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EFFECTS OF INVESTMENT IN WATER- SAVING TECHNOLOGY ON CROPPING PATTERN AND EMPLOYMENT

J. TORKAMANI AND M. HAJI-RAHIMI[1]

Department of Agricultural Economics, College of Agriculture, Shiraz University, Shiraz, I.R. Iran.

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ABSTRACT

Water scarcity is considered to be the most important bottleneck in the development of agricultural sector of Iran. Therefore, water-saving technology has recently attracted the government authorities' attention. This study investigated the effects of water-saving technologies on cropping pattern and employment in Fars province. The findings indicated that investment in irrigation technology could changes the cropping pattern from less capital and water-intensive to more capital and water-intensive crops. Furthermore, the aggregate area under cropping would increase as a result of water-saving. Adoption of water-saving technology increased employment considerably. The best state of technology for employment in all representative farms was partial investment case. The total number of labor employed in small, medium and large representative farms in this state increased about 56%, 17%, and 103% as compared with state of non-investment in new technology, respectively.

Key words: Cropping pattern, Employment, Investment, Water-saving technologies.

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1. Associate Professor and Ph.D. Student, respectively.

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اثر سرمایه گذاری در فناوری آب اندوز بر الگـوی کشـت و اشتغال نیروی کار

جواد ترکمانی و محمود حاجی رحیمی

به ترتیب، دانشیار و دانشجوی دوره دکترای بخش اقتصاد کشاورزی، دانشکده کشاورزی، دانشگاه شیراز. شیراز، جمهوری اسلامی ایران.

چکیده

کمبود آب یکی از تنگناهای اساسی توسعه در بخش کشاورزی ایران است که به تازگی توجه دولتمردان را نیز جلب کرده است. مطالعه حاضر به بررسی اثرات سرمایه گذاری در فناوری آب اندوز در استان فارس پرداخت. یافته های تحقیق نشان داد که سرمایه گذاری در این فناوری می تواند الگوی کشت را از محصولاتی که نیاز کمتری به سرمایه و آب دارد به سوی محصولات بیشتر سرمایه و آب بر هدایت کند. افزون بر آن، صرفه جویی در آب می تواند باعث افزایش سطح زیر کشت کل بشود. استفاده از فناوری آب اندوز اشتغال[1] نیروی کار کشاورزی را به نحو چشمگیری افزایش داد. از نظر افزایش اشتغال، مناسب ترین نوع برنامه برای هر سه مزرعه نماینده مورد مطالعه، سرمایه گذاری جزئی بود. در این حالت، تعداد کل نیروی کار مورد استفاده در مزارع نماینده کوچک، متوسط و بزرگ در مقایسه با حالت عدم سرمایه گذاری به ترتیب ۵۶، ۱۷ و ۱۰۳ درصد افزایش نشان داد.

INTRODUCTION

Water scarcity is considered to be the most important bottleneck in the development of agricultural sector of Iran. So, water-saving technology has recently attracted the government authorities' attention. An important priority in the second five-year- period economic and social development program of the Islamic Republic of Iran (1994-1999) was investment in water-saving technologies, especially sprinkler irrigation. A heavy investment was done but the outcomes of the program do not seem to be satisfactory.

This study investigated the water- saving technology change and its effects on farmers' cropping pattern and labor force employment in Fars province. Fars province is one of the largest agricultural zones in Iran, containing 1.6 million ha crop lands with semi-arid climate. So, it can be considered as a well miniature of whole country.

Water-saving technology involves a shift from the high water consuming conventional surface irrigation to a sprinkler irrigation system. The modernization program was begun in 1994 and until 1997 an area about 10000 ha was involved. The distribution of water-saving irrigation systems in different regions of Fars province is presented in Table 1.

No published study about water-saving irrigation systems in Fars province was found in the literature. Jafari (3) studied the water-saving technologies in Hamadan province. He used dynamic linear programming model for analyzing investment behavior on annual crops. The results of his study indicated that investment in water-saving technologies extended profitable crops, and caused to bring more lands under cultivation. Therefore, demand for labor increased. Nevertheless, adoption decision was highly sensitive to initial costs of the investment, interest rate, and surface irrigation efficiency. Changing the relative crop prices affected the substitution pattern of crops for replanting. Water charges and discount rate proved to have no-effect on investment behavior.

Mallawaarachchi *et al.* (5) studied the investment in water-saving technology on horticultural farms in Murrumbidgee, Australia. They used a long run programming model for analyzing investment behavior on perennial crop farms. The long run programming model has been used to examine possible investment in water-saving technology at different crop prices and input costs. The results indicated that such investment is a profitable option, particularly for those farmers with access to off-farm employment.

Table 1. Distribution of water-saving irrigation systems in Fars province (ha).

Row	Region	Water-saving irrigation system				
		Wheel Move	Fixed Classic	Moving Classic	Gun	Center Pivot
1	Abadeh	119.06	108	201	-	-
2	Darab	132	108	126	-	569
3	Eghlid	233.7	105.6	387.5	167	400.8
4	Estahban	20	5.2	116.5	-	-
5	Fasa	52	13	331.35	-	-
6	Firoozabad	42	124.73	96.65	-	-
7	Jahrom	6.5	107.8	233.5	4.4	-
8	Kazeroon	34	71.67	216.8	20	-
9	Lar	114.5	-	119	-	-
10	Lamerd	47.3	-	133	55	96
11	Mamasani	45	-	85.2	128	-
12	Marwdasht	657.7	31.5	890.35	-	30
13	Nairiz	192	54.4	370.83	-	-
14	Sepidan	56.5	-	171.1	7	-
15	Shiraz	430.3	85.25	1356.51	-	-
	Sum	2182.56	816.02	4818.79	381.4	1122.8

Source: Unpublished information from Agricultural Organization of Fars province.

Caswell and Zilberman (1) introduced an econometric technique to analyze the factors affecting the land shares of alternative irrigation technologies in agriculture. They estimated the likelihood of use of drip, sprinkler, and surface irrigation in the Central Valley of California. Higher water costs, the use of ground water, the production of nuts, and location were found to increase the likelihood of using drip and sprinkler irrigation. They also found that water price increment induced water conservation.

Kumar *et al.* (4) applied cost models for preliminary economic evaluation of sprinkler irrigation systems. These models require limited input data, with simplifying assumptions about field shape, pipe orientation, and sprinkler layout used to size irrigation system components. A sensitivity analysis of the cost models showed that crop price, interest rate, and irrigation system component costs were the most important input parameters affecting model output. Crop price was very significant in determining final profitability of irrigation systems.

Regev *et al.* (6) presented an analysis of modernization of a traditional irrigation project in which the transition to a capital-intensive and water-saving irrigation system was accompanied by a shift to a new crop mix dominated by high-income vegetable crops, grown using a modern technology package. The findings of this study indicated that a modern irrigation project, incorporating drip irrigation systems, in combination with high-value cash crops, attained a high internal rate of return to capital. A modern irrigation project incorporating drip system, but practicing traditional crop mix, was not economically justified. Under conditions of scarce capital resources partial, modernization system which include only selected component of modernization, may be appropriate.

Dinar and Yaron (2) developed a procedure to estimate the technology cycle. The technology cycle were used to estimate diffusion-abandonment patterns for several irrigation technologies that had been abandoned. Results suggested that diffusion were significantly affected by variables such as water price, crop yield price, and subsidy for irrigation equipment.

MATERIALS AND METHODS

The necessary data for this study was collected via interview and questionnaire. Considering the way of distribution of water-saving irrigation systems in Fars province (Table 1), Abadeh, Eglid, Darab, Shiraz, and Marwdasht regions were selected as sampling areas. Then, 30% of farmers in each region who had adopted water-saving systems, and almost the same number of other farmers, were chosen to be interviewed. In that way, 95 questionnaires for 1997-1998 cropping year were completed. The collected data were divided into three homogenous groups on the basis of farm size.

For each of the homogenous group, a representative farm was constructed. Representative farm I was 12.5 ha in size, with 6 alternative crops: wheat, barley, sugar beet, tomato, potato, and alfalfa. Representative farm II was 43.3 ha in size, and 4 alternative crops: wheat, barley, sugar beet, and tomato. Representative farm III was 122 ha in size, and 6 alternative crops: wheat, barley, sugar beet, tomato, potato, and alfalfa. The maximum acreage for tomato in all representative farms was constrained to 6 ha considering the marketing limitations.

This study employed a dynamic linear programming model (DLPM) specified with a 6-year time horizon. The model was designed to enable identification of the long-run equilibrium solution to the optimization problem, which comprises the choice of optimal scale and mix of possible investment streams. The basic structure of DLPM is described below.

Dynamic linear programming model contains more than one period. The periods are related to each other by linking variables. The farm performance is optimized in each period, and at the same time the optimal solutions for different periods are coordinated through an aggregate planning. The structure of dynamic linear programming is shown in Fig. 1.

The relationship between period 1 with period 2 and between period 2 with period 3 are established by L_{12} and L_{23} blocks. L_{13} relates period 1 and period 3 indirectly.

Net Marginal Return of Activities		
Period 1		
L_{12}	Period 2	
L_{13}	L_{23}	Period 3

Fig. 1. The structure of dynamic linear programming model.

It was assumed that the farmers wish to maximize the profits gained from their income generation activities. Production and consumption are two concurrent activities in a farm business and are somehow difficult to separate (5). Therefore, profits were considered to include both consumption and capital accumulation in the model. The objective function was designed to maximize the net cash surplus at the planning horizon. The form of objective function presented below:

$$Max\ Z = C_i^t X_i^t \sum_i^m \sum_j^n$$

subject to:

$$\sum_i^m \sum_j^n (A_{hi})^1 X_i^1 \leq B_h^1$$

$$\sum_i^m \sum_j^n (A_{hi})^2 X_i^2 + \sum_j^m L_{1i}^2 X_i^2 \leq B_h^2$$

$$\sum_i^m \sum_j^n (A_{hi})^t X_i^t + \sum_i^m \sum_j^n Lg_i^t X_i^t \leq B_h^t$$

$$\sum_i^m \sum_j^n (A_{hi})^T X_i^T + \sum_i^m \sum_j^n Lg_i^T X_i^T \leq B_h^T$$

where:

I = Type of irrigation, traditional or microirrigation (1, 2),

J = Number of crops in the patterns,

X_i^t = Activity i in period t,

C_i^t = Gross margin of activity i in period t,

$(A_{hi})^t$ = Technical coefficient of input h for activity i in period t,

$(L_{gi})^t$ = Linking variable g for activity i in period t,

B_h^t = Available amount of input h in period t.

The planning horizon was considered to be 6 yr, because the loan is repaid in this period. The initial source for investment funding is bank loan, followed by the gross margin of each year. The interest rate (with government subsidy) for loan is 6%, and this rate was considered as the discount rate in calculating present values. The alternative activities included cropping wheat, barley, sugar beet, tomato, potato, and alfalfa. The main inputs included capital, land, water in different seasons and different technology and labor in different seasons.

RESULTS AND DISCUSSION

Effects of Water-Saving Technology on Cropping Pattern

Investment in water-saving technology can alter the relative profitability of alternative crops. The relative profitability changes cropping pattern in turn. Moreover, if existing water source is not sufficient for the irrigation of all available lands, adoption of water- saving technology would cause the total area under cropping to be increased. For evaluating the effects of investment in water-saving technologies on cropping pattern, the optimal cropping patterns were determined for representative farms in three states: no-investment, partial investment, and complete investment in water-saving technology. All crops could be irrigated by conventional or by sprinkler systems. The optimal cropping patterns for representative farms 1 to 3 are presented in Tables 2, 3 and 4, respectively.

Table 2. Optimal cropping pattern without investment in water-saving technology (ha).

Farm crop	Irrigation system	First year	Second year	Third year	Fourth year	Fifth year	Sixth year
Representative Farm I							
Wheat	Conventional	2.29	-	-	-	-	-
Barley	Conventional	-	2.66	3.03	3.38	3.57	3.43
Sugar beet	Conventional	-	-	-	-	-	-
Tomatoes	Conventional	1.89	1.54	1.09	0.67	0.30	-
Potatoes	Conventional	-	-	-	-	-	-
Alfalfa	Conventional	0.5	0.5	0.5	0.5	0.5	0.5
Sum		4.68	4.7	4.62	4.55	4.37	3.93
Representative Farm II							
Wheat	Conventional	12.9	12.9	12.9	12.9	12.9	12.9
Barley	Conventional	-	-	-	-	-	-
Sugar beet	Conventional	-	-	-	-	-	-
Tomatoes	Conventional	6	6	6	6	6	6
Sum		18.9	18.9	18.9	18.9	18.9	18.9
Representative Farm III							
Wheat	Conventional	59.67	59.67	59.67	59.67	59.67	59.67
Barley	Conventional	-	-	-	-	-	-
Sugar beet	Conventional	-	-	-	-	-	-
Tomatoes	Conventional	6	6	6	6	6	6
Potatoes	Conventional	-	-	-	-	-	-
Alfalfa	Conventional	-	-	-	-	-	-
Sum		65.67	65.67	65.67	65.67	65.67	65.67

For non-investment case in water-saving technology (Table 2), optimal cropping pattern for the first representative farm contained 2.29 ha wheat, 1.89 ha tomato, and 0.5 ha alfalfa for the first year. Wheat would be removed from the pattern in the second year, instead barley entered and its cropping area increased steadily. Tomato remained in pattern until the fifth year, however, its cropping area decreased. Alfalfa had a constant area of

0.5 ha for all the years. These results indicated that in the planning horizon, the pattern gradually shifted toward capital saving crops. So the income of farm was insufficient for family consumption costs and necessary capital for reinvestment in farm. In other words, this system was unstable.

Table 3. Optimal cropping pattern for partial investment in water-saving technology (ha).

Farm crop	Irrigation system	First year	Secon d year	Third year	Fourth year	Fifth year	Sixth year
Representative Farm I							
Wheat	Conventional	-	-	-	-	-	-
	Sprinkler	4.22	1.48	1.48	1.48	1.48	1.48
Barley	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Sugar beet	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Tomato	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Potato	Conventional	1.22	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Alfalfa	Conventional	-	-	-	-	-	-
	Sprinkler	2.15	3.48	3.48	3.48	3.48	3.48
Sum		7.59	4.96	4.96	4.96	4.96	4.96
Representative Farm II							
Wheat	Conventional	1.68	-	-	-	-	-
	Sprinkler	23.19	26.67	26.67	26.67	26.67	26.67
Barley	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Sugar beet	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Tomato	Conventional	6	6	6	6	6	6
	Sprinkler	-	-	-	-	-	-
Sum		30.87	32.67	32.67	32.67	32.67	32.67
Representative Farm III							
Wheat	Conventional	35.07	-	-	-	-	-
	Sprinkler	-	64.22	64.22	64.22	64.22	64.22
Barley	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Sugar beet	Conventional	-	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Tomato	Conventional	6	6	.6	6	6	6
	Sprinkler	-	-	-	-	-	-
Potato	Conventional	1.22	-	-	-	-	-
	Sprinkler	-	-	-	-	-	-
Alfalfa	Conventional	-	-	-	-	-	-
	Sprinkler	30.5	35.46	3.546	35.46	35.46	35.46
Sum		71.57	105.68	105.7	105.7	105.7	105.7

For the second representative farm, the optimal cropping pattern was constant for all the planning years as 12.9 ha wheat and 6 ha tomato. From the total available land, 43.3 ha, only 18.9 ha were used (44%) and the remaining became idle as a result of water scarcity.

The optimal cropping pattern for the third representative farm consisted of 59.67 ha wheat and 6.00 ha tomato that remained constant for the whole horizon time.

Table 3 summarizes the results of partial investment in water-saving technology state. In this case, the model can choose the kind of irrigation system besides the extent of the area under cropping for each farm crop.

The optimal cropping pattern for the first representative farm contains 4.28 ha wheat and 2.15 ha alfalfa in sprinkler irrigation system, and 1.22 ha potato in conventional irrigation system for the first period. The pattern for the second period to the sixth remains constant and consisted of 1.48 ha wheat and 3.48 ha alfalfa in sprinkler irrigation system. The optimal cropping pattern for the second representative farm consisted of 1.68 ha wheat with conventional irrigation for the first year and 23.19 ha with sprinkler irrigation and 6 ha tomato with conventional irrigation. From the second year, with the removal of capital scarcity, conventional irrigation of wheat were removed, but conventional irrigated tomato remained in the pattern. Optimal cropping pattern for years 2 to 6 consisted of 26.67 ha sprinkler-irrigated wheat and 6 ha conventional irrigated tomato. The extent of increasing area under cropping, as the result of water-saving, in comparison to non-investment case in year 1 and years 2 to 6 was 160% and 170%, respectively. Optimal cropping pattern for representative farm III in this case consisted of 35.07 ha conventional irrigated wheat, 6.00 ha conventional irrigated tomato and 30.5 ha sprinkler irrigated alfalfa for year 1, and 64.22 ha sprinkler irrigated wheat, 6 ha conventional irrigated tomato, and 35.46 sprinkler irrigated alfalfa.

Optimal cropping patterns for complete investment in water-saving technology are presented in Table 4. In this case, the model can only choose sprinkler irrigation system. For the first representative farm, the pattern remained constant for all the six-year period, and consisted of 1.48 ha wheat and 3.48 ha alfalfa. Comparison of Table 2 and Table 4 for this representative farm, indicated that saving water because of new technology did not affect the aggregate area under cropping considerably. However, cultivation of more profitable, as well as more water taker, alfalfa crop was possible. Optimal cropping pattern for representative farm II in this state consisted of 23.34 ha wheat and 6 ha tomato for year 1, and 31.06 ha wheat and 6 ha tomato for years 2 to 6.

Table 4. Optimal cropping pattern for complete investment in water-saving technology (ha).

Farm crop	Irrigation system	First year	Second year	Third year	Fourth year	Fifth year	Sixth year
Representative Farm I							
Wheat	Sprinkler	1.48	1.48	1.48	1.48	1.48	1.48
Barley	Sprinkler	-	-	-	-	-	-
Sugar beet	Sprinkler	-	-	-	-	-	-
Tomato	Sprinkler	-	-	-	-	-	-
Potato	Sprinkler	-	-	-	-	-	-
Alfalfa	Sprinkler	3.48	3.48	3.48	3.48	3.48	3.48
Sum		4.96	4.96	4.96	4.96	4.96	4.96
Representative Farm II							
Wheat	Sprinkler	23.34	31.06	31.06	31.06	31.06	31.06
Barley	Sprinkler	-	-	-	-	-	-
Sugar beet	Sprinkler	-	-	-	-	-	-
Tomato	Sprinkler	6	6	6	6	6	6
Sum		29.34	37.06	37.06	37.06	37.06	37.06
Representative Farm III							
Wheat	Sprinkler	113.05	87.27	87.22	87.38	86.84	63.55
Barley	Sprinkler	-	-	-	-	-	-
Sugar beet	Sprinkler	-	-	-	-	-	-
Tomato	Sprinkler	6	6	6	6	6	6
Potato	Sprinkler	-	-	-	-	-	-
Alfalfa	Sprinkler	-	24.27	24.3	24.3	24.53	38.5
Sum		119.05	117.54	117.5	117.7	117.37	108.05

Optimal cropping pattern for representative farm III in this state consisted of 113.05 ha wheat and 6 ha tomato for year 1; 87.27 ha wheat, 6 ha tomato and 24.27 ha alfalfa for year 2; 87.22 ha wheat, 6 ha tomato and 24.27 alfalfa for year 3; 87.38 ha wheat, 6 ha tomato and 24.3 ha alfalfa for year 4; 86.84 ha wheat, 6 ha tomato and 24.53 ha alfalfa for year 5; and 63.55 ha wheat, 6 ha tomato and 38.5 ha alfalfa for year 6.

Effects of Water-Saving Technology on Employment

Water-saving irrigation systems need less labor force per unit of land. Therefore, adopting these technologies may decrease employment. This problem is very important in Iran suffering from a high unemployment rate. For evaluating the effects of investment in water- saving technologies on employment, the number of labor force employed in different irrigation systems was compared in the three technology states. The results are presented in Table 5.

Table 5: Number of labor force employed in different irrigation systems (man-day).

	Year						Sum
	1	2	3	4	5	6	
Representative Farm I							
Non-investment	194	184	170	156	141	122	967
Partial investment	304	243	243	243	243	235	1511
Complete investment	201	201	201	201	201	194	1199
Representative Farm II							
Non-investment	609	609	609	609	609	609	3654
Partial investment	722	739	739	739	739	605	4283
Complete investment	613	737	737	737	737	580	4142
Representative Farm III							
Non-investment	1648	1648	1648	1648	1648	1648	10104
Partial investment	3040	3574	3574	3574	3574	3252	20588
Complete investment	2049	3166	3167	3163	3175	3365	18085

In spite of the usual assumption, adoption of water-saving technology did increase employment considerably. The best state of technology for employment in all representative farms was partial investment state. The total number of labor employed for the small, medium and large representative farms were 1511, 4283, and 20588 man-day, having 56%, 17%, and 103% increase compared with the state of no-investment in new technology, respectively. The reason of the employment extension is that the water-saving technology under the conditions of our study, that water source is the limiting factor of farming, notably increased the total area under cropping.

The positive effect of increasing the area under cropping recovered the negative effect of decreasing the employment per unit of land. Since the partial investment state did not impose the kind of irrigation system and used simultaneously the advantage of two alternative technologies, it was a very appropriate state from the employment viewpoint.

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