Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2022.28208

263 (2022) 78–86
July

Cost-benefit analysis of the shift from traditional irrigation systems to modern irrigation methods by small farmers in Al-Ahsa and its role in the dissemination of modern irrigation techniques

Salah M. Sidahmed*, Mohammed A. Alomair*

Saudi Irrigation Organization (SIO), Kingdom of Saudi Arabia, P.O. Box: 279 Al-Hassa, 31982, Saudi Arabia, emails: salahmsd50@gmail.com (S.M. Sidahmed), ma.alomair@sio.gov.sa (M.A. Alomair)

Received 28 February 2022; Accepted 26 April 2022

ABSTRACT

This study explores the feasibility of investing in modern irrigation methods for small farmers who rely on date palms as the main crop. The financial and cost-benefit analysis proves that the investment in such a method has the ability to recover all the costs at the end of the first year and then realize benefits. The feasibility was highest for the farmers who use irrigation water provided by the Saudi Irrigation Organization (SIO) compared to those who use their own private wells. The reduction in the electricity bill estimated at about 40% because of rationalizing the use of water constitutes an incentive for owners of private wells to switch to modern irrigation methods, and their benefits will be the highest in case they shut down their wells and use water provided by SIO. The study also tested the ability of small farmers to pay the irrigation water tariff expected to be applied in the future, and showed that the highest price a palm date farmer can pay is estimated at about 0.06 riyals/m^3 of water, which is an indication of their ability to respond if water tariff is imposed. And based on the amount of water that SIO provided to farmers during 2019, if the mentioned rate of water value is adopted as a tariff, the return for SIO is estimated at about 8–9 million riyals annually.

Keywords: Rationalizing the use of water; Cost-benefit analysis; Modern irrigation methods; Saudi Irrigation Organization; Ability to pay; Water tariff

1. Introduction

The agricultural sector is the largest water consuming sector in the Kingdom of Saudi Arabia in terms of size and growth rate, as it consumes more than 80% of total water demand and is growing at an annual rate of 7% (The National Water Strategy 2030). Considering the limited sources of groundwater and surface water, this exacerbates the problem of water scarcity and constitutes a major challenge facing the agricultural sector and the irrigation sector. To meet this challenge and achieve sustainable agricultural development, both the National Water Strategy and Saudi Irrigation Organization (SIO) strategy included ambitious initiatives to reduce the demand for agricultural water through the application of modern irrigation techniques, and the best practices of agriculture and irrigation, besides increasing the utilization of sustainable water sources such as renewable water (treated sewage effluent), dam water and rain harvesting. Although the high rates of development achieved by the agricultural sector during the last three decades, which was represented in achieving self-sufficiency in many important agricultural products, it faces major challenges, the most important of which is the low water use efficiency of the already scarce water sources, and its dependence on non-renewable groundwater resources, which reach a percentage of about 90% of the total water consumed in the sector (The National Water Strategy 2030). The average irrigation efficiency in Saudi Arabia over the past decade is estimated to be around

* Corresponding author.

Presented at the 14th Gulf Water Conference: Water in the GCC… Towards Economic Efficiency and Financial Sustainability, 13–15 February 2022, Riyadh, Saudi Arabia

53%, although international best practices indicate the possibility of achieving efficiency ranging from 75% to 85% (The National Water Strategy 2030).

It is believed that the low water efficiency in the agricultural sector is due to the low rates of adoption of modern irrigation techniques and systems, especially in the irrigated areas that still use traditional irrigation systems with low efficiency, such as the regions of Jazan and Makkah. Fig. 1 shows the average prevalence rate of irrigation methods in the Kingdom, and its prevalence in the main regions.

In the case of Al-Ahsa project area, which is the focus of this study, the development of traditional irrigation methods began early by introducing enhanced surface irrigation methods that consume less water known as Bouaki, Tadwees and Circle irrigation to replace the traditional flood irrigation. In the Tadwees method, the land is divided into longitudinal slices, a slice is irrigated, and the adjacent slice is left without irrigation, and the young palm trees are planted in the middle of the irrigated slices (Fig. 2). In the Al-Bouaki method, land is backfilled around the mature palm trees to raise its level, irrigation water is given to the adjacent slides (Al-Bouaki – Fig. 3), and due to the length of the date palm tree roots, it can reach the water in the adjacent irrigated slides. In the circle irrigation method, irrigation is carried out in circular basins with diameters of up to 3 m, keeping 7 m space between any two basins, and the palm tree is inside the basin (Fig. 4).

With the establishment of the Water extension Department in 1,417 AH, the application of modern irrigation methods known as bubbler irrigation began (Fig. 5), and this was accompanied by awareness programs and incentives to encourage farmers to adopt modern irrigation methods, that included:

- SIO participates in the costs of introducing the modern irrigation system especially the network, storage basin and pump) in varying proportions according to the farm area.

Fig. 2. Tadwees method.

Fig. 3. Bawaki method.

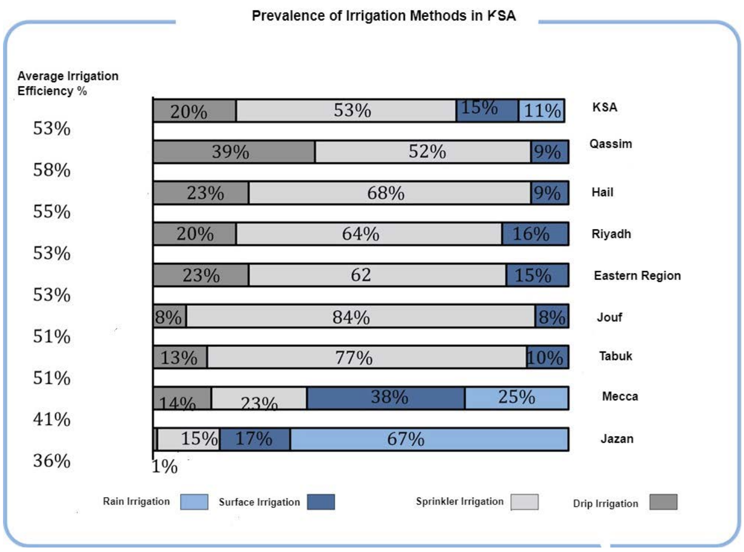

Fig. 1. Prevalence of irrigation methods in the main regions of KSA (*Source*: SIO Strategy 2018).

- Buying dates from farmers who implement modern irrigation methods at a higher price (5 riyals/kg instead of 3 riyals/kg for non-implementers).
- Shortening the irrigation period from 7 to 4 days, or from 14 to 7 days for farmers who switch to modern irrigation methods.

Accordingly, there has been steady progress in switching from the traditional irrigation system to modern irrigation systems. The number of farms that converted to modern irrigation until 2019 reached about 6381 farms with an area of 2018 ha, or 25% of the number of farms within the command area of the project. It is expected that the percentage of conversion to modern irrigation methods will increase steadily after the irrigation network with open channels was converted into a pressurized distribution network, which provides sufficient pressure at the entrance to the farm with a 3 bar, enabling the farmer to connect his field network without the need for a pump or a storage pond.

This study aims to:

- Highlight the feasibility of investing in the introduction of modern irrigation methods by farmers as an alternative to the traditional methods used.

Fig. 4. Circle method.

Fig. 5. Bubbler method.

- Test the ability of small palm tree farmers to pay in case of imposing a tariff for irrigation water, so that this would be a guiding indicator for SIO to plan and take decision regarding imposing irrigation water tariff.
- Assist SIO in its plans to implement an incentive system that promotes the application of modern irrigation techniques among small farmers, whether those who benefit from SIO's water sources or those who use their private wells for irrigation.

2. Literature survey

One of the most important challenges facing water resources in the Kingdom alongside the scarcity is the low efficiency of agricultural water use, especially in oases and old cultivation areas, where the prevailing irrigation methods are still the traditional surface irrigation methods, whose average efficiency is estimated at about 30% (the SIO strategy). To address this, studies indicated a trend towards introducing modern irrigation techniques and methods that lead to raising the efficiency of low surface field irrigation methods, in addition to achieving a significant reduction in consumption and cost of energy and labor. Table 1 shows the reduction in the cost of energy and labor by using modern irrigation techniques compared to using surface field irrigation methods in some Arab countries.

However, modernizing traditional field irrigation methods in the Arab countries faces some technical, economic and social obstacles and difficulties, the most important of which are: the weak water extension and management services, the high cost of introducing modern irrigation methods compared to traditional irrigation methods, and the weak agricultural yield for small farmers with a small area, which does not help Cost recovery; in addition to the scarcity of specialized research centers (The Arab Organization for Agricultural Development 1999). The study titled "Factors Affecting the Adoption of Modern Irrigation

Table 1
Energy and labor cost reduction in adopting modern irrigation methods compared to traditional surface methods

Country	Reduction in the cost of energy and labor by using modern irrigation methods compared to surface irrigation	
	Energy %	Labor %
Jordan	42.3	
Qatar	44.8	
Kuwait	78.9	90
Syria	42.0	70.3
UAE	41.9	50
Palestine	52.5	
Egypt	–	49.9
Yemen	–	33
Sultanate of Oman	–	97

Source: Adapted from a study evaluating the uses of modern irrigation techniques under Arab Agricultural conditions – The Arab Organization for Agricultural Development

Techniques in the Kingdom" (King Abdulaziz City for Science and Technology – General Administration of Grant Programs 03-641 – Project: A T) concluded that the high cost and difficulty of maintenance were the most important obstacles against the adoption of modern irrigation methods by farmers, and recommends implementing financing policies and support for the cost of modern irrigation network so that the farmer can adopt them.

In Tabuk region Al-Zaidi et al. [1] conducted a study to determine the relationship between some personal characteristics and socio-economic conditions of farmers and their attitudes towards using both traditional and modern irrigation methods, in addition to identifying the factors that affect farmers' attitudes towards using modern irrigation methods. Regarding the trends towards modern irrigation methods, it was found that about 28.3% of the total respondents/farmers have positive attitudes and about 71.7% have a neutral orientation. The results also reflected a significant and positive correlation for factors such as: age, area cultivated using traditional methods, land area, and farmers' attitude towards using traditional irrigation methods. In contrast to a significant inverse positive relationship between the number of family workers in agriculture, annual income, and farmers' attitudes towards using different irrigation methods. The study recommended carrying out large-scale awareness campaigns for farmers using various modern methods for water conservation.

In the Qassim region, AL-Subaiee et al. [2] conducted a study with the aim of determining the irrigation methods used by farmers and the obstacles that face the adoption of modern irrigation methods. The results of the study indicated that more than a third (38.3%) of farmers use the surface (flood) irrigation method, while about 31.2% of the farmers used the drip irrigation method. A significant and positive correlation was achieved between educational levels and the level of using modern irrigation methods. However, the age and years of experience of the farmers were negatively correlated with using modern irrigation methods, while the farm area was negatively correlated with the use of traditional irrigation methods. The study recommended launching extension education programs to enhance the rates of farmers' adoption of modern irrigation methods to conserve the limited water resources.

Lazaridou et al. [3] also conducted a study examining farmers' willingness to pay for the use of treated wastewater for irrigation in the Nestos region, Greece. This was done by applying the Contingent Valuation Method (CVM) to the results of a questionnaire that included 302 farmers. The results showed that farmers expressed a positive attitude towards the use of treated wastewater, as they were 64.2% willing to pay its cost, but they were willing to pay an average cash amount of 20.54 Euro/ha/y, which is much less than what they pay for fresh water, which is equivalent to only 12.7% of the cost of using fresh water. In addition, the analysis shows that the use of treated wastewater in agriculture is more acceptable to farmers who are aware of its environmental benefits.

Cost-benefit analysis (CBA) is generally considered a suitable decision-making mechanism and one of the tools used by policy makers to choose among several alternative investment opportunities, and it is a widely practiced technique for testing the financial viability of any project, that is, whether the investment to be made is profitable financially or not. In Mongolia, Baranchuluun et al. [4] used a cost-benefit analysis to assess the response of farmers to the trade-off between different irrigation systems including drip irrigation, sprinkler irrigation and surface irrigation (strip irrigation) for growing types of vegetables such as tomatoes, cabbage, radish, and potatoes by each of the mentioned irrigation methods. The results of the analysis showed that the drip irrigation method is the most effective and the best alternative for farms and saves water and labor compared to surface irrigation methods.

In Iraqi Kurdistan Zagonari [5] combined financial analysis, cost-benefit analysis, and social status to assess and determine the feasibility of the financial and social sustainability of the Shahrazour Irrigation Project. The results indicated that in case the price of the irrigation tariff imposed on farmers is between 0.32 and 0.57 US$ and that the interest rate of the loan paid by the farmer is less than 3%, the irrigation project can achieve financial feasibility at a rate of 13.6% for all reliable economic solutions and social sustainability at a rate of 35.8% of the proposed solutions.

Also Luhach et al. [6] used economic analysis to test the feasibility of investing in drip and sprinkler irrigation methods compared to traditional surface irrigation methods in Haryana, India, where a number of farms were selected that produce grapes and citrus, including 60 farms drip irrigated, 60 sprinkler irrigated and 60 surface irrigated. By estimating the construction and operating costs and production inputs, as well as calculating the returns, the net present value, the internal return rate and the benefits/costs ratio were calculated. The results indicated a higher value in both the drip and sprinkler irrigation methods compared to the surface irrigation method. Thus, drip irrigation and sprinkler irrigation are considered water-saving techniques with better economic feasibility than surface irrigation, and investment in them should be encouraged.

In the Punjab province of Pakistan (Amar Razzaq et al. [7]) carried out an economic analysis, measurement, and comparison of water productivity of modern and traditional irrigation systems using primary data collected from 120 farms where mango and wheat crops are grown. Economic analysis indicators were estimated for cost benefit ratio (BCR) and net present value (NPV). The results of the study showed that users of modern irrigation systems (sprinkler and drip irrigation) obtained higher total values of cost-benefit ratio and net present value, which indicates that adopting modern irrigation methods was an economically viable option. In addition, the water productivity of farms using modern irrigation methods was higher than that of traditional farms.

Regarding analyzing the farmers' willingness and their ability to pay the cost of irrigation water, Tabieh et al. [8] conducted a study to determine the farmers' ability to pay the cost of irrigation water in the Jordan River Valley. The Residual Imputation Approach was used to determine the real cost of irrigation water, where all production costs except the cost of water are deducted from the total return of the farm. The study also found that the profitability of water and, consequently, the value of irrigation water showed a high level of variance by location, type of crop, quality and source of irrigation water, planting season and irrigation technique used. For example, it was found that the profitability of surface water is the highest, followed by mixed water and then groundwater is the lowest. They also found that the average value of irrigation water was 0.51 JD/m^3 at the state level, and the highest value is for water used for irrigation of: vegetables under greenhouses, citrus crops, other fruit trees and field crops such as wheat, respectively. The results showed that the cost of irrigation water is equivalent to 1.1% of the total cost, which is considered low so that it does not encourage farmers to save water. The weighted average of farmers' maximum ability to pay for irrigation water in the Jordan Valley was estimated at 0.76 JD/m^3 of water (1 JD = 5.28 SAR).

3. Study area and data collected

This study was carried out in Al-Ahsa project, which is managed by SIO and located in the Eastern region of Saudi Arabia (Fig. 6). The necessary data for the study was collected after a comprehensive survey and inventory of the farms applying modern irrigation methods (bubbler irrigation). 100 farms were selected distributed over the ten irrigation zones that make up the entire project area, 90% of them benefit from the project's irrigation water and the rest from private wells. The farms were subjected to a questionnaire from September to December 2020, which included meetings with farmers to take data on the components of the irrigation network in terms of types and diameters of pipes, valves, drippers/emitters and their cost, storage tanks, pump, energy and fuel cost in the case of a private well, in addition to other production inputs such as service, fertilization and crop protection etc., as well as productivity and marketing data. Then the cost of introducing modern irrigation methods for certain farms is estimated.

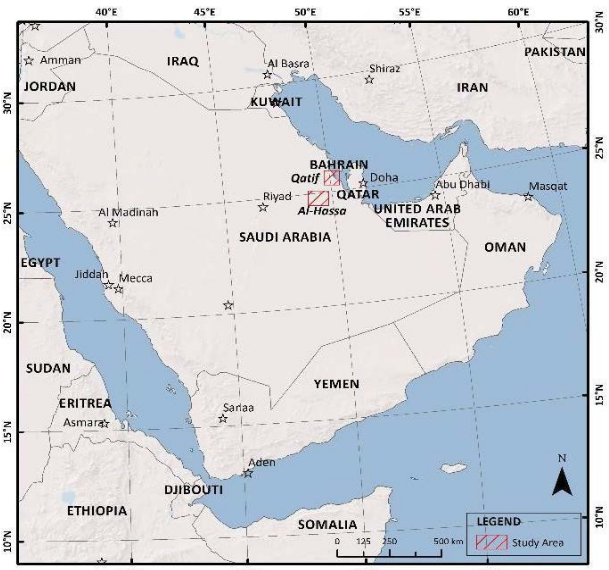

Fig. 6. Al-Ahsa project area.

Since the small farmers are the target segment of the study because it represents most of the farmers in the project, it was taken into account that the cost-benefit analysis and financial analysis are designed to suit this segment, and therefore, through statistical analysis, the average area representing the segment of small farmers was chosen at about 3 dunums (3,000 m^2). Then, Excel programs were used to calculate the cost and benefits (CBA) and make financial analysis. Cost-benefit analysis is widely used to test the financial viability of a project, that is, whether the investment to be made is financially rewarding and worth making or not [9]. A cash flow analysis was conducted for a period of 10 y to determine the payback period for the investment in modern irrigation methods.

Accordingly, the following indicators were estimated as a function of the feasibility of investing small farmers in modern irrigation techniques as an alternative to traditional irrigation methods for a farm irrigated from SIO water resource, and another irrigated from a private well.

A cost-benefit analysis model of a small palm tree farm was also carried out using the data of productivity, benefits and all costs incurred by the farmer during the production process, and then estimating the share of irrigation water from the total costs, thus sensing the extent of the farmer's ability to pay any tariff that could be imposed on irrigation water.

4. Results and discussion

Through the questionnaire data, which included 100 farms, the cost of introducing the modern irrigation system with the Bubblers system was estimated in those farms. The cost of introducing modern irrigation methods amounted to 8,150 riyals, including the irrigation network consisting of plastic pipes with diameters 3, 2 and 0.25-inch; In addition to a pond/tank of dimensions (1.5 m × 4 m × 5 m) and a pump capacity of 2.5–5 HP. Table 2 shows the cost details, bearing in mind that the cost drops to 2,100 riyals in the case of farms that irrigate from SIO project, taking advantage of the pressure available in the network (about 3 bar), and therefore do not need neither a pump nor a storage pond.

Accordingly, cost-benefit analysis and financial analysis were used for a period of 10 y in order to determine the feasibility of investing in the application of modern irrigation methods from the point of view of the simple farmer,

Parameter	Equation	Feasibility
Benefit-cost ratio, BCR	BCR = Total benefits/Total cost	If ratio >1 project feasible
Repayment period	Investment cost/yearly income	Shorter the repayment period, the more feasible the project
Residual imputation approach	Water cost = total revenue – cost of other inputs	Farmer/user ability to pay water tariff indicator

and to determine the recovery period for the cost of investment in modern irrigation methods for a farm with an area of 3 dunams irrigated from SIO project (with a pond and a pump) and another of the same area irrigated from a private well. Taking into consideration all the costs that the farmer will incur, including the annual maintenance costs and the replacement of the irrigation network and the pump. Table 3 shows the data and assumptions used in the financial analysis.

The results of the financial and cost/benefit analyses indicated that the investment of the farmer who irrigates from the project in introducing modern irrigation methods, which amounts to 8,150 riyals during the first year, will rise to 8,605 riyals as a result of annual maintenance costs, and in the 10th y the irrigation network and pump will be replaced. The analysis showed according to Table 4 the high feasibility of investing in the introduction of modern irrigation methods, as the farmer can recover the full cost of the investment at the end of the second year, with a cumulative value of 1,729 riyals, in the case of option (B) when the farmer sells his production at a price of 3 riyals/kg; The interest rises in the case of option (A) when the farmer sells his production at the incentive price of 5 riyals/kg, as he recovers the investment cost in the first year.

The results also showed the high feasibility of investing in the introduction of modern irrigation methods for the farmer who irrigates from a private well, as he recovers the investment cost at the end of the second year, in addition to saving about 40% of the electricity cost, estimated at about 1,500 riyals annually because of raising the irrigation efficiency from 50% to 90% after switching to modern irrigation (Table 5). But if he stops using the well and turns to benefit from the project's water, his benefits will be higher, as he will save the entire electricity consumption of 1,500 riyals annually. Also Table 5 shows that the reduction in the electricity consumption alone is not sufficient to recover the cost of investment in modern irrigation.

With regard to the analysis of farmers' willingness and ability to pay the cost of irrigation water (Table 6), a cost-benefit analysis was conducted, and the Residual Imputation Approach was used to determine the cost of irrigation water after deducting all production costs except for water cost from the total return of the farm and the difference represents the cost of water. Where the results showed that the value of water amounted to 0.06 riyals/m^3 (i.e., about 114 riyals/dunam/y) and is an indicator of the economic efficiency of water and an indication of the maximum capacity of the farmer to pay the irrigation water tariff [8]. In a report by MEWA, the Residual Imputation Approach was used to estimate the cost of treated wastewater produced by the National Water Company. The cost was determined for the sectors of agriculture, industry, municipalities and rest houses.

5. Recommendations

Given the high feasibility and benefits for farmers who invest in the application of modern irrigation methods, in addition to its contribution to reducing agricultural water consumption, it is recommended that SIO provides more incentives for small farmers and consider the possibility of bearing part of the cost of the irrigation network in addition to providing advice and technical support.

Activating programs with the Saudi Agricultural Development Fund to provide loans for farmers to be used in introducing modern irrigation methods.

Motivating the owners of private wells to apply modern irrigation methods by offering to provide them with

Table 2
Cost of bubbler irrigation system components

Area	Reservoir Cost		Pump Cost		Irrigation System Cost		Installation Cost		Total Cost		
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Av.
3 Dunam	4000	3000	2700	2400	1200	1000	1200	800	9100	7200	8150

The cost of farms irrigated by private wells that have a pump and tank = 8150 SAR/ Dunam
The cost of farms irrigated by Saudi Irrigation Organization that have a pump and tank = 8150 SAR/ Dunam
The cost of farms irrigated by Saudi Irrigation Organization that do not need neither a tank nor a pump = 2100 SAR/ Dunam

Table 3
Data and assumptions used in financial analysis

Number of date palm tree/ha	100 ha	–According to MEWA recommendations
Production	60 kg/tree	60 kg/tree taken as average
Water quantity/ha	19000 m^3/year	–SIO
Bubbler irrigation efficiency	90%	–SIO
Surface irrigation efficiency	50%	–SIO
Inflation rate	2.5%	–General Authority for Statistics
Subsidized price for dates	5 SAR/kg	–Dates factory
non-subsidized price for dates	3 SAR/kg	–questionnaire
Electricity cost(private well)	500 SAR/donum	–questionnaire

Table 4
Financial analysis to recover the investment cost of a farm with an area of 3 donums irrigated by SIO

Investment	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Cost of irrigation network											
Main and lateral pipes, bubblers	1,100										1,408
Cost of network installation	1,000										1,280
Cost of pond/tank	3,500										
Cost of pump	2,550										2,614
Cost of investment	8,150										5,302
Cost of annual maintenance											
Pump	255	261	268	275	281	289	296	303	311	318	326
Pond/Tank	35	36	37	38	39	40	41	42	43	44	45
Farm network	165	169	173	178	182	187	191	196	201	206	211
Total annual cost	8,605	466	478	490	502	515	528	541	554	568	5,884
Cumulative cost	8,605	9,071	9,549	10,039	10,542	11,056	11,584	12,125	12,679	13,248	19,132
Annual benefits											
Option a (5 SAR/kg)	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Option b (3 SAR/kg)	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400
Annual response											
Option a (5 SAR/kg)	395	8,534	8,522	8,510	8,498	8,485	8,472	8,459	8,446	8,432	3,116
Option b (3 SAR/kg	–3,205	4,934	4,922	4,910	4,898	4,885	4,872	4,859	4,846	4,832	–484
Cumulative annual response											
Option a (5 SAR/kg)	395	8,929	17,451	25,961	34,458	42,944	51,416	59,875	68,321	76,752	79,868
Option b (3 SAR/kg)	–3,205	1,729	6,651	11,561	16,458	21,344	26,216	31,075	35,921	40,752	40,268

Table 5
Financial analysis to recover the investment cost of a farm with an area of 3 donums irrigated by private well

Investment	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Cost of irrigation network											
Main and lateral pipes, bubblers	1,100										1,408
Cost of network installation	1,000					1,131					1,280
Cost of pond/tank	3,500										
Cost of pump	2,550										
Cost of investment	8,150					1,131					2,688
Cost of annual maintenance											
Pump	255	261	268	275	281	289	296	303	311	318	326
Pond/Tank	35	36	37	38	39	40	41	42	43	44	45
Farm network	165	169	173	178	182	187	191	196	201	206	211
Total annual cost	8,605	466	478	490	502	1,646	528	541	554	568	3,270
Cumulative cost	8,605	9,071	9,549	10,039	10,542	12,187	12,715	13,256	13,810	14,379	17,649
Annual benefits											
Reduction in electricity consumption SAR/year	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Option a (5 SAR/kg)	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Option b (3 SAR/kg)	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400	5,400
Annual response											
Reduction in electricity consumption SAR/year	–7,105	1,034	1,022	1,010	998	–146	972	959	946	932	–1,770
Option a (5 SAR/kg)	395	8,534	8,522	8,510	8,498	7,354	8,472	8,459	8,446	8,432	5,730
Option b (3 SAR/kg)	–3,205	4,934	4,922	4,910	4,898	3,754	4,872	4,859	4,846	4,832	2,130
Cumulative annual response											
Reduction in electricity consumption	–8,125	–7,091	–6,069	–5,059	–4,062	–4,207	–3,235	–2,276	–1,330	–399	–2,169
Option a (5 SAR/kg)	5,195	13,729	22,251	30,761	39,258	46,613	55,085	63,544	71,990	80,421	86,151
Option b (3 SAR/kg)	–325	4,609	9,531	14,441	19,338	23,093	27,965	32,824	37,670	42,501	44,631

Table 6
Calculation of the cost of irrigation water as an indicator of the farmer's ability to pay for water tariff

	Price/unit	Quantity/ton	Ton/ha	Total income (SAR)
Production	9.2	1.0	9.2	5,000
Production cost (SAR)				
Organic fertilizer (kg/ha)	8,000.0	869.6	0.3	260.9
Chemical fertilizer				
Urea (kg/ha)	100.0	10.9	1.6	17.4
DAB (kg/ha)	200.0	21.7	4.0	87.0
Pesticides (kg/ha)	7.0	0.8	120.0	91.3
Protection (palm insects, etc.)	2,500.0	271.7	217.4	217.4
Service (using machines)	10.0	1.1	140.0	152.2
Labour				
Cleaning (SAR)	2,000.0	217.4	217.4	217.4
Pollination (SAR)	1,000.0	108.7	108.7	108.7
Harvesting (SAR)	3,000.0	326.1	326.1	326.2
Crop containers (SAR)	2,200.0	239.1	239.1	239.1
Transport (SAR)	2,000.0	217.4	217.4	217.4
Zakat (SAR)	3,360.0	365.2	365.2	365.2
Land rent (SAR)	10,000.0	1,087.0	1,087.0	1,087.0
Total cost				3,387.0
Quantity of water used	19,000.0 m^3/ha	2,065.2 m^3/ton		
Assuming a 30% profit margin				
Total cost should not exceed 3,500 riyals (70% of 5,000)				
Total cost of producing a ton = 3,500–3,387 = 113 riyals				
Value of water should not exceed 0.06 riyals/m^3 (113/2,065.2 = 0.054 riyals/m^3)				

irrigation water from SIO, which is currently provided free of charge.

Given the importance of the irrigation water tariff in reducing water consumption in addition to its contribution to bearing part of the operating and maintenance costs and modernizing the infrastructure of irrigation projects, it is recommended to adopt and apply an appropriate tariff for irrigation water after conducting studies that take into account all the influencing factors such as water quality, type of crop and irrigation method as well as the socio-economic conditions of farmers.

References

[1] A.A. Al-Zaidi, M.B. Baig, E.A. Elhag, M.B.A. Al-Juhani, Chapter 8 – Farmers' Attitude toward the Traditional and Modern Irrigation Methods in Tabuk Region—Kingdom of Saudi Arabia, M. Behnassi et al., Eds., Science, Policy and Politics of Modern Agricultural System, Springer Science+Business Media Dordrecht, 2014.

[2] F.S.F. AL-Subaiee, H.M. Al-Ghobari, M.B. Baig, E.A. Elhag, M.T. Abu-Riziga, Studies on adoption of irrigation methods by the date palm farmers in Al-Qassim area – Kingdom of Saudi Arabia, Bulg. J. Agric. Sci., 19 (2013) 1337–1345.

[3] D. Lazaridou, A. Michailidis, K. Mattas, Evaluating the willingness to pay for using recycled water for irrigation, Sustainability, 11 (2019) 5220, doi: 10.3390/su11195220.

[4] Sh. Baranchuluun, D. Bayanjargal, G. Adiyabadam, A cost benefit analysis of crop production with various irrigation systems, IFEAMA SPSCP, 5 (2014) 146–156.

[5] F. Zagonari, Combining econometric, cost–benefit, and financial methodologies in a framework to increase diffusion and to predict the feasibility and sustainability of irrigation schemes: a case study in Kurdistan, Iraq, Water, 9 (2017) 821, doi: 10.3390/w9110821.

[6] M.S. Luhach, R.K. Khatkar, V.K. Singh, R.S. Khatry, Economic analysis of Sprinkler and drip irrigation technology in Haryana, Agric. Econ. Res. Rev., 17 (2004) 107–113.

[7] A. Razzaq, A. Rehman, A.H. Qureshi, I. Javed, R. Saqib, M.N. Iqbal, An economic analysis of high efficiency irrigation systems in Punjab, Pakistan, Sarhad J. Agric., 34 (2018) 818–826.

[8] M. Tabieh, E. Al-Karablieh, A. Salman, H. Al-Qudah, A. Al-Rimawi, T. Qtaishat, Farmers' ability to pay for irrigation water in the Jordan Valley, J. Water Resour. Prot., 7 (2015) 1157–1172.

[9] N.E. Boardman, Cost–Benefit Analysis: Concepts and Practice, 3rd ed., Prentice Hall, Upper Saddle River, NJ, 2006.

[10] S. Kiruthika, D. Suresh Kumar, Socio-economic impacts of the adoption of MIS (Micro-irrigation system) among small and marginal farmers of Coimbatore district, India, J. Appl. Nat. Sci., 12 (2020) 312–318.

[11] MEWA, Treated Sewage Effluent (TSE) Pricing Strategy TSE Pricing Strategy, Booz Allen Hamilton, Unpublished Report, 2016.