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Economic Efficiency of Drip Irrigation System in Case of High-Value Crop Cultivation

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ABSTRACT

In current conditions of significant reduction in underground water basin reserves in Ararat Valley, there is a need to introduce effective irrigation technologies and provide their economic justification.

In this research paper it has been shown, that in case of surface irrigation of high-value crops in Ararat Valley and its low-lying (irrigated) zone, 457.8 mln m^3 water, and in case of drip irrigation – 171.7 mln m^3 water is required. The total costs of introducing drip irrigation system in these fields ranges from AMD 742609-1995000, with a payback period of 1 to 1.5 years.

Introduction

Local supply of irrigation water to a plant root zone is the basic point of drip irrigation in terms of peculiarities of its biological development phases and soil-climatic conditions. The first research works on drip irrigation in open fields were conducted in Israel in the 1950s, as a result of which this technology was intensively introduced in the country's agricultural sector (Magersa and Abdulahi, 2015). Currently, drip irrigation systems have been introduced in many economically developed countries of the world, which has been a great impetus for the development of irrigated agriculture and efficient use of water resources (Velasco-Munoz, et al., 2019, Kooij, et al., 2013). Studies have shown that in case of drip irrigation, the water norm can be reduced in 2 times compared to the traditional irrigation method, and if the best conditions are provided, the payback period for drip irrigation system expenses would be one year. With the introduction of this system, there is no problems with crop water stress and soil overmoistening. Optimal soil moisture level promotes crops balanced growth and development, which leads to an increase in yield and crop quality. In case of drip irrigation, small volume of water allows to provide soil moisture indices in a root system of a crop, under which it is possible to obtain the maximum yield with minimum water consumption.

The first attempts to introduce a drip irrigation system in Armenia were made by E. Akopov (Akopov, et al., 1985), and later these works were continued by G. Yeghiazaryan and V. Kobelyan (Yeghiazaryan and Kobelyan, 2011, Kobelyan, 2011).

Over the past few years, due to the improvident consumption of water resources in the underground water basin of Ararat Valley, there is a severe shortage of irrigation water in the Republic of Armenia. It has a negative impact on sustainable irrigation water supply and socioeconomic conditions of the population. Relevant measures are implemented by the government to solve the problem, such as construction of new reservoirs, recharge of groundwater resources, but these processes require significant financial resources and take considerable time to implement.

The problem can be solved by introducing drip irrigation system in lands, that are used for the cultivation of high-value crops. However, the introduction of this system requires economic justification for different crops, which will allow farmers to estimate credit risks accurately. The aim of this paper is to make comparative analysis of surface and drip irrigation methods, as well as to justify economic efficiency of drip irrigation system introduction.

Materials and methods

Within the framework of the research, water-economic indicators in Ararat valley and its low-lying (irrigated) zones have been studied, the costs of drip irrigation system introduction in the field of high-value crops, the irrigation norm for 1 ha area, cost of irrigation water, as well as payback periods and net present values have been calculated.

Systematic, comparative, case study analytic, calculation and statistical tabular methods have been used within the studies. Researches have been implemented on the basis of our studies and statistical data published in the reports of the RA National Statistical Committee.

Results and discussions

In order to reveal the efficiency of different irrigation types in Ararat valley and its low-lying zone, water-economic indicators have been studied, which are summarized in Table 1.

Table 1. Irrigation norms for high-value crops in Ararat valley and its low-lying (irrigated) zone and required water volumes in case of surface irrigation*

Marz (Province)	Crop	Land used for cultivation	Irrigation norm	Required water volume
		Ha	m^3/ha	mln m^3
Ararat Marz	Fruit-Grape	5821	5120	29.8
	Cucurbits - Potato	4536	7500	34.0
		6091	8450	51.5
		508	3290	1.7
Armavir Marz	Fruit - Grape	7963	5120	40.8
	Cucurbits - Potato	6444	7500	48.3
		11465	8450	96.9
		1182	3290	3.9
Aragatsotn Marz, Ashtarak province	Fruit - Grape	1116	4960	5.5
	Cucurbits - Potato	650	6280	4.1
		206	6720	1.4
		134	3450	0.5
Kotayk Marz, Nairi province	Fruit - Grape	1546	4960	7.7
	Cucurbits - Potato	24	6280	0.2
		118	6720	0.8
		17	3450	0.1
Total		**47821**		**327.0**
Total (Taking into account 40 % water loss)				**457.8**

* 1. "Sown areas of agricultural crops, planting area of permanent crops, gross harvest and average crop capacity for 2019" Statistical report, Statistical committee, B. Terteryan and others, 2007.

The lands, that are used for the cultivation of high-value crops in the mentioned region take up 47821 hectares, for the irrigation of which 327.0 mln m^3 of water is required. Taking into account 40 % water losses in the system, 457.8 mln m^3 of irrigation water is required in case of surface irrigation method. In case of drip irrigation method 163.5 mln m^3 of water is required (the norm of irrigation water is reduced by 50 %). Considering the 5 % water losses in the system, the water demand makes 171.7 mln m^3 (Table 2).

Table 2. Required volume of irrigation water for high-value crop cultivation in Ararat Valley and its low-lying (irrigated) zone in case of different irrigation methods

Irrigation method	Required water volume, mln m^3	Average irrigation norm, m^3/ha	Cost of irrigation water per ha, AMD
Surface irrigation	457.8	9573	105303
Drip irrigation	171.7	3590	39490

*Composed by the author.

Table 3. Approximate calculation of costs required for drip irrigation system installation in 1hectare apple orchard (4x2.5 m)

The name of installation item	Measurement unit	Quantity	Cost (AMD)	Amount AMD)
1. Distribution Network				
Main polyethylene /PE/ pipeline, d=63 mm	m	100	700	70000
PE connection, d=16 mm	ps	25	200	5000
Irrigation PE pipeline, d=16 mm	m	2500	150	375000
Irrigation ring PE pipeline dripper	m	3000	120	360000
Hose tee PE d=16mm	ps	1000	150	150000
Double stopper	ps	1000	30	30000
Clamping stakes	ps	4000	50	200000
Final stopper d=16 mm	ps	25	100	2500
Total - 1				1192500
2. Head Unit				
Pump unit	ps	1	42000	42000
Fertilizer system	collection	1	50000	50000
Filtration system	ps	1	85000	85000
Valve	ps	1	10000	10000
Plunger	ps	1	12000	12000
Manometer	ps	2	12000	12000
Shaped parts	collection	1	16500	16500
Separation PE pipeline	m	10	1100	11000
Total - 2				238500
3. Design and installation works				
Locality research	ha	1	12000	12000
Design	ha	1	35000	35000
Earthworks	ha	1	100000	100000
Installation	ha	1	210750	210750
Total - 3				357750
Unforeseen expenses		5 %		89438
Total				1878188

*Composed by the author.

Irrigation water requirements for 1 ha and the costs according to the tariff of 11 dr/m^3 have been calculated. In case of mechanical irrigation it is 9573 m^3/ha, and water cost is 105303 AMD/ha, in case of drip irrigation, respectively, 3590 m^3/ha and 39490 AMD/ha.

Thus, upon the introduction of a drip irrigation system, the required water volume and the cost of irrigation water per hectare is reduced by 2.67 times.

Table 3 presents the calculation of costs based on the example of 1 hectare apple orchard to identify the amount of materials, equipment, design and installation operations required for the introduction of drip irrigation system and the amount of financial investment.

Discussing the data in the table 3, it can be stated that AMD 1878188 is required for the introduction of drip system for 1 hectare apple orchard. The total cost includes the distribution network, construction of which requires AMD 1192500 or 63.5 % of the total costs, AMD 238500 for the head unit or 12.7 % of the total costs, AMD 57750 for design and installation works or 18.8 % of the total costs.

To justify the economic efficiency of drip irrigation, the costs of installation of drip irrigation system for 1 ha high-value crop field is given in Table 4.

The fluctuation of distribution network costs (from AMD 455900 to AMD 1192500) is conditioned by sowing density of crops. Higher costs are required for apple and onion fields (AMD 1192500 and AMD 1425000), where sowing density is significantly higher (4x2.5 and 0.4x0.1 m).

Table 4. Calculation of costs of drip irrigation system introduction for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	Planting scheme, mxm	Quantity in 1 ha, pcs	Expenditures, thousand AMD			
			Distribution network	Head unit	Design and installation	Total
Fruits						
Apricot	8x8	170	455.900	227.55	319.13	1002.58
Cherry	6x6	290	614.300	245.720	337.865	1197.885
Peach	5x5	400	720.000	252.000	426.600	1398.600
Apple	4x2.5	1000	1192.500	238.500	357.750	1788.750
Nut	6x5	333	529.637	254.000	292.000	1075.637
Grape	3x1.5	2267	587.820	235.128	352.692	1175.640
Melons and Vegetables						
Watermelon	3x0.75	4400	207.609	239.000	296.000	742.609
Cucumber	1 x 0.5	13400	364.196	263.000	354.000	981.196
Tomato	0.8 x0.8	15625	775.000	193.750	348.750	1317.500
Onion	0.4 x 0.1	250000	1425.000	213.750	356.250	1995.000
Patato	0.8 x 0.2	6250	775.000	193.750	348.750	1317.500
Berries						
Strawberry	1x 0.3	33333	357.000	266.000	354.000	977.000

Table 5. Costs of introduction of drip irrigation system, cultivation of high-value crops, the income and payback period for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	Drip irrigation system cost, AMD	Cultivation costs, AMD	Gross income, AMD	Net income, AMD	Payback period Year
Fruits					
Apricot	1002580	852000	1875000	1023000	1.0
Cherry	1197885	1222380	2375000	1152620	1.0
Peach	1398600	954 000	3000000	2046000	0.7
Apple	1788750	1346000	2434000	1088000	1.6
Nut	1075637	1154660	2500000	1345340	0.8
Grape	1175640	1573000	3300000	1727000	0.7
Melons and Vegetables					
Watermelon	742609	952000	3400000	2448000	0.3
Cucumber	981196	1235000	2757000	1522000	0.6
Tomato	1317500	1597000	4675000	3078000	0.4
Onion	1995000	1575000	3086400	1511400	1.3
Patato	1317500	1799 000	3173000	1374000	1.0
Berries					
Strawberry	977000	1273000	10000000	8727000	0.1

*Composed by the author.

Thus, the total cost of drip irrigation system for one hectare land used for cultivation of high value crops fluctuates between AMD 742609-1995000. Lower costs are required for watermelon cultivation and higher for onion cultivation, which is also due to the sowing density of the crop.

Table 5 shows the costs required for the cultivation of these crops, gross output and revenue, as well as the payback period for the introduction of a drip irrigation system.

It is important to note, that in case of cultivation of perennial plants, the income fluctuates in the range of AMD 1-2 mln, in case of melons and vegetables – in the range of AMD 1.374 and 3.078 mln. Cultivation of grapes and peaches is more distinguished in terms of profitability, the incomes of which, respectively, make about AMD 1.73 and 2.05 mln.

The highest income is provided via cultivation of tomatoes, and in cultivation of potatoes it is significantly lower – AMD 1.37 mln. Strawberry cultivation stands out with its high profitability, the income of which makes AMD 8.73 mln.

The payback period (PP) for the installation of a drip irrigation system has been calculated, which ranges from 1 to 1.5 years.

Thus, in case of high-value crop cultivation, expenditures of drip irrigation system introduction are reimbursed averagely within up to one year.

In order to justify the economic efficiency of the system introduction, the net present values (NPV) of the investments have been calculated using the following well-known formula (Table 6):

$$NPV = \sum_{i=1}^{0} \frac{CF_t}{(1+r)^t} - CF_0 , \qquad (1)$$

where: CF_t is a cash flow during a single period, r is a discount rate or return that could be earned in alternative investments, t is a number of time periods, CF_0 is an initial investment.

The data presented in Table 6 confirm, that in case of one year period the NPV is negative for crops with a payback period of 1 year or more. In case of two year period, the NPV is positive for all crops, because the investment costs are lump sum. Thus, the lowest index is for the apple orchard, the highest - for strawberries. The regularity is the same as for PP.

Table 6. NPV of the investment for 1 hectare orchard in Ararat Valley and its low-lying (irrigated) zone*

Crops	NPV, AMD /during 1 year period/	NPV, AMD /during 2 year period/
Fruits		
Apricot	-72580	772875
Cherry	-150049	802529
Peach	461400	2152309
Apple	-799659	99514
Nut	147399	1259251
Grape	394360	1821633
Melons and Vegetables		
Watermelon	1482846	4991204
Cucumber	402440	1660292
Tomato	1480682	4024483
Onion	-621000	628091
Patato	-68409	1067128
Berries		
Strawberry	6956636	14169033

*Composed by the author.

Conclusion

• The lands used for cultivation of high-value crops in Ararat Valley and its low-lying (irrigated) zone take up 47821 hectares, for the irrigation of which 586.9 mln m^3 water in case of surface irrigation, and 244.4 mln m^3 water in case of drip irrigation is required. Irrigation water average requirement is 10090 m^3 in case of mechanical irrigation, and the cost of water is AMD 110990. It has been proved that in case of introduction of drip irrigation system these indicators make, respectively, 4202 m^3 and AMD 46222.

• It has been shown, that the total cost of drip irrigation system introduction for one hectare land, that is used for apple cultivation, makes about AMD 1878000, 63.5 % of which is needed for construction of distribution network, 12.7 % for head unit, and 18.8 % for design and installation.

• The total costs of introduction of drip irrigation system in lands, that are used for cultivation of high-value crops fluctuates in the range of AMD 742609-1995000, the payback period of which constitutes 1-1.5 years.

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