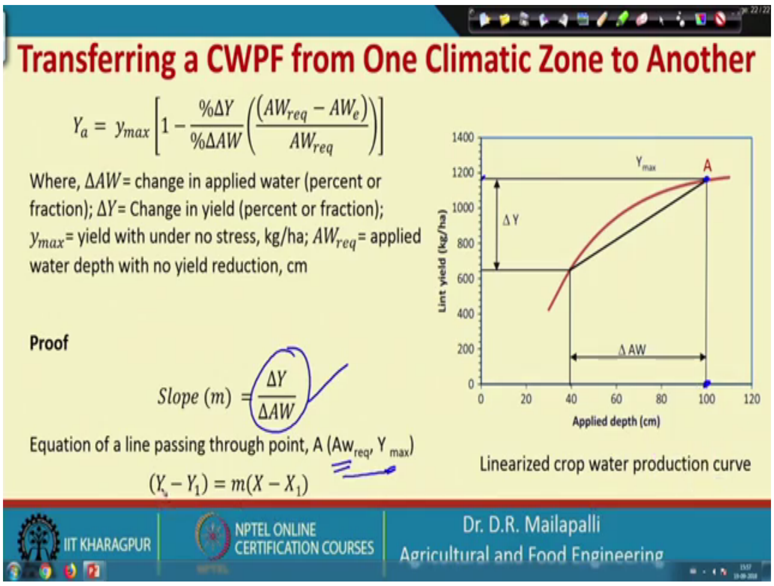

So, as I said this is finally, you get the equation for I mean linearized; linearized curve equation or equation of the line which is equivalent to the curve. So, where Y a is the actual yield y max is the maximum yield and delta Y delta AW is the differences in yields as well as water applied and this is required and this is experimentally determined a AW and AW required ok.

So, now we can also have the proof for this. So, like for example, slope here is delta Y by delta AW; equation of line passing through AW required so, this is the AW required and then Y max. So, this is Y max, this is a my Y max. So, knowing the slope and knowing the equations this is just substitute this is a line equation Y minus Y 1 minus m into X minus X 1.

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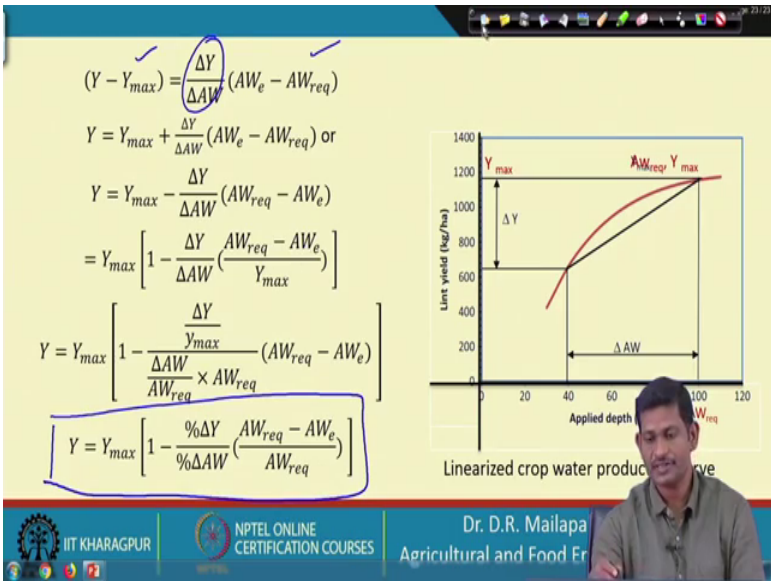

And then, if you can follow the procedure like substitute the particular point in this is the slope, and these two are the points and then substitute it and the simplify it. And finally, you get Y equal to Y max 1 minus percentage delta Y by percentage delta AW into AW required minus AW e by AW required ok. So, you can go through the step this is easy steps right.

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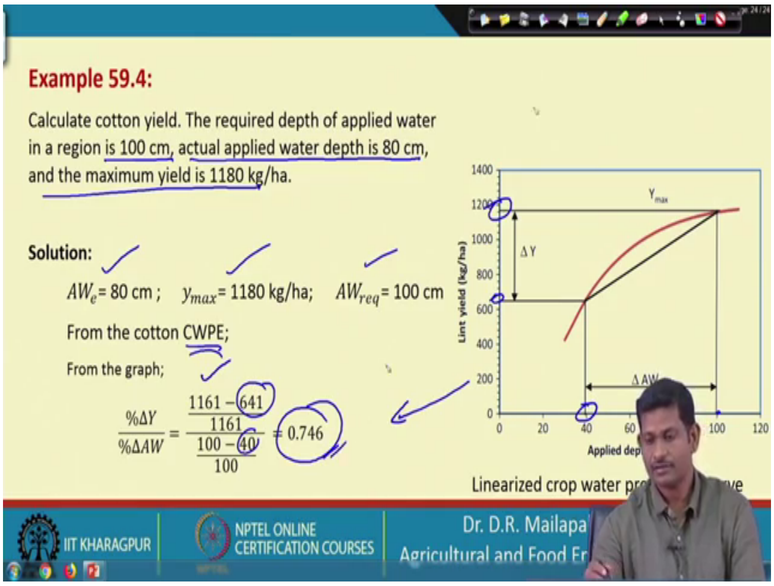

Now, example 4: to calculate the cotton yield the required depth of applied water in the region is 100 centimeter and actual applied depth is 80 centimeter and the maximum yield is 1180 kg per hectare. So, this is the maximum yield actual applied AW e e e 80 centimeter and in the region 100 centimeter; AW e 80 centimeter, maxim 1180, AW required 100 centimeter. So, from this from this graph so, this is already available graph from the experiment; so, use this graph.

So, from the CPWE this graph what happened 11; so, for 100 percent 100 percent you get 1161 here and then for 40 for 40 you get 641 right 641. So, substitute this you get this is the slope of this particular I mean line.

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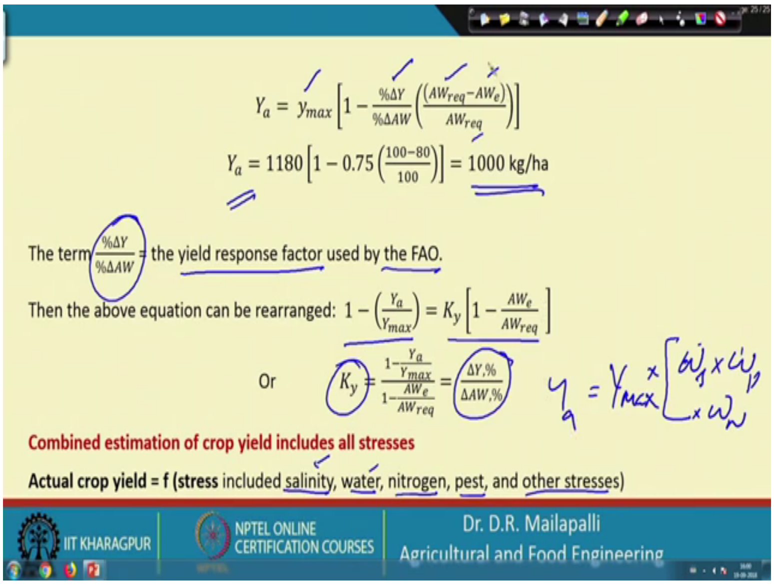

So, this knowing this slope so, knowing this slope and knowing the other parameters. So, this is the slope is known and y max is known and all other parameters are known ok. So, now the actual yield will be 1000 kg per hectare. So, the term this one is known as yield response factor which is defined by FAO. So, I mean if you bring that equation rearrange the terms; so, that will be 1 minus Y a by Y max K y into 1 minus AW e by AW required. And, K y this yield response factor which is equal to you know this could be a slope or 1 minus Y a by Y max by 1 minus AW e by AW required.

So, knowing the stresses I mean yield reduction due to different stresses, the combined yield can be estimated is this is the function of the stresses included salinity stress, water stress, nitrogen stress, pest stress and all other stresses. So, these are all percentages. So, knowing the potential yield right, knowing the potential yield e max, that is a e max multiplied by all you know let us say yield reduction due to this yield reduction due to water stress right. So, let us say water stress and yield reduction due to pests right and yield reduction due to nitrogen. So, all these things are in percentages you get this is the actual yield.

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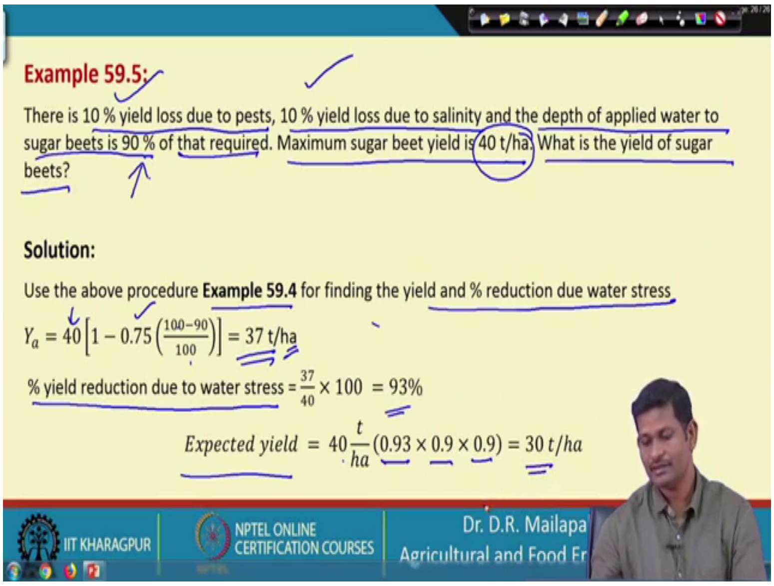

So, let us see that example here for yield reduction. So, there is a 10 percent yield loss due to pests, 10 percent yield loss due to salinity and the depth of applied water to the sugar beets in 90 percent of the required and maximum sugar beet yield is 40 tons per hectare. What is the yield of sugar beets? So, here yield loss for pests and for due to salinity are given and we have to find out yield loss due to water stress. And, then I mean plug it with maximum yield and you get the actual yield. So, use the above procedure that is from the previous example. Find the percentage yield reduction due to water stress that is Y a 40, this is a Y max and 1 minus this is the slope of that particular curve 0.75 100 minus 90.

So, this is a apply I mean 90 percentage of that being a so; called be at applied water apply water to sugar beet is 90 percent ok. The depth of applied water to sugar beet is 90 percent of that required ok. So, that is 100 minus 90 by 100 and you get 37 tons per hectare and percentage yield reduction due to water stress is 37 by 100 40 right. So, this is this is this much is actually yield divided by 37 by 40. So, that will be 93 percent and expected yield will be 40 and 0.93 0.9 is due to the pests and 0.9 is due to the salinity. So, total you get 30 tons per hectare. So, the actual yield is 30 tons per not 40 tons per hectare because.

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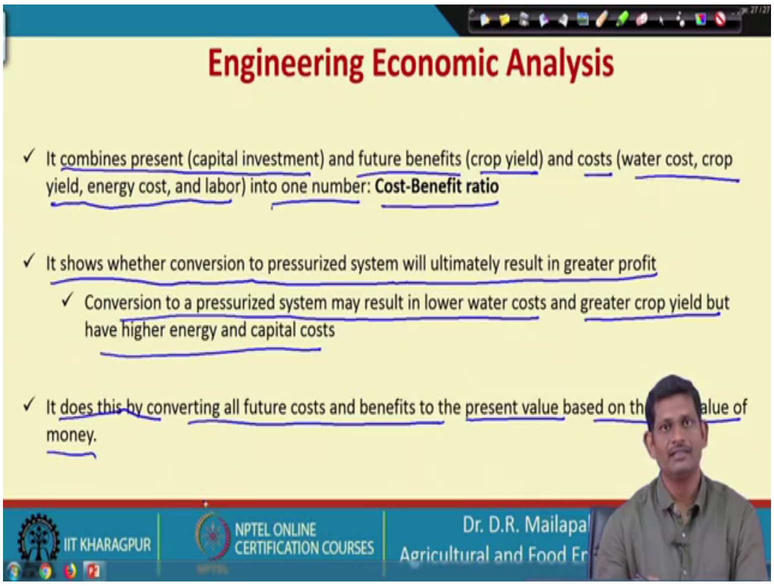

So, now next is the engineering economics. So these, whatever we have learned the previous slides; that is to estimate the economics or the profit for a particular season ok. So, knowing that now you do see whether investing such irrigation project is profitable or not. So, here the engineering you know economics analysis will definitely help to decide whether to invest or not. So, it combines the present that is the capital investment and future benefits there is a crop yield, and other benefits and costs water cost, crop yield, energy cost and labor into one number. So, this cost benefit ratio. So, this is very important as a in the beginning of the lecture I told so, there are two indicators: one is a net present value and then cost benefit ratio.

So, knowing the you know magnitude of these values definitely will see whether investing in this particular you know particular project is beneficial or not. So, it shows whether conversion to pressurize system will ultimately result in greater profit or not. So, this is and the for example, conversion to pressure system may result in lower water cost and greater yield, but higher energy cost or capital cost. Because, it has you know other components as well as a pump and all other components and that really not requiring creative surface irrigation system. So, this always trade off between you know the yield as well as the costs ok.

So, it does it does this by converting all future costs and benefits to the present value based on the time value of the money. So, what he does engineering economic so, if you are putting some money in the particular project? So, and the benefits you are expecting for example, 10 years or 20 years time right. So, if you are expecting 10,000 dollars from the particular project. So, I calculate; s the present value of the particular benefit and the cost the present cost, so then the compare present cost and benefits. And finally, it says whether I mean investing in this particular project is worth or not ok.

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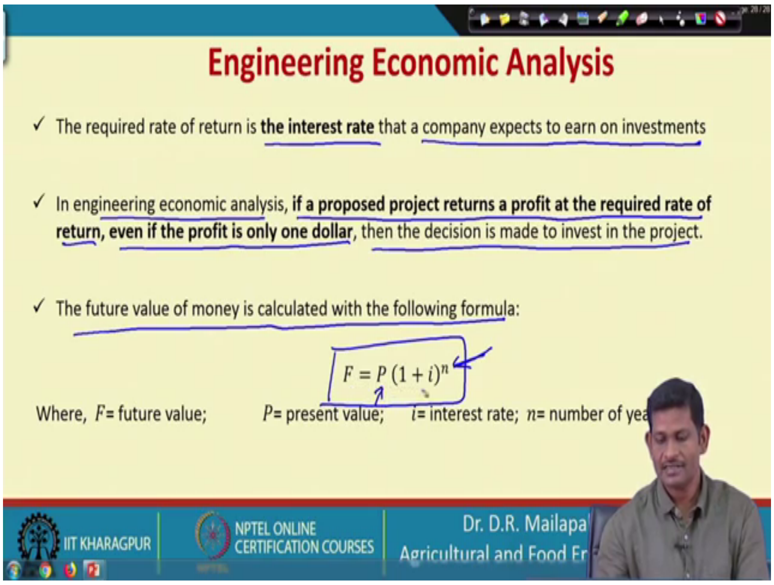

So, the required rate of return this is the terminologies we use so, the interest rate. So, that a company expects to end on investments. So, this interest rate, interest rate is the required rate of returns. In engineering economic analysis, if a proposed project returns a profit at the required rate of in return, even if the profit is only one dollar right, then the decision is made to invest the project.

So, in this is the thumb rule or common sense that if you are getting in a profit of one dollar definitely you go and invest in the project. The future value of money is calculated the following formula; this is F is equal to P plus P into 1 plus i power n, n is the project life and then P is the present value and i is the interest rate, n is the number of years and F is the future value.

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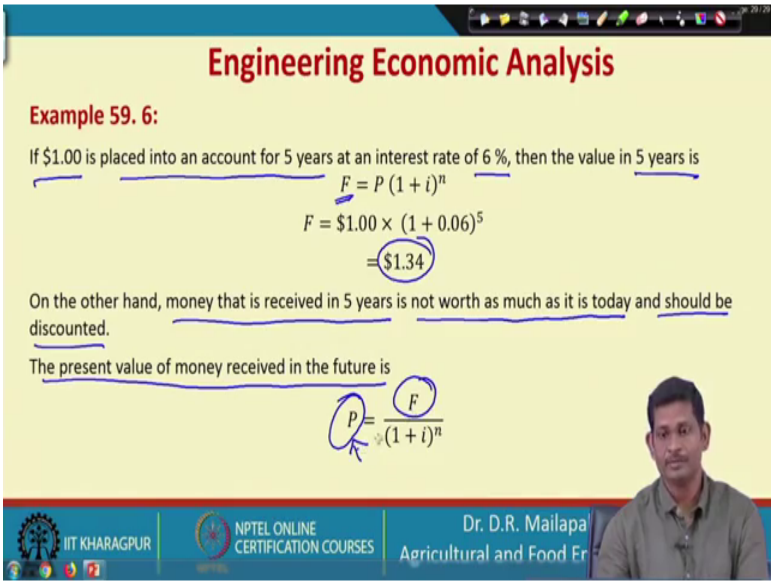

So, the same thing you can also get the for example, here if suppose 1 dollar is placed into an account for a 5 years at an interest rate of 6 percent, then the value of 5 years is the future value will be 1 dollar 34 cents. So, on the other hand money that is received in 5 years is not what as much as today and should be discounted.

So this is, I think in the I mean week number 11 in week number 11 lecture number 4 if you refer so, we used discounting factor right. So, that the same kind of concept we will be using you know in irrigation also. So, the present value of money received in this future is so, this is the reverse. So, if you knowing the expecting expectations the future, you can also calculate what is the value in the present.

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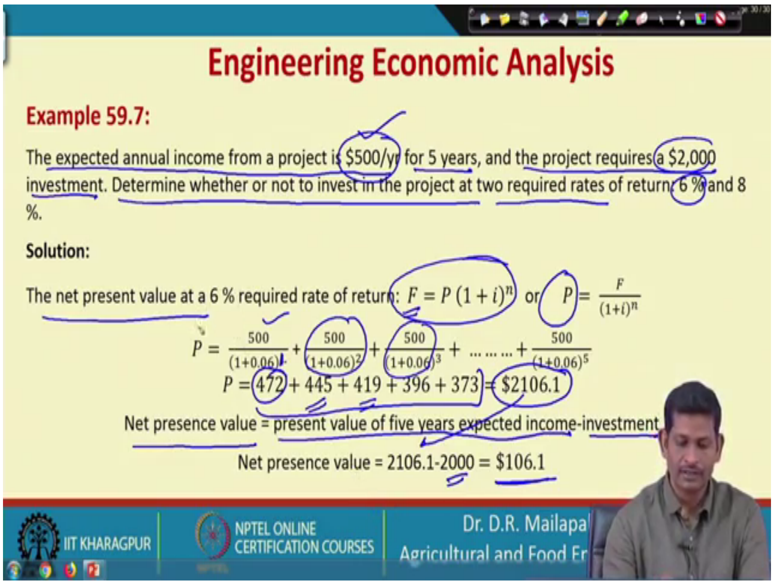

So, for example, here in this example the expected annual income from a project is 500 dollar per year for 5 years, and the project requires 2000 dollars investment. Determine whether or not invest in the project at two interest rates: one is 6 percent and 8 percent interest rates ok. So, here annual income is given. So, every year you are expecting 500 dollar per year for 5 years and the project requires 2000 dollars investments, investment is given. So, let us see net present value at 6 percent interest rate will be; so, F this is the formula we will be using and the for the present value.

So, P is equal to F by 1 plus i by n. So, this is what we expect in every year. So, there is a 500 a 1 plus 0.06 in first year. So, this is the value and the same thing in second year this is the value, third year this is the value. I mean in third year so, all these things when you combine. So, this will be the present value of the future value ok, future price present value of the future benefit you can say. So, the net present value present value will be present value of the 5 years expected income minus investment. So, this one minus income I mean investment is 2000, you get 106.1 dollar I mean if you are going with 6 percent interest rate.

So, similarly you can calculate for 8 percent interest rate.

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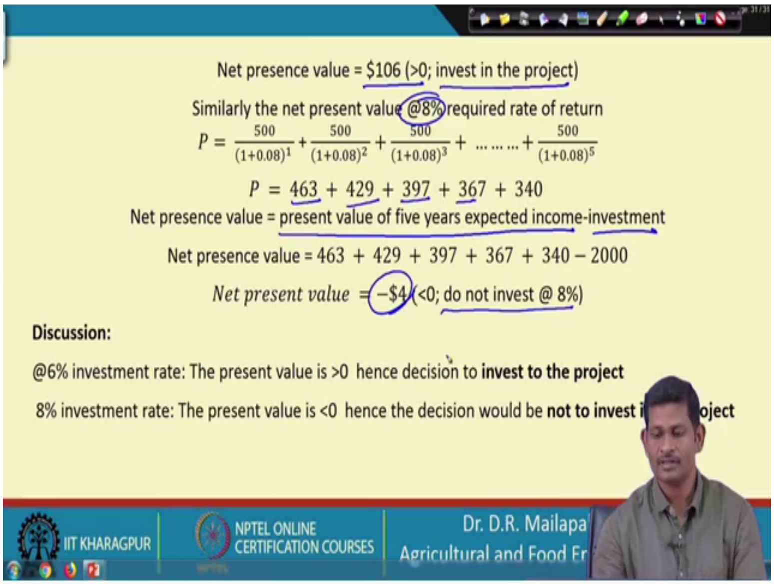

And since it is you know greater than 0 definitely you have to invest in the project. So, similarly you can estimate the present value of the worth of the benefits with at 8 percent interest rate. So, is the same formula you get this is the present value of benefit at first year, present value of benefit of second year, present value of you know income in the third year. So, like there it goes.

So, net present value is equal to present value of 5 years expected income minus investment. So, that will be negative. So, the negative in the sense you do not invest at 8 percent. So, if you are investing at 6 percent that is profitable and do not invest at 8 percent ok. So, that is the meaning of this.

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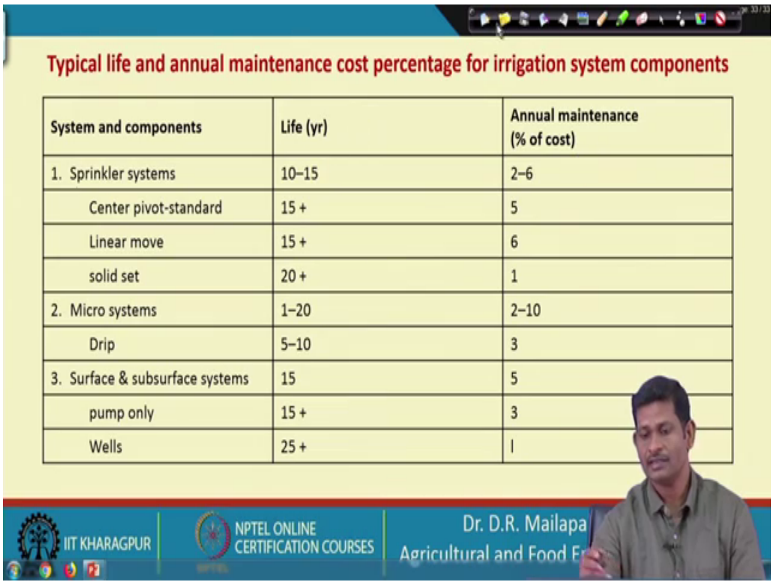

System and components	Life (yr)	Annual maintenance (% of cost)
1. Sprinkler systems	10–15	2–6
Center pivot-standard	15 +	5
Linear move	15 +	6
solid set	20 +	1
2. Micro systems	1–20	2–10
Drip	5–10	3
3. Surface & subsurface systems	15	5
pump only	15 +	3
Wells	25 +	I

And so, here it will give the typical annual maintenance cost percentage for irrigation system. So, this is the life of irrigation systems and annual maintenance cost. So, this will be useful while calculating the economics of irrigation system.

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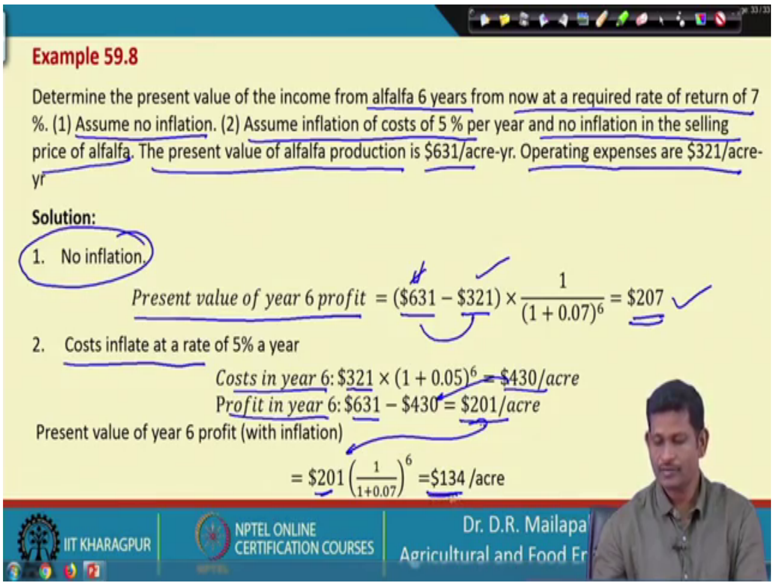

And this is an example: determine the present value of the income from alfalfa 6 years from now at a required rate of interest of 7 percent. So, first assume no inflation right, assume inflation cost of 5 percent per year and no inflation in the selling price of the alfalfa. The present value of alfalfa production is 631 per acre per year. Operating expenses are 321 per acre per year. So, with this information the first if you consider the no inflations. So, inflation in the sense so, if you have you know particular value of asset right. So, that value will increase over the period of time; so, that is inflation.

Now, present value of year 6 year 6 profit; so, there it will 631 minus so, this will be the 631 is a present value right and then this operate operating expenses so and so for that difference if you can calculate what is the present value. So, that is 207 dollar and cost inflated at rate of 5 percent. So, this is with no inflation, this is what present value, this is positive. And, cost in the year 6 6 321 this operating cost.

Because, inflation is given on operating cost only one place and you get 430 and profit in the year 631 minus 430 you get 201 per acre ok. So, present value of here 6 profit with inflation. So, with inflation the present value so, this is profit up to 6 years and bring it to the present value so that is 134 per acre ok. So, with inflation you get 134 without inflation you get 207 ok.

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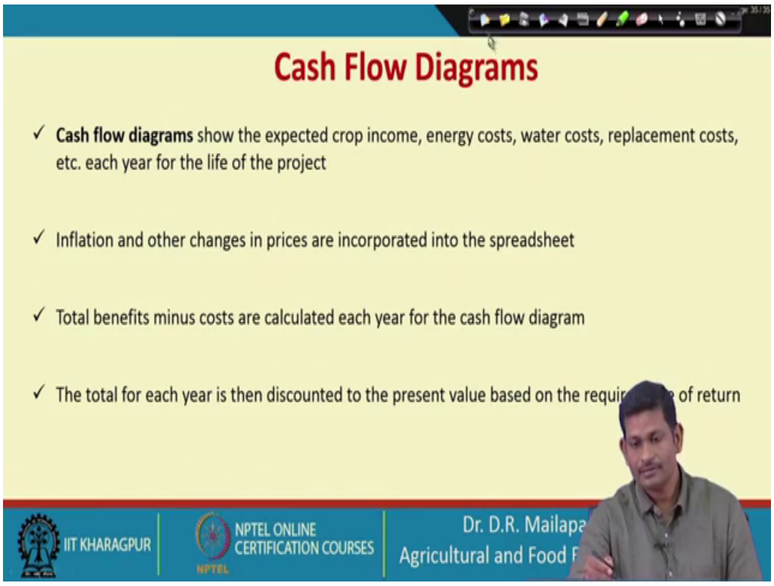

Cash flow diagram is so, this basically this will indicates; so, if you have invested in a particular project and expecting the benefit after 10 years, 20 years. So, you I mean you have to bring the benefits to the present value and cost to the present value and then compare you get the; you know I mean cost benefit analysis or the net positive value net sorry net present value. So, all these three indicators in cash flow diagram will be judging whether investing in a particular project, drainage or irrigation project is beneficial or not; with the particular interest and over the period of time ok. And, this is about the irrigation economics.

So, the in this lecture basically we were looking into the project, I mean the economics of the whole irrigation project as well as the individual seasonal you know benefits. So, once knowing the seasonal benefits by knowing the production cost, water cost and then environmental cost; you will be estimating the profits of that particular year. So, then with that profits and then I mean if you have invested in that or you are expecting in 10 years; so every year you are expecting this much benefits. And using cash flow diagram or cash flow or discounting analysis. So, all these economic indicators will be used to identify, I mean to judge whether investing in this particular project is worth or not, ok.

Thank you.