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A Cost Benefit Analysis of Crop production with various irrigation systems

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Abstract

Cost Benefit analysis is often used to assess adaptation approaches. In this study we investigate costs and benefits associated with adaptation approaches employed by farmers with various irrigation systems expressing in monetary term and identify the most effective and economic options based on general information and responses of farmers. Study area is Kharkhiraa and Turgen river basin of Uvs aimag which is located in the western part of Mongolia. Irrigated farming takes an important place in this area and most of the households use the furrow irrigation which costs less than other systems. But there are huge amount of water loss, a lack of sustainable maintenance and water dispute during the irrigation.

In this paper we focus on drip and sprinkler irrigation systems compared with furrow irrigation in potatoes, radish, headed cabbage and tomatoes using cost benefit analysis. Findings from this study show that drip irrigation can be water and labor saving alternative to conventional irrigation strategies.

Key words: Cost benefit analysis, crop production, irrigation system

Introduction

The "Ecosystem-based Adaptation Approach to Maintaining Water Security in Critical Water Catchments in Mongolia" project has being implemented by the Ministry of Environment and Green Development of Mongolia with funding of the UNDP and Adaptation Fund in 2 target areas Harkhiraa and Turgen river basin located in Altai mountains/Great lakes and Dornod steppe/Ulz river basin to support maintenance of ecosystem functions and land use and water provisioning services by addressing critical needs for survival of rural communities and national economy.

Findings from international researchers' study show that drip irrigation can be water and labor saving alternative to conventional irrigation strategies. In Ulaangom soum the most citizens and entities engaging on agriculture and crop production grow potatoes and food vegetables and there is a tendency to grow in the future.

Total crop area in Ulaangom soum is 366 hectares. Out of 158 hectares of potatoes and vegetables, 125 hectares, 80 hectares of wheat, in the other 3 hectares are planted with barley oat products. The future climate change in western part Mongolia shows in increase in air temperature by 5.0-5.5^{0}C and summer precipitation will be decreased by 5-10% which could in turn increase heat and water supply of crops. Therefore it is important to use suitable water saving irrigation system and advanced technologies for farming.

Therefore in this paper we focus on drip and sprinkler irrigation in potatoes, radish, headed cabbage and tomatoes selected as an ecosystem based adaptation appropriate measures and use the cost benefit analysis to compare them with conventional system such as furrow irrigation.

Table 1. Selected irrigation systems and crop type

Irrigation system	Potatoes	Radish	Headed cabbage	Tomatoes
Furrow irrigation	+	+	+	+
Drip irrigation	+	+	+	+
Sprinkler irrigation	+	+	+	+

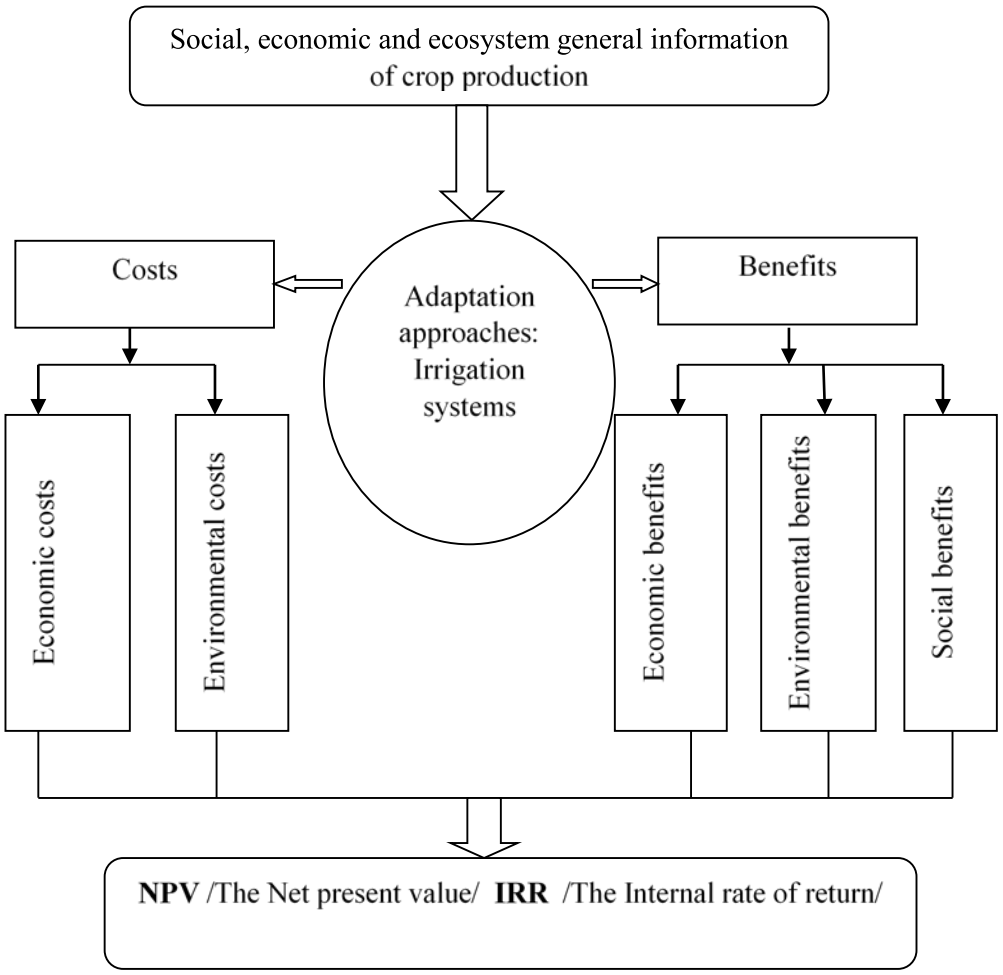
Methodolgy and Data

Cost Benefit analysis model

Cost Benefit analysis evaluates and compares all of costs and benefits of the environmental, social and economic positive and negative impacts of the adaptation approaches which are expressed in monetary term based on its general information.

Crop production costs include operating cost, fixed cost and consumption of water and benefits are sales revenue and water and labor saving using the irrigation systems. In our study, costs and benefits of the crop farming consist of the following components:

1. Costs
    - Economic costs: Investment cost, fixed cost, operating cost
    - Environmental cost: Water loss
2. Benefits
    - Economic benefits: Revenue, additional yield
    - Environmental benefit: Water saving
    - Social bebefits: Labour saving, social insurance



Adaptation planners can use three main indicators for choosing the most efficient approaches:

1. The net present value (NPV) –the difference between the present value of the costs and the present value of the benefits:

$$NPV = PV(B) - PV(C)$$

where B- benefits, C- costs, PV- the present value.

If NPV is greater than zero, then the adaptation approach can be implemented. A high NPV indicates the most efficient and economic adaptation approach.

2. The benefit - cost ratio (BCR) – the ratio of the present value of benefits and the present value of costs. The benefits and cost are each discounted a chosen discount rate.

$$BCR = PV(B)/PV(C)$$

The benefit-cost ratio shows the overall value for money of the project. If the ratio greater that 1, the approach is acceptable.

3. The internal rate of return (IRR) - the discount rate where NPV equal to zero. In other words,

$$NPV = 0$$

The higher an approach's IRR, the more desirable it is.

In our study we constructed the cost benefit analysis model using Microsoft EXCEL software and the model consists of 7 main parts mutually connected each others.

Data

Data were obtained form 2013/2014 crop season. The initial costs and technology card of the crop were used to calculate the costs and benefits of crop farming. During the project we have visited and conducted a survey from farmers who were supported with irrigation system by the project.

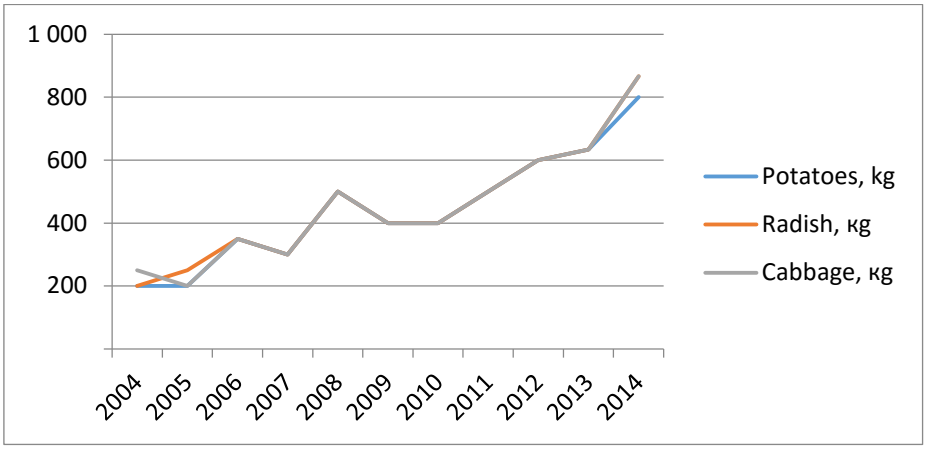
To calculate the future value of the benefits and costs, we use an inflation rate and growth rate. According to the National Statistical Office (NSO) report the inflation rate of Mongolia was 13 present in 2014. An average quantity and price of vegetables data from NSO were used to calculate crop revenue. The yield of potatoes per hectare is increasing in average 3.7 percent nationwide and 6.6 percent in Uvs province in the last 20 years. Therefore annual average rate was taken as 6.6 percent for CBA.

Table 2. Vegetable harvested and average unit price

	Crop type	Yield, (t/ha)	UnitpPrice, (tug./kg)
1	Potatoes	14.0	800
2	Radish	15.0	867
3	Headed cabbage	22.0	867
4	Tomatoes	34.0	2000

Source: National Statistical Office (NSO) of Mongolia

According to statistics, in 2014 compared to 2010, vegetable prices increased 2 times. Vegetable prices are cheaper during the fall harvest, but the spring season is almost 2-fold higher. Autumn vegetable harvesting time or price in October was selected for the estimation of CBA. In the last 10 years, vegetable prices have increased by an average of 18 percent per year.



Costs and benefits

Investment costs for the crop farming consist of costs for equipment, infrastructure and building which are used for the sustainable farming. The fixed costs occur regardless of farming and will generally be the depreciation and interest. The deprecation is calculated by the straight line method. Operating costs are related to the daily activities of farming and vary depend on the frequency of irrigation, amount of water appled per irrigation, consumption of fuel and number of area irrigated. The most important variable cost is labour cost which is used for cultivation the land, irrigation, maintenance and harvesting. Material costs include the costs of seeds and fertilizer. Annual repair and maintanence costs would be 6 present of the initial investment for the irrigation system. Water is a limited resource. Water loss is measured by the amount of water applied for irrigation using the irrigation norm of crops and water ecological and economic evaluation.

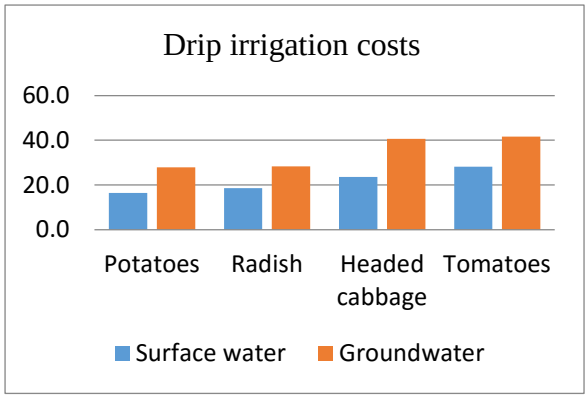
The benefits of the irrigated farming are the crop revenue, increased yields using the irrigation system, land rent, water and labour savings and social insurance.

Results of Cost benefit analysis

The total costs and benefits furrow, drip and sprinkler irrigation systems in each vegetable crop production using different water source such as surface water and groundwater are given in the following tables and figures.

Table 3. Furrow irrigation costs

Costs	Surface water			
	Potatoes	Radish	Headed cabbage	Tomatoes
Investment cost	3000.0	3000.0	3000.0	3000.0
Fixed cost	300.0	300.0	300.0	300.0
Operating cost	6679.0	8960.4	12194.6	14661.8
Environmental cost	1061.8	557.7	3035.2	1823.3
Annual total cost	11040.8	12818.1	18529.8	19785.1



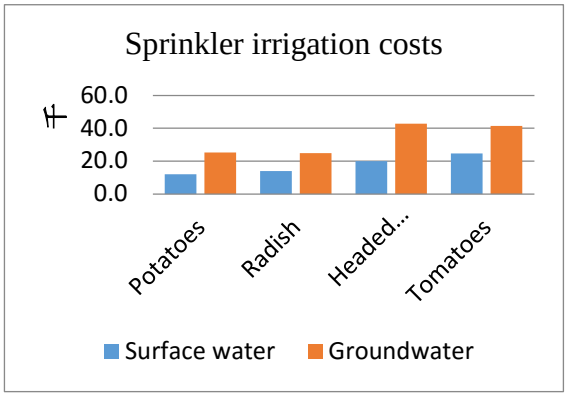


Figure 4. Total costs by water source

A summary of the findings shows that the costs using groundwater for crop farming are double and more expensive than the cost of surface water. The cost of furrow irrigation using surface water in radish is 12,8 m.tug./ha/year, while the cost of drip irrigation 18,6 m.tug/ha/year. The difference is 6 m.tug/ha/year. The huge cost of drip irrigation system is primary caused by the expenses to the initial investment compared to the furrow and sprinkler irrigation system.

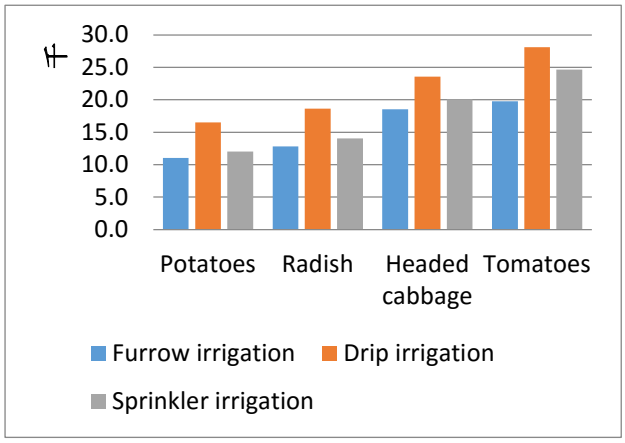


Figure 5. Annual total costs, surface water

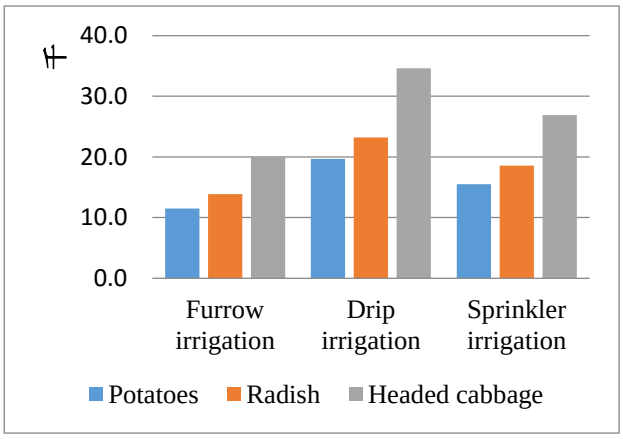


Figure 6. Total benefits

The total costs of each irrigation system are summarized in the figure 5. The graphs show that the costs of furrow irrigation and sprinkler irrigation using groundwater in headed cabbage and tomatoes are higher and the costs for potato production are lower compared to others.

Table 4. Potato production costs, thous.tug/ha (Surface water)

Costs	Furrow irrigation	Drip irrigation	Sprinkler irrigation
Investment cost	3000.0	8000	3400
Fixed cost	300.0	213.3	68.0
Operating cost	6679.0	7626.2	7524.5
Environmental cost	1061.8	668.9	1040.5
Annual total cost	**11040.8**	**16508.4**	**12033.0**

Table 4 shows that even the cost of drip irrigation in general is expensive than the alternativies like furrow and sprinkler irrigation, there is a large difference in the water use in the three systems. Drip irrigation in potato uses 9,215м^3/ha which is 5,412м^3/ha smaller than that of furrow irrigation and 5119.5м^3/ha smaller than that of sprinkler irrigation.

To summarize, the benefits of drip irrigation system are higher and enables the farmer to save water and labour compared with furrow and sprinkler irrigation. For example, using drip irrigation saves 0.7 persons/day and 915.8 м^3/ha water in potato production, 3.5 persons/day and 507 м^3/ha water in radish and 4.9 persons/day and 2830 м^3/ha water in headed cabbage while sprinkler irrigation saves 49.5 м^3/ha water in potato production and 1.4 persons/day and 26 м^3/ha water in radish. (Table 5.)

Table 5. Labour and water savings

Indicator	Unit	Potatoes	Radish	Headed cabbage	Tomatoes
Drip irrigation					
Labour	person.day	0.7	3.5	4.9	2.6
Water	м3/ha	915.8	507.0	2830.0	1700.0
Sprinkler irrigation					
Labour	person.day	0.0	1.4	0.0	0.0
Water	м3/ha	49.5	26.0	141.5	85

NPV, BCR and IRR

Using the total cost and benefit we calculated the net present value (NPV), benefit - cost ratio (BCR) and the internal rate of return (IRR) for each crop and irrigation method and results are in the following tables.

Table 6. Furrow irrigation results

Indicator	Drip irrigation: surface water			
	Potatoes	Radish	Headed cabbage	Tomatoes
The net present value, NPV	41.46	53.68	52.60	549.01
The internal rate of return, IRR	-	-	-	-
Benefit-cost ratio, CBR	2.12	2.21	1.78	6.22

As shown above, although furrow irrigation using surface water in vegetable production has no economic loss, it is more harmful for environment and ecosystem.
Below tables show that even the costs in the initial investment for drip irrigation are high compared to others, drip irrigation is the most efficient method in vegetable crop production using any water source.

Table 7. Drip irrigation results: Surface water

Indicator	Drip irrigation: surface water			
	Potatoes	Radish	Headed cabbage	Tomatoes
The net present value, NPV	117.3	137.1	200.0	1006.6
The internal rate of return, IRR	-	-	-	-
Benefit-cost ratio, CBR	3.6	3.5	3.2	9.2

Table 8. Drip irrigation results: Groundwater

Indicator	Drip irrigation: grounwater			
	Potatoes	Radish	Headed cabbage	Tomatoes
The net present value, NPV	71.6	108.7	101.54	942.7
The internal rate of return, IRR	1.2	2.8	127.49	-
Benefit-cost ratio, CBR	2.1	2.6	1.74	6.1

Below table shows that sprinkler irrigation in vegetable production is practically more efficient compared to the furrow irrigation.

Table 9. Sprinkler irrigation results

Indicator	Sprinkler irrigation: surface water			
	Potatoes	Radish	Headed cabbage	Tomatoes
The net present value, NPV	76.5	93.3	112.3	757.8
The internal rate of return, IRR	-	-	-	-
Benefit-cost ratio, CBR	2.7	2.7	2.3	6.7

From the net present value calculation, we can see that the net present value for drip irrigation in potato is 117.3 and for sprinkler irrigation 76.5, which are three times and double respectively higher than that of furrow irrigation. The pattern is same for other vegetables

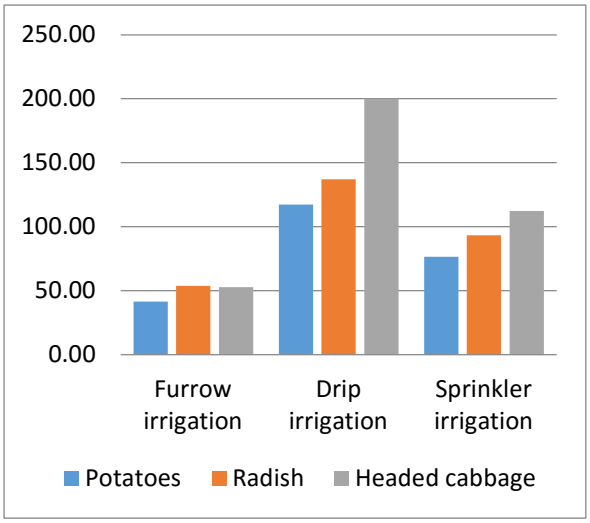


Figure 7. NPV, surface water

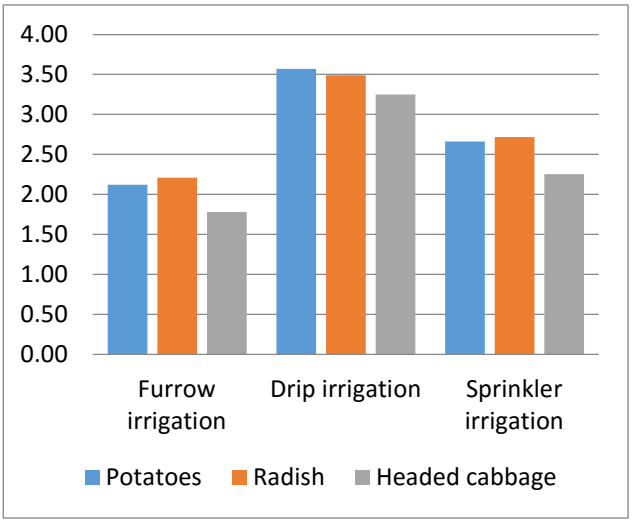


Figure 8. BCR

Benefit – cost ratio (BCR) clearly indicates that furrow irrigation has the lowest efficiency. Findings from this study show that drip irrigation in vegetable production is the most efficient and technology compared with furrow irrigation and sprinkler irrigation.

Conclusion

1. In many areas of Mongolia, under scarce water conditions farmers still use primitive methods of irrigation. Replacing the furrow irrigation with precise irrigation systems has become the main interest of decition makers and policy planners in Mongolia.
2. The main objective of this work was to gather information from farmers and published reports, determine the expected return from drip irrigation and compare the costs and benefits of drip irrigation to furrow irrigation in crop farming. However, there is a shortage of primary data of costs and benefits for irrigation systems, crop technology carts and statistical information were used to analysis costs and benefits of furrow, drip and sprinkler irrigation systems.
3. Farmers who were interviewed were unable to quatify the benefits and costs of drip irrigation, but were convinced of positive yield and quality responces from drip irrigation.
4. To make the model more user - friendly for farmers and Government agiencies a number of simplifying assumptions have been adopted and some externalities left out.
5. According to the cost benefit analysis indicators drip irrigation is the most efficient method not only reduce costs, but also to protect the environment as well.

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