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An Investigation into the Economic Benefits and Savings Resulting From the Pressurized Irrigation System Development in Ardabil Province

S. Rahmani[1*], S. Yazdani[2], A. Mahmoudi[3], M. Shokat Fadaei[4], A. Souri[5]

1. Assistant Professor, Agricultural Research Organization, Tehran, Iran
2. Professor, Faculty of Agriculture, Tehran University, Tehran, Iran
3. Associate Professor, Payam Noor University, Eastern Tehran Branch, Tehran, Iran
4. Associate Professor, Payam Noor University, Eastern Tehran Branch, Tehran, Iran
5. Associate Professor, Faculty of Economics, Tehran University, Tehran, Iran

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ABSTRACT

In arid and semi-arid regions of Iran as the rainfall is reduced and the population and the demand for food continue to grow, high-quality water consumption and the development of planting area increasingly gain importance. The present study was aimed to evaluate the economic benefits of the pressurized irrigation system in Ardabil Province, Iran by a survey methodology, production function, and farmers' data for the growing season 2014-2015 (using a questionnaire). Results show that pressurized irrigation system not only reduces water consumption by as high as 17%, but it also optimizes the application of other production inputs and enhances the productivity of production inputs and water.

1. Introduction

As high as 97.4% of whole global water is formed by the salt water of seas and oceans and is unusable. Just 2.6% is composed of fresh water, a great part of which is unavailable in the form of ice in the polar zones and natural glaciers (1.98%) and groundwater (0.59%). So, only 0.014% of whole global water remains to be used, of which about 0.001% is grasped in the atmosphere, rivers, plants and animals, 0.005% forms the soil moisture, and 0.007% constitutes the fresh water of lakes (Ministry of Energy, 2013). A report by the UN projects that 31 countries will be exposed to the water crisis in foreseeable future and it lists Iran among countries with the most critical status. It is projected that over two-third of the world population will be posed to serious water shortage and the remaining to water scarcity by 2025. Saudi Arabia will be completely emptied of water in 50 years. The crisis has already started to appear in China, Africa, India, Thailand, Mexico, Egypt, and Iran. The major rivers of the world are gravely under threat including the Nile in Egypt, the Ganges in Southern Asia, the Yellow River in China, and the Colorado River in the US. According to the UN, the exploitable water resources in Iran will decline from 200 billion m3 in 1990 to 726-860 billion m3 in 2025 (UN, 2012). Iran's lying on the dry belt of the Earth has rendered the water the most critical limiting factor of agricultural production and a matter of high economic importance. Water is considered as the major factor of food security and economic cycle in irrigated agriculture too. Presently, the annual precipitation in Iran is 415 billion m3 of which 135 billion m3 is renewable of which 95% (128 billion m3) is exploitable. As high as 93% of this amount of water is consumed in agriculture with the efficiency of less than 45% (Golian et al., 2007)

Irrigation is an attempt by mankind to manipulate the hydrological cycle for crop production. In other words, irrigation is the technique of meeting a plant's water requirement. The commonly used irrigation methods can be divided into two broad categories of surface irrigation methods and pressurized irrigation methods (Ansary et al., 2010). Water efficiency of farms depends on irrigation method so that the average global efficiency ranges from 53% in traditional irrigation method to 90% in modern irrigation methods. The global area of land irrigated by pressurized method is 25.4 million ha in which Germany, the UK, the US, Lithuania, Jordan, Malawi, Austria, Finland, Czech, and France have the highest share and Poland, Taiwan, Portuguese, Turkey, Syria, Mexico, China, India, and Iran have the lowest share (ICID, 2010).

Iran is among the first countries that implemented pressurized sprinkler and drip irrigation systems over 40 years ago. In Iran's Development Vision, a serious attention is given to the issue of water, especially water in agriculture. A glance at this plan shows that the water-related policies and programs in Iran stress out the followings:

- Curbing water wastage and losses and conserving its economical value

[*] Corresponding author's email:
Srahmani62@gmail.com

- Saving in water use, allocating it optimally, and increase water use efficiency and productivity
- Promoting optimum consumption culture and empowering human resource in this field
- Attending the creation of a balance between feeding and harvesting of underground resources in agricultural fields
- Developing balancing schemes like Abkhandari, basin management, revival of Qanats, reform in practices, etc.
- Participating private sector in water resources utilization and management system
- Supplying inexpensive facilities for the construction and development of relevant infrastructure and investing in water restraint and storage
- Restraining and exploiting water inflow from overseas
- Developing a national document for comprehensive water resources exploitation pattern and management plan
- Controlling the growth of planting area, installing contours, developing greenhouse planting and balancing groundwater resources (Afrakhteh et al., 2013).

Extensive efforts have been made in the last two decades to improve water use and its productivity so that presently over 1.5 million ha of irrigated lands in Iran are equipped with the pressurized irrigation system. The water resources of Ardabil Province is 3,407 million m3 including 3,132 million m3 surface water and 275 million m3 underground water exploited by 5,389 wells, 221 Qanats and 3,255 springs (Water and Sewage Company of Ardabil Province, 2015). Currently, the province has 221.7 thousand ha irrigated farms, out of which 15.9 thousand ha with the user population of 1.75 thousand people are covered by the pressurized irrigation system (Jihad-e Agriculture Organization of Ardabil Province, 2015). The objective of the present study was to examine the economic impacts of the pressurized irrigation system from farmers' viewpoint and to identify the underpinning factors.

Speelman et al. (2008) used data envelopment analysis to estimate water use efficiency in South Africa's farms and its determinants. They revealed that mean water efficiency was 43 and 67% under constant returns to scale and variable returns to scale conditions, respectively it influenced by such factors as irrigation method, land ownership, land size, and crop selection. Frija et al. (2009), also, investigated into water use efficiency and the effective factors in the greenhouses of Tunisia by data envelopment analysis and estimated mean water efficiency at 42 and 52% under constant returns to scale and variable returns to scale conditions, respectively. They reported that training and investment in the application of irrigation technologies would influence water efficiency favorably and land size would influence it adversely.

In a study on factors affecting the adoption of new irrigation systems in Faridan County of Isfahan, Iran, Gholamrezai et al. (2014) found that the adoption of new irrigation systems was influenced by economic, social, supportive, individual and environmental factors. Also, Ezzati et al. (2014) examined the obstacles challenging wheat growers in the use of pressurized irrigation technology from the viewpoint of the members of agriculture production cooperatives in Ardabil and Bilesavar Townships, Iran and found significant differences in wheat production per ha and in net annual income per ha before and after the implementation of pressurized irrigation system at the one percent level.

In an attempt to estimate factors influencing the adoption of the pressurized irrigation systems by olive farmers in Guilan Province, Iran, Hajivand and Mashreghi (2012) reported that the adoption of pressurized irrigation was positively and significantly influenced by the variables of farming experience, awareness of the benefits and advantages of pressurized irrigation, attending extension courses, land size, annual income, and education level. In an economic assessment and comparison of gravity and pressurized irrigation systems in water distribution network in the Sistan Region, Piri et al. (2015) showed that farmers' income did not significantly differ between two irrigation models due to high construction costs, low irrigation efficiency, and the lack of proper management of water.

In a study on determinants of pressurized irrigation technology adoption by farmers in Mamasani County of Fars Province, Iran, Roustai et al. (2015) found that attending extension training courses, age, planting area, and ownership type had a significant impact on the adoption of irrigation technology by farmers. Amini (2014) and Ezzati et al. (2014) reported that the number of land plots and their size were effective on the development and adoption of land integration so that farmers' production and income were increased and they showed more willingness to land integration and planting aggregation as the area of the farms was higher.

2. Methodology

The development of a proper methodology to analyze and describe the consequences of a certain policy requires the understanding of the literature pertaining to the methodology. The policymaking and planning for all economic sectors including agricultural sector have been well-understood for a long time. Therefore, nations spend a lot of money on policymaking and planning in this sector. As expenditure is increased on the conservation of basic resources like water and it is needed to maximize production, it increasingly becomes imperative to evaluate the policies, plans, investments, and expenditure on their fulfillment in order to estimate their performance.

Table 1. Advantages of econometric vs. economic surplus technique

No.	Econometric technique	Economic surplus technique
1	Reflects the positive and negative impact of research.	More focuses on positive impact of research.
2	Can count the small impact of research.	Focuses on technologies developed by research.
3	Can reflect the impact of gradual variations of technology on scale, organization and specialization.	-
4	Can examine the impact of other factors like education, infrastructure availability and programs on productivity.	More often merely on the impact of research.

Source: Heisey et al. (2010)

Norton and Davis (1981) divided economic assessment of agriculture into two categories of ex-post and ex-ante assessments. The former includes (i) economic surplus or cost-benefit approach, (ii) production function approach, (iii) income method, and (iv) feeding impacts analysis. The latter includes (i) ranking approaches, (ii) cost-benefit analysis, (iii) simulation, and (iv) mathematical programming. Heisey et al. (2010) listed the advantages of economic surplus technique and econometric as summarized in Table 1.

There are specific methods for economic evaluation, some with extensive and some with more limited applications. Researchers use various techniques and models in their studies on the role of factors and inputs in crop production such as:

- Mathematical programming,
- Network analysis process,
- Econometric.

Ragnar Frisch, the Norwegian economist and statistician, coined the term econometrics in 1936. Econometrics does not limit the evaluations of economic phenomenon to their holistic, abstract analysis and scrutinize them with statistical methods. Therefore, it mostly functions in empirical research as a prediction tool to help policymaking.

The production function is a regular technique used to reflect the relationship between different quantities of a certain input or resource consumed to yield a product (output) and/or its performance. In other words, it is a technical relationship between production factors (input) and product. Inputs are combined according to this relationship and by the existing technologies to finally yield the product. According to production theories, the production of a certain quantity of a product is a function of the utilization of different inputs. If Y denotes crop production rate, we will have:

$$Y=f(X_1,\bar{X}_2) \quad (1)$$

Where, f is the functional relationship, X is the vector of variable inputs, and $\bar{X}$ is the vector of constant and quasi-constant inputs (Debertin, 1997). In other words, production function captures the physical relationship between production quantity and consumed quantities of inputs. There are over 30 models to estimate production function, among which the most famous ones are the Cobb-Douglas production function, the extended second-order production function, the constant elasticity of substitution (CES) production function, the Leontief production function, the transcendental production function, and the translog function.

Since the translog production function is used more frequently in agricultural research than other production functions and is our choice for the present work, it is briefly described here. This model of production function was first developed by Christensen and the colleagues in 1973. It captures the first order, second order, and the interactions between the independent variables. It is mainly characterized by variable scale elasticity so that a distinct elasticity can be assumed at different points of the function curve. Thus, the slope of its analog production curve can be either positive or negative. Unlike other models, the Dogan theory does not hold true for this function and this type of production function cannot be used to derive the cost function. The translog production function with n inputs is in the following form:

$$\log y=\log a+\sum_{i=1}^{n}\beta_i \log x_i+\sum_{i=1}^{n}\gamma_i(\log x_i)^2+\sum_{i=1}^{n}\sum_{j=1}^{n}\delta_{ij}\log x_i \log x_j+ui \quad (2)$$

Where, y represents crop production rate, x_i represents inputs, and ui represents scholastic error term. This function is turned into the Cobb-Douglas production function if $\beta_i+\gamma_{ij}=0$ (Sankhayan, 1996).

In economics, elasticity reflects the variation of a variable in percent as other effective factors vary by one percent. Production elasticity of 1 expresses the percent variations of the production for one unit variation of variable input provided that other inputs are constant. After estimating production function by the ordinary least squares method, selecting the final model, and determining the effective coefficients of the estimated production factors, the partial productivity of each production factor can be estimated by the equation $VMP_X=P_X$. The concepts *average productivity* (AP) and *marginal productivity* (MP) are used to estimate partial productivity and the economic status of the consumption of inputs. From an economic perspective, productivity is divided into average productivity and marginal productivity. The simplest way to calculate productivity is to use the derivative of the production function with respect to the respective production factor. Scale elasticity is gained from the sum of production elasticity's, too.

$$E_s = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} \frac{MP_i}{AP_i} \quad (3)$$

After the estimation of MP, the value of MP can be calculated by the following equation;

$$VMP_{X_i} = MP_{X_i} \times PY \quad (4)$$

Since the prices in crop markets relatively follow the trend in the competitive marketplace, then if the value of marginal productivity is equal to its price, the quantities of inputs consumption can be said to be optimum.

$$VMP_{X_i} = P_{X_i} \Rightarrow \frac{VMP_{X_i}}{P_{X_i}} \quad (5)$$

The efficient use of production factors is shown by $\frac{VMP_{X_i}}{P_{X_i}}$ ratio, in which P_{Xi} denotes average price of ith input and VMP_{Xi} denotes the value of marginal productivity of ith input. $\frac{VMP_{X_i}}{P_{X_i}}$ ratio is obtained for each input. If $\frac{VMP_{X_i}}{P_{X_i}} < 1$, the ith input is overused and its consumption should be lessened. If $\frac{VMP_{X_i}}{P_{X_i}} = 1$, the ith input is used optimally and its consumption rate should be kept. If $\frac{VMP_{X_i}}{P_{X_i}} > 1$, the ith input is used under-optimally and its consumption rate should be increased (Green, 2008)

In production function technique, the appropriate model is selected on the basis of econometric criteria such as the coefficient of determination, the number of significance, and normality test. The translog production function was selected as the function of the present work. The transcendental logarithmic (or the so-called translog) production function is a highly flexible function. It is one of the several feasible, simple mathematical functions that are applied in econometric theory to analyze theoretical issues in the measurement of inputs substitution (Yazdani, 2013). Thus, we applied the translog production function using cross-section data to study the impact of irrigation method on production and other production inputs.

The model considers the logarithm of the product as the dependent variable (y). The data were collected from the farmers across the province by a survey using a questionnaire in 2014-2015 growing season. The questionnaire was composed of two sections – demographic section and technical (agronomic) section. The statistical population included two groups of local farmers – those using traditional irrigation and those using pressurized irrigation. Using random sampling, 170 questionnaires were administered to the farmers of both groups (overall, 340 questionnaires). Then, they were used to derive the information for final analysis.

Table 2. Independent variables of the function

Variable	Description	Variable	Description
X_1	Logarithm of planting area	X_7	Machinery use rate in hr
X_2	Volume of consumed water in m^3	X_8	Farmer's experience in yr
X_3	Seeding rate in kg	X_9	Farmer's being trained (virtual)
X_4	Fertilization rate in kg	X_{10}	Farmer's literacy (virtual)
X_5	Herbicide rate in kg	X_{11}	Irrigation method (modern practice, d = 1; traditional practice, d = 0)
X_6	Irrigation labor in person-day		

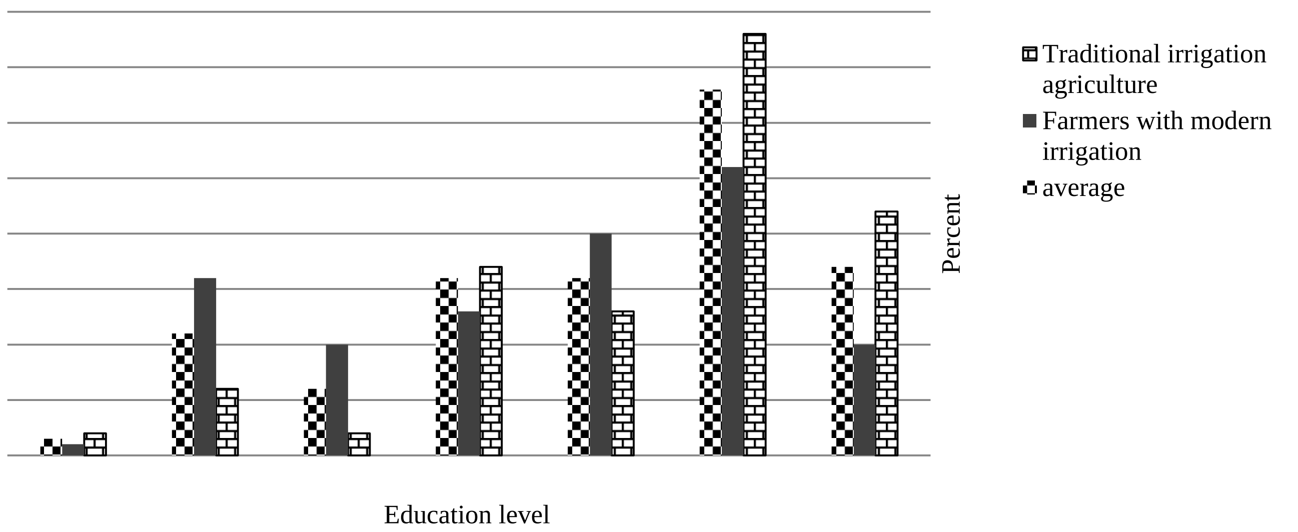

Figure 1. Distribution of educational levels among farmers

From an agricultural economics perspective, the size and number of farm lots influence the costs and income, so that a basic action to develop modern irrigation system is to integrate the fragmented farm lots.

As is evident in Table 3, the average number of farm lots is 8.3. This is 8 lots for farmers using traditional irrigation system and 8.6 lots for those using the modern system. The average size of each farm lot is estimated to be 1.73 ha. This is 1.8 ha for farmers using the modern system and 1.66 ha for those who use traditional system. The water requirement of the studied three crops in the region is supplied by effective rainfall (25%) and irrigation (75%) during the growth period and/or growing season. As Table 4 reveals, the amount of water consumed for the plants are 28 and 51% higher than the water requirement that can be supplied by irrigation in pressurized and traditional irrigation systems, respectively.

The comparison of water consumption rate between traditional and pressurized irrigation systems shows that the former uses 15% less water than the latter. However, the water consumption rate of both methods is higher than the rate required for the crop to be supplied by irrigation.

Table 3. Number of farm lots and mean farm size

Number of farm lots												
Lot No.	<5		6-10		11-15		16-20		>21		Average	
Farmers' group	TIS	MIS	TIS	MIS	TIS	MIS	TIS	MIS	TIS	MIS	TIS	MIS
Percent	26	28	43	42	13	18	10	7	8	5	8	8.6
Average	27		42.5		15.5		8.5		6.5		8.3	

Mean farm lot size (ha)										
Lot size	<1		1.1-2		2.1-3		>3.1		Average	
Farmers' group	TIS	MIS	TIS	MIS	TIS	MIS	TIS	MIS	TIS	MIS
Percent	20	14	50	43	22	27	8	6	1.66	1.8
Average	17		46.5		24.5		7		1.73	

TIS: traditional irrigation system; MIS: modern irrigation system. (Source: Research findings)

Table 4. Water consumption rate and its comparison with water requirement (in ha-m^3)

Component	Crop: Potato	Wheat	Alfalfa	Mean
Total water requirement	6160	4710	7090	5987
Water supplied by rainfall	1090	1990	1210	1430
Water supplied by irrigation	5070	2720	5880	4557
Volume of water consumption in tradition irrigation	8347	4380	7650	6792
Ratio of water consumed by traditional method to water supplied by irrigation	1.64	1.61	1.30	1.51
Volume of water consumption in modern system	6945	3690	6760	5798
Ratio of water consumed by modern method to water supplied by irrigation	1.36	1.35	1.14	1.28
Modern: traditional ratio	0.83	0.84	0.88	0.85
Saving percent in water consumption	17	16	12	15

Source: Research findings

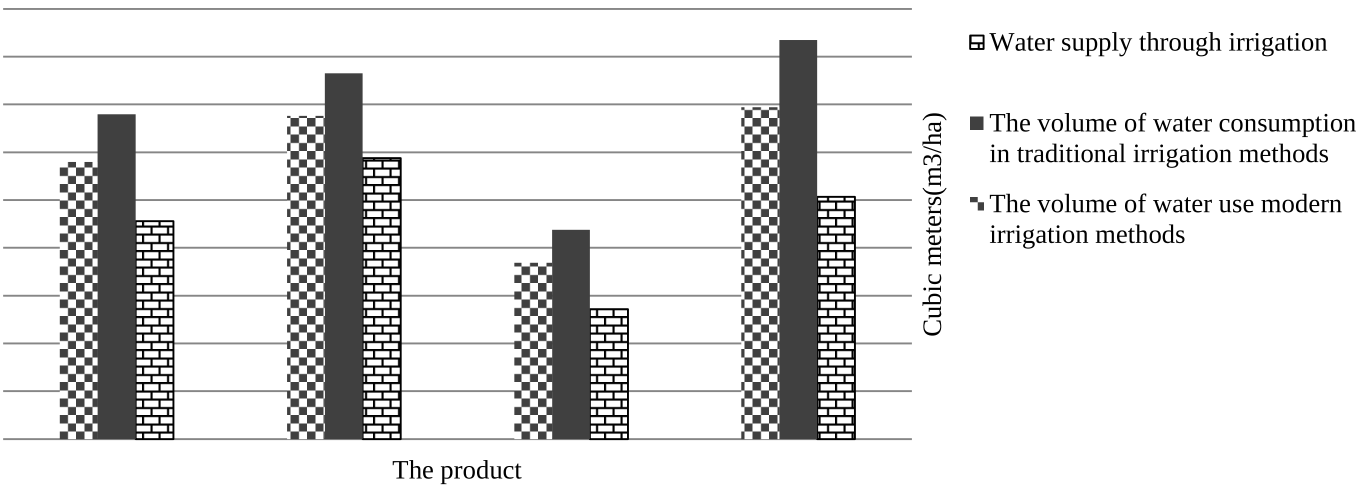

Figure 2. Comparison of water requirement and the volume of water consumption for the studied crops (m^3/ha)

According to the statistics released by the Ministry of Jihad-e Agriculture, the average yield of wheat, potato, and alfalfa is 2788, 23303 and 4358 kg ha^{-1} in Ardabil Province, Iran. Table 5 shows that these figures are 2698, 20400 and 5350 kg ha^{-1} for farmers using traditional irrigation in the studied population and 3850, 32680 and 9820 kg ha^{-1} for those using modern irrigation, respectively. In other words, the production efficiency of modern irrigation system is about 1.6 times as high as that of the traditional irrigation system.

Table 5. Comparison of mean production rate of some crops between two irrigation systems (kg ha-1)

Crop	Irrigation system: Traditional irrigation system	Irrigation system: Modern irrigation system	Modern: traditional ratio
Potato	20400	32680	1.6
Wheat	2698	3850	1.42
Alfalfa	5250	9820	1.87
Mean	-	-	1.163

Source: Research findings.

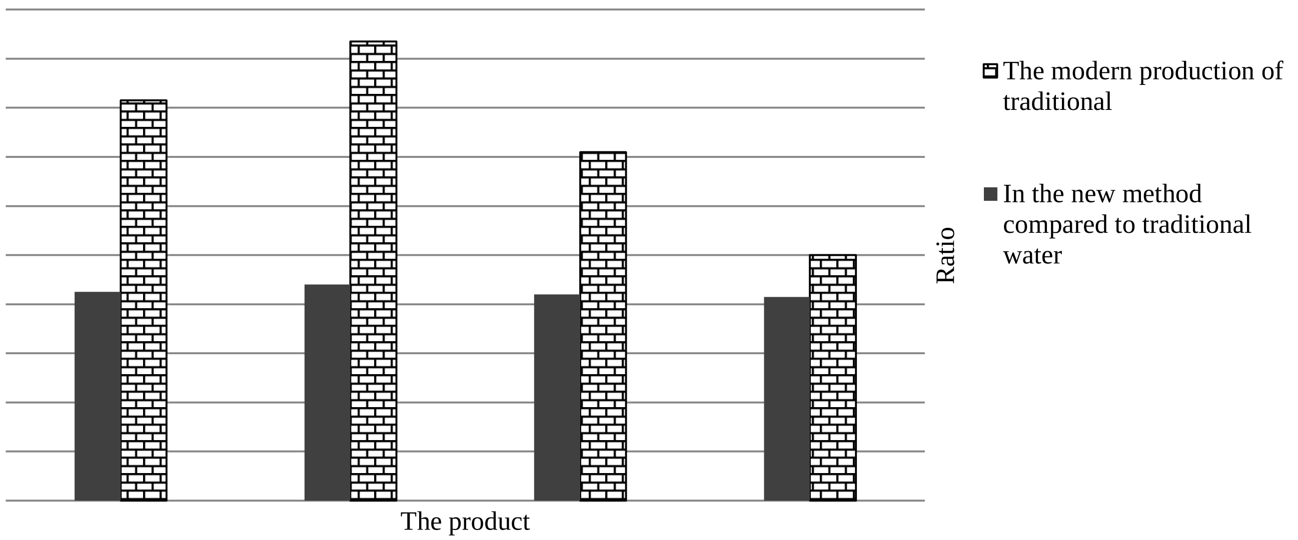

Figure 3. Comparison of the volume of water consumption and crop production rate between two irrigation systems

Table 6 tabulates the production costs and the share of water and irrigation cost in total production cost in two studied irrigation systems. Accordingly, the total production cost ratio of modern irrigation to traditional irrigation is estimated at 0.55 for potato, 1.07 for wheat and 1.03 for alfalfa. Water cost is higher in production by modern irrigation than in production by the traditional method so that the ratio is 1.56 for potato, 1.12 for wheat and 1.36 for alfalfa. One major reason is the Agricultural Water Pricing Act.

Table 6. Comparison of production costs between two irrigation systems (million IRR per ha)

Crop	Costs	Irrigation system: Traditional	Irrigation system: Modern	Modern: traditional ratio
Potato	Total cost	81.5	45.7	0.55
	Water cost	2.8	4.4	1.56
	Water share	3	9.6	3.2
Wheat	Total cost	17.6	19	1.07
	Water cost	2.8	3.2	1.12
	Water share	15	16	1.07
Alfalfa	Total cost	21.2	22	1.03
	Water cost	1.7	2.3	1.36
	Water share	8	10	1.25

Source: Research findings

Overall, in modern irrigation system, the production costs are lower but the water price exhibits an increase due to the establishment of the irrigation system and the Water Pricing Act according to which water is priced in proportion to the crop production rate. It should be noted that according to Water Pricing Act, farmers should pay 3% of their crop value as the water price if they use modern irrigation system but they should pay 1% if they use traditional irrigation system. Thus, the higher the crop production per ha, the higher the water price. From the income perspective, the income of the two studied groups of farmers – i.e. those using traditional irrigation and those using pressurized irrigation – differed by 20%.

Table 7. Comparison of mean income and production costs between two irrigation systems (million IRR per ha)

Crop	Income: TIS	Income: MIS	Cost: TIS	Cost: MIS	Income: cost ratio: TIS	Income: cost ratio: MIS
Potato	122	144	82	73	1.49	1.95
Wheat	37	49	19	26	2	1.86
Alfalfa	43	115	21	44	2.01	2.62
Average	67	102	41	48	1.83	2.03

TIS: Traditional irrigation system; MIS: Modern irrigation system. Source: Research findings

The deployment of modern irrigation system impacts crop production and the consumed input mix directly and indirectly. In other words, modern irrigation system changes the consumption rate of inputs including water, fertilizers, seeds, machinery, and herbicides, resulting in the variations in crop production rate.

As can be seen in Table 8, the R^2 of the estimated translog production function shows that independent variables account for 86% of dependent variable (crop production rate) and F-value and its significance at the 1% level confirm the estimated translog production function. On the other hand, Durbin-Watson stat is estimated to be close to 2 (1.99), implying the lack of autocorrelation between variables. As well, partial correlation coefficients were used to identify the collinearity. When correlation coefficients are small between descriptive variables, it does not mean that there is no collinearity and even there may be a relatively high collinearity in the model. This is checked by partial correlation coefficients, which shows that the estimated coefficients were less than the value of $\sqrt{R^2}$ and thus, the collinearity is negligible between the descriptive variables.

Table 8. Results of estimation of the translog production function

Variable	Coefficient	Standard error	t-statistic	Sig. level
y-intercept	5.73	1.5	3.83	0.002
Volume of water consumption	-0.42	0.16	-1.83	0.01
Seeding rate	1.10	0.30	2.58	0.002
Machinery use rate	0.45	0.22	2.06	0.041
Squared planting area	-0.48	0.24	-2.02	0.044
Interaction between planting area and volume of water consumption	0.16	0.07	2.38	0.18
Interaction between planting area and seeding rate	-0.20	0.08	-2.43	0.16
Interaction between planting area and fertilization rate	0.15	0.09	1.73	0.87
Interaction between planting area and machinery use	-0.06	0.03	-1.94	0.053
Interaction between education and irrigation labor	0.98	0.54	1.81	0.072
Interaction between education and herbicide use	0.2	0.11	1.77	0.077
Impact of dummy variable on seeding rate	-0.77	0.34	-2.25	0.025
Impact of dummy variable of irrigation method on seed consumption and training	0.53	0.17	3.19	0.007
Impact of dummy variable of irrigation method on training	-0.24	0.12	-1.95	0.052
Dummy variable of irrigation method	0.7	1.80	2.19	0.030

R-squared = 0.86 Adjusted R-squared = 0.85
Sum squared resid = 42.57 S.E. of regression = 0.37
F-statistic = 133.92 Durbin-Watson stat = 1.99
Prob (F-statistic) = 0.001
Source: Research findings

The results were validated by parametric stability test and noise terms normality test. Results revealed that none of the cumulative errors violate the boundaries and the test shows no structural alterations. The White statistic was used to check heteroscedasticity too, according to which the values of R^2 and F were smaller in the White statistic than in the estimated production function and the White statistic had a significant F implying the significant difference in R^2 obtained for the White statistic and the estimated production function. Then, the H_0 assumption (that is, the variance is constant) is confirmed and the estimated production function has higher stability.

The significance of the coefficient of the dummy variable (i.e. irrigation method) in Table 8 shows that modern irrigation method is influential in the upward shift of production y-intercept. Also, the impact of education was significant on production by modern irrigation method, leaving a positive influence on the (upward) slope of production curve. Therefore, the pressurized irrigation method can be considered as an effective technology to improve the production. The production trend is improved through the changes in the combinations and rates of production resources and inputs towards their optimum use. However, the adherence to the principles of sound application of inputs and the timing of their use is not ineffective in the improvement of production trend. Not only does it reduce the production costs and increase production, but it also helps the sustainability of resources and base inputs of production.

Also, Table 8 shows the negative relationship between crop production rate and the volume of the water consumption. In other words, results show that despite irrigation has evolved from traditional form to modern form and the volume of water consumption has been decreased, the volume of water consumption is still higher than plant/crop water requirement. Indeed, water is still overused. As shown by previous calculations, the rate of water consumption in modern irrigation system – though is less than that of traditional system – is still higher than plant water requirement. Coefficients confirm this finding and it is necessary to reduce the amount of water consumption to the level of plant water requirement. In farming with modern irrigation method, seeding rate is directly related to crop production rate. Also, the interactions planting area × water volume, planting area × fertilization rate, education × irrigation labor, and education × herbicide rate are positive for crop production rate. As well, the interactions planting area × seeding rate, planting area × machinery and education × seeding rate are negatively related to crop production rate.

Table 9 tabulates the production elasticity with respect to different inputs in two studied production methods (traditional and modern irrigation systems) for potato after the estimation of the production function for both groups (farmers using modern irrigation and those using traditional irrigation). Production elasticity was positive and less than one for planting area, seed, labor, and machinery in both production methods (traditional and modern irrigation). In other words, production occurs in the second economic region of production for these inputs. The production elasticity was negative for fertilizer in both production methods, implying that production occurs in the third region – that is uneconomical – for the consumed fertilizer.

Table 9. Comparison of coefficient and elasticity of production in two irrigation systems

Input	Irrigation method	Mean consumed input (kg ha^{-1})	Bi	Ei
Land (ha)	Traditional	-	0.37	0.0002
	Modern	-	0.25	0.0008
Seed (kg)	Traditional	1358	0.55	0.04
	Modern	930.9	0.35	0.01
Fertilizer (kg)	Traditional	1009.6	-0.02	-0.001
	Modern	819.7	-0.11	-0.003
Labor (person-day)	Traditional	77.4	0.06	0.0002
	Modern	21.8	0.26	0.0002
Water (m^3)	Traditional	8347	-0.06	-0.025
	Modern	6945	0.023	0.05
Machinery (hr)	Traditional	248.6	0.036	0.0004
	Modern	462.1	0.42	0.006
Total elasticity	Traditional	-	-	0.015

Source: Research findings.

Production elasticity with respect to water was estimated to be negative in the traditional irrigation and positive and less than one in the modern irrigation system. In other words, water is overused in production by traditional irrigation, and final production occurs in the third production region that is uneconomical. But in the modern irrigation system, production elasticity is improved and positive for water, shifting it to the second economic region of the production function. However, since it is less than one, it shows that water still needs to be saved.

In Table 9, total production elasticity is estimated at 0.015 for traditional irrigation method and 0.063 for modern irrigation method. Total production elasticity is four times as great in modern irrigation method as in traditional irrigation method. In other words, not only does the use of modern irrigation reduce water consumption and result in its sound application, but it also leads to the sound use of other inputs in crop production. As can be seen, production occurs in the second economic region of production in both production methods (traditional and modern irrigation) given the fact that the production elasticity is positive.

The concepts average productivity (AP) and marginal productivity (MP) are used to calculate partial productivity and estimate the economic status of the inputs use. The Vmp/Px ratio is equal to one for optimum condition. If it is higher than one it will imply the under-optimal use of inputs; otherwise, it will imply their overuse in crop production. Table 10 presents water productivity in traditional and modern irrigation systems.

According to Table 10, the ratio of final product value to water price (Vmp/Px) is negative and less than one for traditional irrigation and positive and greater than one for modern irrigation method. It implies that both methods apply more water for crop production than required by the plants and that more water is used in traditional irrigation than in modern irrigation. In any case, it is required to reduce the water consumption in both method.

Table 10. Comparison of water productivity in two production methods of potato (modern and traditional irrigation systems)

Irrigation method	Y: production (kg ha^{-1})	Volume of water consumption (m^3 ha^{-1})	Crop value (1000 IRR)	P_X: unit priceof water (IRR)	AP	Mp	Vmp (IRR)	Vmp/Px
Traditional	20400	8347	132600	1589	2.44	-0.06	-390	-0.25
Modern	32680	6945	212420	9176	4.71	0.023	14.95	0.002

Source: Research findings

Saboohi et al. (2007) and Gharaghani et al. (2009) concluded that increasing water price would not lead to the reduction of water consumption in farms because no relationship was revealed between water price and water consumption rate. In other words, water price is not determined on the basis of water consumption rate. Doppler et al. (2002) found that irrigation water allocation on the basis of its real price would have a high potential to improve the financial return of agricultural sector and that higher real price of water under risk conditions would reduce crop production. According to Molden et al. (2010), irrigation water pricing policy is not by itself a valid tool to improve irrigation efficiency and farmers can be motivated by different pricing methods to select and grow more water deficit-adapted crops.

The negative elasticity of production with respect to the irrigation labor can be related to the facts that, on the one hand, when modern irrigation system is deployed, less labor is used by irrigation operations and, on the other hand, family labor is often used by agricultural sector in the studied region and thus, it is removed from agricultural system resulting in the overuse of labor in agricultural activities. In a study in Shahriar County of Tehran, Amini (2014) found that from farmers' viewpoint, higher productivity, improvement in crop quality, less labor requirement, higher yield, higher planting area, and more uniform irrigation of farms were among the factors that would affect the adoption of drip irrigation system. Therefore, it is expected that as pressurized irrigation system is deployed, less labor is used for irrigation as compared to the traditional irrigation system. This reflects the concern that farmers asserted about potential unemployment with the establishment of the pressurized irrigation system. This concern was graver in farming communities in which family labor is used to a greater extent. So, it can be regarded as a factor hindering the adoption and development of pressurized irrigation system.

The elasticity of production was positive with respect to planting area, showing that the establishment of the modern irrigation system would enhance crop production by extending planting area through farm integration and defragmentation. The positive elasticity of production with respect to planting area is due to the fact that farms mostly have low and, in some cases, uneconomical planting area in the studied region. Hence, the pressurized irrigation system can partially allow integrating the farms which would result in production gain. This would, in turn, help the pressurized irrigation system being economically justifiable.

The fertilizer included in the production function was chemical fertilizer. The rate of chemical fertilizer use in Iran is much lower than the global average and the average of Asia. According to FAO (2011), the average rate of chemical fertilizer use is 331 kg ha^{-1} in the world and 144 kg ha^{-1} in Asian countries and that of Iran is 57% of the rate of Asia. According to the estimations on the basis of average application rate of the world and of Asia as well as soil test and given the performance of nutrients used in different cultivations, Iran's farms annually need over 5.5 million metric tons chemical fertilizer, whilst only 3.65 million metric tons are supplied to farmers. The annual chemical fertilizer use is 94.5 thousand tons in Ardabil Province (Ardabil Agriculture Organization (2014).

The elasticity of the production with respect to the fertilization in the estimated model reveals that this input is underused and that it needs to be increased. However, this shortage is partially offset by manure application. Farmers grow animals in addition to plants and since manure is more available to them for no or little cost, they are inclined to apply it to meet a part of their fertilization requirement. Piri et al. (2015) showed that fertilization rate was 30% lower than the recommendation in sprinkler irrigation system, resulting in lower costs and higher income from the crop production.

In traditional agriculture, labor has more share than machinery and capital, and machinery is used to a lesser extent. The elasticity of production with respect to the applied machinery was, therefore, estimated to be positive. The fulfillment of modern irrigation system is accompanied with the integration, defragmentation, and leveling of farms, paving the way for more use of agricultural machinery and tools. Thus, the elasticity of production was positive with respect to machinery and its value shows that this input can be used to a greater extent.

One another input included in the production function model was the rate of herbicide application. Production elasticity was estimated to be positive with respect to herbicide application. The economic recommendation is to increase herbicide application. But the technical recommendation will be the opposite. Firstly, the rate of herbicide application depends on the prevalence of pests and diseases. Secondly, the management of pests and diseases by herbicides is the last option due to their harmful environmental consequences and it is applied just when the other practices come to be found ineffective. The management of plant diseases and pests has been based on the chemical control and the application of herbicides until 2006 so that annual herbicide application rate tended to exceed 35,000 t in Iran. Presently, the diseases and pests tend to be controlled by non-chemical and biological methods. Thus, herbicide application rate has decreased to 16,500 t yr^{-1}. This figure is 590 t for Ardabil Province, indicating higher per ha herbicide application rate than the country-wise average. Mohseni et al. (2009) report that herbicide application rate increases as canola is introduced into planting pattern and that the policy of substituting canola for wheat cannot be a policy on managing water demand.

It may seem that farmers are well-aware of the adequate seeding rate, but a considerable part of the applied seeds is wasted by pests and diseases, weak plants, non-uniformity (excessive plant population) where growth conditions are not provided for all of them, and so on. Estimations imply the wastages of 25-30% of the consumed seeds, which is not often included in farmers' calculations or sometimes it is hard to be estimated by farmers. Because of high seed wastage, the production elasticity was positive with respect to seed, showing that seeding rate should be increased.

One of the most important inputs which may impact the optimum use of other inputs in crop production is the management. The essence of this input is the human resource management and the sound management of production inputs. Human factor determines how much input should be applied when and how. Human resource and farmers' training can help the application of sound management on the production process. Likewise, the estimated model shows that training can improve crop production through facilitating farmers' adoption of new technology.

3. Conclusion

Modern irrigation development is indeed confirmed and emphasized by farmers too, but they criticize how it is developed. The prerequisite for the satisfactory fulfillment of modern irrigation system in farms is the correct and timely meeting of commitments supposed to be fulfilled between farmers and governmental agencies. Results of the present study show that the program designed for the development of modern irrigation system is not comprehensive enough so that the information has been well communicated to farmers and farmers are suffering from the bureaucratic maze, the lack of cooperation between governmental agencies, and prolonged fulfillment period of the project.

The management of water consumption is assessed to be weak in the fulfillment of modern irrigation scheme. On the one hand, the training programs are not well planned and fulfilled and on the other hand, Water Pricing Act is not oriented with management and control of water consumption rate and the objectives of the modern irrigation scheme. According to this act, water price is a proportion of crop production rate (1-3% in modern irrigation method and 3% in mechanized irrigation) so that farmers with higher crop production rate should pay more for water. This act discourages the fulfillment of the scheme because water consumption rate has no role to play in determining water price. In fact, farmers who consume more water and produce less crop pay a lower price for water than farmers who consume less water and produce more crop. Therefore, water price is ineffective in water consumption management.

Overall, the development of modern irrigation across the agricultural farms in Iran would reduce water consumption (by as high as 17%) and production costs. It would, also, improve farmers' production and income by as high as 20% through adherence to sound and scientific principles of production and input consumption for their optimum use. In addition, water productivity would be improved to 0.002 with the development of modern irrigation system from -0.25 in the traditional irrigation system.

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