Micro Irrigation Engineering

Prof. Kamlesh Narayan Tiwari
Department of Agricultural and Food Engineering
Indian Institute of Technology – Kharagpur

Lecture – 58
Tutorial 11- Numerical Examples on Economics of Micro Irrigation System

Hello, participants. I welcome you to Lecture 58 of Micro Irrigation Engineering subject. Lecture 58 is Tutorial 11. And, this Tutorial 11 is on the numerical problems of economics of micro irrigation system. We dealt several topics related to micro irrigation system. And, its economic evaluation is very important. So, we discussed in theory class about how to evaluate the economics of micro irrigation system. And, a system can be made feasible or operational, when it is economically viable and it can be adopted by the community. So, let us get into the economics of micro irrigation system.

So, in this particular lecture, we will deal with problems where benefit cost is evaluated. We will deal with the break even analysis is being done. We will also deal with how to determine the economic pipe size selection by considering the cost of energy, by considering the size of the pipeline, by considering the criteria for critical flow velocity.

So, Question 1, in Question 1, we have been given a Banana crop is cultivated in 1 hectare area. Drip irrigation system has been installed to irrigate Banana crop. Total cost incurred to produce 875 quintal per hectare of Banana is rupees 43,000. The Banana is sold at the rate of rupees 300 per quintal. When drip irrigation system has been used, there is a saving in water. And, from this saving in water, 0.8 hectare additional area is cultivated. And, this has, when we are cultivating additional area, this gives additional cost or expenditure of 34,400 rupees. We are required to find out benefit cost ratio and additional net extra income due to drip irrigation.

So, total area under drip irrigation system, now, 1 hectare plus 0.8 hectare. So, it has become total area is 1.8 hectare. Now, individually, when we have been also given that for cultivation of the Banana from 1 hectare area, the cost comes to 43,000 rupees. And then, from 1 hectare area, the production is coming as 875 quintal per hectare. Now, the cost of production from 0.8 hectare area is 34,400 rupees. The Banana is being sold rupees 300 per quintal.

So, these are the data available to us. From these data, we are required to obtain benefit cost ratio. So, the total cost of production to grow Banana crop is cost required for 1 hectare and cost required for 0.8 hectare. So, cost of production of 1 hectare is given as 43,000 rupees and cost of production from 0.8 hectare is given as 34,400 rupees. So, sum of these 2 values, 43,000 plus 34,400, we get 77,400 rupees. This is the total cost of production to grow Banana in 1.8 hectare.

Now, we will work out selling price. So, selling price of the Banana from 1 hectare, selling price of the Banana from 0.8 hectare, this will become the total selling price. So, cost of means production we know. The production is 875 quintal per hectare. Selling price is rupees 300. Here, same thing that it is from 0.8 hectare. So, the production from 0.8 hectare is 0.8 times 875.

So, so many quintals we will get from 0.8 hectare and that will be multiplied by 300. So, if we are multiplying by 300 and then we are getting the total selling price from 1 hectare is 262,500 rupees from 1 hectare and 210,000 rupees from 0.8 hectare. So, total cost from selling price from 1.8 hectare is 472,500 rupees. So, the benefit obtained after selling, then, what we will do?

The selling price from the 1.8 hectare is 472,500 minus the production cost from 1.8 hectare is 77,400. So, this is the benefit. So, net benefit from 1.8 hectare is 395,100. So, benefit cost ratio can be obtained. That is a net benefit divided by the cost of production. So, net benefit is 395,100 divided by 77,400. So, this gives the value of 5.1.

When we are calculating gross benefit cost ratio, this is the net benefit cost ratio. This has got the real meaning. But, when we are interested someone is interested to get the gross benefit cost ratio, then in that case, we are required to find out from this value. That is your production, your total benefit which we are getting. So, 472,500 divided by the production cost that is 77,400. That is the gross benefit cost ratio.

But, as far as the net benefit is to concern, so, net benefit cost ratio it is 395,100 divided by 77,400. So, this is the benefit cost ratio. Now, additional net income due to drip irrigation is additional income minus additional cost. So, additional income is 210,000 minus 34,400. So, this is 175,600 is the additional net income due to adoption of drip irrigation system for cultivating Banana crop.

Question 2, in Question 2, the fixed cost of manufacturing a micro irrigation system component accessory is given as rupees 38,900. The variable cost of each unit of accessory product is rupees 5. So, each unit has got the variable cost of rupees 5. And, this is the fixed cost of producing that particular accessory product. Now, the selling price of the product is rupees 25 per unit.

Now, the question is determine the quantity of above mentioned units produced at break-even point. Means, how many number of unit one should produce so that there is no loss. So, that we are required to find out from this particular question.

So, we have been given in this question fixed cost as 38,900. We have been given selling price of the product which is being manufactured from that particular company is rupees 25 per unit. And then, variable cost involved to produce this particular unit is rupees 5 per unit. So, from this particular given data, we are required to find out how many number of unit one should produce at break-even points.

So, break-even point is estimated by using the expression.

$$BEP = \frac{TFC}{(SP - VCP)}$$

That is a total fixed cost divided by selling price minus variable cost per unit of production. So, we have been we have got total fixed cost. We have got variable cost per unit of production. We have got selling price of per unit of production. So, we just simply we will substitute and get the value.

$$BEP = \frac{38900}{(25-5)} = 1945\ Units$$

So, BEP that is break-even point is 1,945 number of units. If it is produced, it will be at break-even point.

Question 3, in Question 3, we are given the total cost of drippers, manifold, screen filter, venturi, fertilizer tank. All these components of drip irrigation system unit is kept under Group A. Means, drip emitters, manifold, screen filter, venturi, fertilizer tank, it is kept under Group A. And, this has been worked out as 18,600 rupees for 1 hectare area. Now, the another component of the drip system that is a lateral and lateral which is used in for the crop which is at 2 meter by 2 meter geometry is rupees 32,585.

This is item in Group B. So, there are 2 items. One is means one items which are under Group A are drip emitters, manifold, screen filter, venturi. Cost is 18,600. Under the item Group B, it is lateral. The cost is 32,585. The bank interest rate is 12%. And then the life of the Group A means these components which are used under Group A, the life of those components is 10 years. Life of the item Group B is 7 years. So, for these 2 groups, the life is also different. That is 10 years and 7 years. We are required to determine the annual cost of the drip systems of components in Group A and also Group B. So, we will work out individual annual cost for the Group A and Group B.

So, in this question, we have been given interest rate as 12%. And, for items under Group A that the life of the system is 10 years. And then, the capital recovery factor for the Group A is given by

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

So, this is for any item whether it is a group. This is a general formula. Now, for Group A, only n and then the interest rate is to be put up.

Same formula will be used for Group B to find out the capital recovery factor for Group B. Only in that case, n will be 7. So, for n equal to 10 and the bank interest rate is 12%. So, substituting the values of i, we are getting the capital recovery factor for items in Group A is 0.177. So, annual cost we are getting is 3,292.2 rupees. This is the annual cost for the items under Group A.

Now, capital recovery factor for Group B is the same formula. The n is the only factor which is 7 years and then interest rate is same. So, we are getting capital recovery factor with 7 years of the life of the components and 12 per cent is the prevailing bank interest rate is 0.219. Now, this annual cost of the Group B is your capital recovery factor multiplied by the fixed cost. So, capital recovery factor is 0.219 multiplied by 32,585. It gives us 7,136.11 rupees for the item under Group B.

Now, annual cost means when we are taking total system cost. So, annual cost of the drip irrigation system components in Group A and Group B is estimated. So, we have got this value as 3,292.2 plus 7,136.11. So, total cost is 10,428.31. This is the total annual cost for the drip irrigation system components in Group A and Group B. So, this is our answer.

Question 4, we have been given a PVC pipe of 200 meter long. This is the length of the pipeline which carries water at the flow rate of 10 liter per second, a pipeline of 200 meter long which is carrying water 10 liter per second. This is the discharge it is carrying. The coefficient for Hazen William's equation, C is 150 for the pipe material. And, the critical flow velocity is 1.5 meter per second.

So, the Hazen William's equation is used to estimate head loss due to friction. And, in this equation, there is one constant which coefficient which comes that will depend upon the type of pipe material. So, value of C it varies from 120 to 150. Of course, it will again change if it is a cast iron pipeline if it is aluminium pipeline. But, in drip irrigation system, we are using plastic pipes.

So, range of C, normally, it is 120 to 150 and these plastic pipeline could be made up of the LDPE, LLDPE, PVC, and HDPE. So, there this could be the pipeline. So, here C is that is the coefficient which we will be using that is given as a C equal to 150. And then, another point it is given the critical flow velocity is 1.5 meter per second. The expected life of the pipe is 20 years. So, 20 years is considered as a life of the pipes.

Now, electric motor coupled pump operates 1500 hours in a year. And, this pump has an efficiency of 70%. So, efficiency that means of the pump is 70%. And, it is operating 1500 hours in a year. Electricity cost is rupees 7 per kilowatt hour. Means, 1 unit it is costing rupees 7. The fuel use factor for electricity is 0.88. Means, this factor is dimensionless. That is kilowatt hour divided by kilowatt hour. So, this is 0.88.

The per meter cost of PVC pipeline of different sizes are given in the following table. So, this is the table. Means, the pipes are of 63 millimeter, 75 millimeter, 90 millimeter, 110 millimeter. And then, their corresponding cost is also available which is varying from rupees 108 for 63 millimeter pipeline and then 250 rupees per 110 millimeter pipeline. Now, we will use this table. As the table which is available, information is available. Bank interest rate is 9%. 9% is the rate of interest which bank will charge. We are required to determine economical pipe size, which pipeline from the 63 to 110 millimeter size one should use so that this is economically viable in long run.

Now, once again I am reading the data which is given in this question. Q is given as 10 liter per second. Length of the PVC pipeline is 200 meter. The electricity cost is rupees 7 per kilowatt hour. The time of operation of the pump in a year is 1500. The efficiency of the pump is 70%. Bank interest rate is 9%. Life of the PVC pipeline which is used as 10 years and then this is the factor which we gave that this is the fuel use factor for electricity. That is Kf equal to 0.88. The Hazen Williams constant C equal to 150 and critical velocity is 1.5 meter per second.

Now, annual cost of the pipeline is computed. As we have done in the previous problem, so, we will be using the expression.

$AC = CRF \times PW$ **(present worth)**

That annual cost is given by capital recovery factor multiplied by present worth value of the any product or any item. So, CRF is estimated, so CRF is given by

$$CRF = \frac{i \times (1+i)^n}{(1+i)^n - 1}$$

So, i is 9%. So, we are putting here the value of i is 0.09 into 1 plus 0.09 to the power 20 because n is 20 years divided by 1 plus 0.09 to the power 20 minus 1. So, when we are substituting, we get this expression, the numerator as 0.5 and denominator as 4.60. So, CRF is 0.1087. So, annual cost of 63 millimeter pipeline, we are substituting the value. We have got this CRF at 0.1087 multiplied by because this is a 200 meter line long pipeline. And then, for 63 millimeter pipeline in the table, we have been given 108 rupees per meter, so, 200 into 108. So, we are getting the value of annual cost of 63 millimeter pipeline as 2,347.92.

Similarly, we will calculate the value of annual cost of the pipeline for other diameters. So, when we have calculated same way we have been given these pipelines. We have been given the price also. And then, total price we are getting and then multiplying with the capital recovery factor which is a constant because the bank interest rate is 9% and then n equal to 20 years. So, we are getting the annual cost of the pipeline.

So, annual cost for 63 millimeter pipeline is 2,347 rupees 92 paisa. For other pipelines of 75 millimeter, you can see 3,261 rupees. And similarly, for 110 millimeter pipeline, it is 5,435 rupees.

So, now, we have got the annual cost. Now, let us try to find out the annual electricity cost for these pipelines. So, for getting the Cp value, that is annual electricity cost. First, we will calculate the head loss due to friction from these pipelines. So, head loss due to friction from these pipelines can be calculated by using the Hazen William's equation.

$$h_f = 1.212\times10^{10}\times L\times\left(\frac{Q}{C}\right)^{1.852}\times D^{-4.87}$$

This is the unit constant because we are using a specific unit. So, this particular is a constant which will come out of the unit which we are using. So, into L is the length of pipeline. Q is the discharge. So, Q is the discharge in liter per second. C is the coefficient, D is the diameter of pipeline in millimeter.

So, length is given 200 meter. Discharge, we have been already given in this question. Discharge is available. And then, C is given. Diameter of pipeline 63, 75, 90, 110, these values are known. So, we will be calculating this thing. So, first, we will first calculate the water horsepower. So, water power or water horsepower is estimated by using the expression.

$$WP = \frac{9.8\times Q\times H_t}{1000}$$

Now, total head here Ht which is it is used here as such the value of Hf which we are calculating. And then, break horsepower, whatever the WP that is water horsepower we have got that is to be divided by the pump efficiency. It will give the break power or break horsepower we can say.

So, and then, the Cp, that is the annual electricity cost is calculated by using the expression.

$$C_p = \frac{BP \times T \times C_f}{K_f}$$

That is Cp equal to BP that is the break horsepower or break power multiplied by the total time of operation in hours and then, Cf is the cost of electricity that this is also given per unit and then, Kf, which was the factor that the fuel use factor. So, Cf is known to us. Time of operation is known to us. Break horsepower, we are calculating from the water horsepower. And, water horsepower is calculated by using the head loss due to friction from the Hazen William's equation.

So, those are the steps. Now, let us try to get the value of hf. So, hf is calculated by substituting the value of this is your unit constant multiplication and this is a 200 meter L. This is the discharge in 10 liter per second. And, C, this is your C value as 50 and 63 millimeter the pipeline. So, when we are multiplying all these, we get 27.77 meter as head loss due to friction. And, this value is used to calculate Ht.

So, this is as such it is used for Ht. And then, 9.8 into 10, that is Q, so, divided by 1000. So, we are getting Wp as 2.72 for 63 millimeter pipeline. And, for brake power, here, this 2.72 divided by the pump efficiency of 0.7. So, we get 3.89. And then, Cp, this is means cost of electricity. So, this we are getting the value of brake power. That is 3.89 multiplied by the time of operation 1500 hours and multiplied by electricity that is 7 hour and divided by Kf. So, this value is your 7, is the electricity cost per unit. That is 7 rupees per unit divided by Kf. That is 0.88. So, for 63 millimeter pipeline, the Cp, annual electricity cost is coming 46,414 rupees 77 paisa.

So, then, we will also find out how much is the velocity of flow it takes place from the pipeline. So, velocity from the pipeline is given by

$$V = \frac{Q}{A} = \frac{Q}{\left(\frac{\pi}{4} \times d^2\right)} = \frac{10 \times 10^{-3}}{\left(\frac{\pi}{4} \times 0.063^2\right)} = 3.2\, m\, s^{-1}$$

So, when we are putting this in a cubic meter and this is also in a square meter, so, we get the velocity is V equal to 3.2 meter per second. Similarly, for all pipes of other diameters 75 millimeter, 90 millimeter, 110 millimeter, all those steps have been calculated.

So, for 63 millimeter pipeline, we have got the head loss due to friction 27.77. We calculated water power as a 2.72. Then, we calculated brake horsepower as a 3.89. Just now we calculated the velocity of flow is 3.21. And then, annual pipeline cost, we got 2,347 rupees 92 paisa. And then, annual electricity cost is 46,414.77. And then, total cost means annual cost of the pipe plus annual electricity cost. So, total annual cost is coming 48,762 rupees 69 paisa is the total cost. Similarly, for all other pipeline, we have calculated head loss due to friction from 75 millimeter pipeline. That is 11.88 water power we calculated. Brake power, we have calculated. Critical velocity, we have calculated. Annual cost of the pipeline, we have calculated. Annual electricity, we have calculated.

In the same way, and then, we are getting total annual cost of 75 millimeter pipe size is 23,103.61 rupees. Similarly, for 90 millimeter pipeline, we have calculated, which is coming 12,831 rupees 21 paisa; 110 millimeter pipeline, we are getting 8,537.27 rupees. So, what we are seeing? As the pipe size increases, there is increase in the cost of the pipeline. There was increase in the cost of the pipeline because the size matters. So, what we see here the annual cost of the pipeline is increasing. Annual cost of the pipeline for the 63 millimeter pipeline was 2,347.92, then, for 75, 3,200 and then it is coming 5,435 rupees. So, annual cost has increased for the pipeline. But, electricity cost, you can see here, as the pipe size increase, there is a reduction in the head loss due to friction. And, there is a significant head loss.

So, this significant head loss that has caused decrease in the annual electricity charge. So, annual electricity charge for the 63 millimeter pipeline was as high as 46,414 rupees 77 paisa which has now come to 3,102 rupees 27 paisa when we are using 110 millimeter pipe size. So, this is to be noted that the cost of electricity is going down as when the pipe size increases. So, total cost has reduced. And then, second criteria which was given to us that the critical velocity should not exceed 1.5 meter per second. So, here means as you have increased the size of the pipeline, what we are seeing that the velocity through the pipeline has decreased. But, still, it was more than 1.5 meter per second. So, at 110 millimeter pipe size, the critical velocity is less than 1.5. So, what we see that this is, so, based on using the critical velocity criteria.

And also, the annual cost total annual cost including the size of the annual cost of the pipeline and the annual electricity charge, so, 110 millimeter pipe is most economical. So, the interpretation once again I am reading that the pipe cost increases substantially in accordance with the increase in the pipe size whereas energy cost decreases. So, energy cost for the 63 millimeter pipeline is almost more than the 5 times of the energy cost for 110 millimeter pipe size. Whereas, it is it is not following the other cases. It is the other pipe sizes it is not falling under the velocity criteria of 1.5 meter per second. So, considering the 1.5 meter per second the velocity as well as the energy cost, so, 110 millimeter pipe size is most economical.

So, we worked out those problems. And, for more problems, you can refer these books which are given here. These books I have been referring in other topics also.

Let us summarize this lecture. The benefit cost analysis part, the Banana crop we have estimated. We have got the break-even point analysis also and capital recovery factor. We worked out the economical pipe size diameter selection in this lecture. And, in the forthcoming lecture, we will be discussing on new topic that is on precision agriculture. Thank you very much.