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# The Assessment of Final Value of Selected Agricultural Products under Water Economic Scenarios

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**Abstract**

This research is an attempt to determine the agronomic plan, shadow price, and final value with an emphasis on the optimization of water use in five main agricultural regions of Kerman province (Kerman, Baft, Bardsir, Bam, and Jiroft) and five crops (wheat, barley, potato, onion, and tomato). Analysis was based on three scenarios: (i) current planting conditions, (ii) profit maximization considering the constraints of required water and land, and (iii) profit maximization considering the constraints, including land and local consumption constraint. The results revealed that wheat and barley are eliminated from the planting pattern when water and land constraints are applied (Scenario 2), but other crops gain more planting area. Under all constraints (Scenario 3), barley is eliminated from the planting pattern, but other crops will not have changes in the cultivation area.

**Keywords**: Final Value, Crop Pattern, Shadow Price, Agricultural Crops, Kerman.

**JEL Classification**: Q10, N5.

## 1. Introduction

In developing countries, agriculture is the predominant activity of many people. In addition, agriculture has a close relationship with the

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economies of the countries and is an integral part of the national economy (Sardar Shahraki et al., 2018; Huard, 2008). Also, the agricultural sector has a major contribution to GDP and has played an important role in food security (OECD, 2009). The agricultural sector of each country is due to its nature and its strong dependence on the nature of the larger water consumer (ICWE, 2012). The complex nature of water resource issues requires methods that integrate different managerial approaches in agriculture (Sardar Shahraki et al., 2017; 2016). Demand for water is rising because of the ever-growing population, the expansion of urbanization, and the development of agricultural and industrial projects (RazaviToosi and Samani, 2016). Therefore, since the amount of renewable water is limited and constant, competition between the users of drinking water, agriculture and industry on the one hand and competition at catchment level on the other hand may be intensified in future and may be challenged seriously (Sardar Shahraki et al., 2016; 2019). Water scarcity in some areas will endanger the security and health of the economy. Thus, water scarcity has been surfaced as one of the major problems in most countries, especially in countries with a growing population. Since the available water resources are limited, the only solution to this crisis seems to be the optimal use of water resources and the enhancement of their productivity in different sectors, particularly in agricultural sector (Keramatzadeh et al., 2006). The agricultural sector is the world's largest water consumer. In Iran, this sector consumes about 83 billion $m^3$ of total available water, i.e. 93 billion $m^3$. Given the lack of water resources, especially in arid and semi-arid regions, the use of this vital resource has been limited (Sardar Shahraki et al., 2018; Delshad et al., 2011). Considering the limitation of water resources in Iran, it is imperative to increase the production by improving the yield per unit of water consumption. Irrigation planning can help enhancing water use efficiency through adjusting and supplying proper amount of irrigation at different growth stages (Sardar Shahraki et al., 2018; Shahinrokhsar and Raeisi, 2011). Therefore, the enhancement of water use efficiency, especially in the agricultural sector (as the largest water user), should be considered in economic, social and cultural development plans. Water use in this sector can be optimized by diverse infrastructural, managerial and technical approaches including optimum irrigation management, efficiency improvement of water transfer from source to consumption point, reduction of water wastage in fields, integration and leveling of other novel irrigation techniques, determination of proper tariff for water, and the selection of appropriate cultivars and planting patterns. Since water supply cost in Iran has been remarkably increased in terms of surface and underground water resources, water use optimization depends on maximizing water use efficiency (WUE) which can be made possible by the use of water plumbing and drip irrigation. Although we are suffering from water scarcity, agricultural research can provide us with the solutions for water management at farm level. Presently, mathematical programming models are used to analyze water use in agriculture.

Kerman Province covers an area of 183.193 $m^3$ in southeastern Iran. The highlands of this province are the continuation of the mountain ranges of Central Iran. The extreme end of Zagros Mountain Range and the high mountains in the province divide it into two distinct zones: desert arid zone and temperate mountainous zone. The agricultural sector of the province is highly talented and enjoys a high potential, so that it has a special place in terms of planting area and production of many horticultural and agricultural crops in Iran. This figures show the high potential of the province versus the total average of the country when contrasted with the share of other provinces and their horticulture area. The data for productive employment of this sector are contradictory. But, it is generally believed that 10-30% of province population, mostly living in rural areas, is directly or indirectly involved in agricultural production. In total, the agricultural sector of the province is of special importance and value, and the socioeconomic life of people in this province is directly or indirectly dependent on the agricultural production.

The main factor limiting the agricultural sector of Kerman Province is water since the province is poor in terms of surface waters, and the balance of underground water exploitation is negative in most parts of the province. Indeed, the crops in this region are mostly adapted to arid conditions due to water limitations. This implies that the province is suffering from water scarcity, and the recent droughts have necessitated the development of a program to meet water requirements. The agricultural research can be used to find out approaches and solutions for water management. The objective of the present study was to optimize water use for irrigation in Kerman Province. To this end, five crops (wheat, barley, potato, onion, and tomato) were analyzed in five regions (Kerman, Baft, Bardsir, Bam, and Jiroft).

## 2. Research Objectives

- Finding an agronomic plan for selected crops of Kerman Province with an emphasis on water input under different scenarios;
- Determining the shadow price and final value in different agricultural regions of Kerman Province under different scenarios.

Figure (1) shows the status of selected agricultural productions in Kerman province in this study.

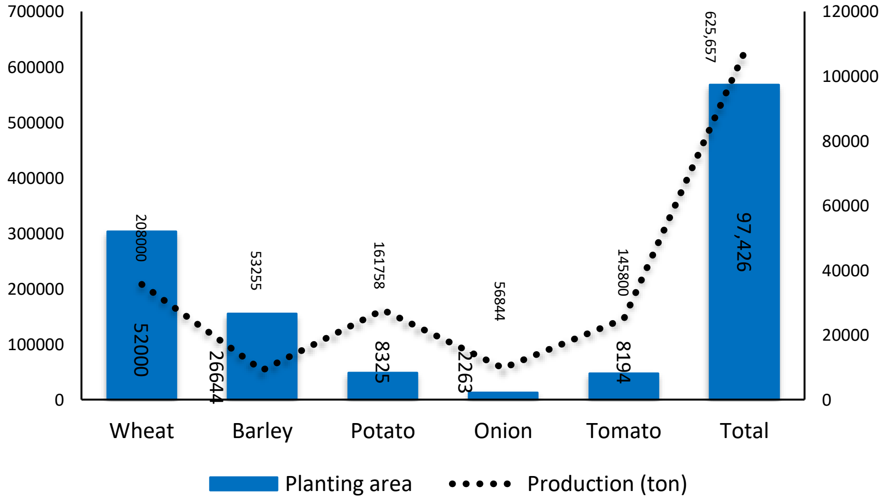


**Figure 1:** Planting area and production rate of selected crops in Kerman Province
**Source**: Statistical Book of Jihad-e Agriculture Organization of Kerman Province, 2017

## 3. Literature Review

A literature review shows that extensive studies have been done on mathematical programming models for optimization in various fields including water management. Ghadami et al. (2006) explored the optimization of exploiting multi-reservoir water resource systems using genetic algorithm. They developed a deterministic genetic algorithm for optimum use of a multi-reservoir system for agricultural purposes in Northern Khorasan. Ghaderi et al. (2006) modeled the optimum integrated exploitation of Shahriar plain and used the results of the model to determine the time and location for optimal exploitation of surface and underground water resources. Keramatzadeh et al. (2006) used linear programming technique for economic valuation of agricultural water. They reported that under optimal planting pattern in the farms fed by Barezo Dam, Shirvan, the economic value of the dam water was 470, 474 and 595 IRR[1] in February-March, March-April, and April-May, respectively. Abbasi and Ghadami (2007) studied the impact of planting pattern optimization on reducing water use and increasing income in Fariman Plain of Torbat-e Jam and found that the the trend of planting pattern in different years of the project was so that the net profit was increased with the decrease in the exploitation of underground water resources. The negative balance of the region would be mitigated and would become positive gradually by finding the optimum pattern of using the existing water resources and by using the model. Eskandari et al. (2009) explored the impact of irrigation networks on the improvement of irrigation management and the economic status of farmer families. They reported that the management of optimal use of water in agriculture can improve family income and alleviate poverty. In their study on the effect of WUE in terms of local relative advantages on two crops including wheat and corn, Dehghani Sanij et al. (2008) found that according to WUE, wheat growing should be prioritized in regions where 400 mm water is used and WUE reaches about 1 kg $m^{-3}$. Also, the growing of corn was found to be in priority because its water use was 600 mm and its WUE was about 1.3 $kgm^{-3}$.

Water management has been subject to extensive studies throughout the world. The diverse techniques of optimization and their applications in water resources engineering, especially water use in agriculture, have been comprehensively reviewed by some researchers (e.g. Yang et al., 2006; Hoekstra & Chapagain, 2007; Rogers et al., 2002; Playán & Mateos, 2006). In a study on irrigation water use management and optimization in the Jordan valley, Al-Weshah (2000) estimated the

1. Rial (Iranian currency)

value added per $m^3$ water. He stated that water shortage can be alleviated by the management of irrigation water resources using relative selection of optimal planting pattern crops and water pricing. Doppler et al. (2002) worked on the impact of water price approaches on optimal allocation of irrigation water in the bank of the Jordan River using linear programming models. They concluded that local farmers' income can be enhanced and their risk can be mitigated by optimal pricing and allocation of water. Nazer et al. (2009) focused on optimization of irrigation water use in five agricultural zones in the West Bank of Palestine and its influence on some fruit and vegetable crops. They applied linear programming technique to maximize the profit on the basis of certain constraints. Their results implied that local planting pattern change would reduce water wastage by about 4% and would enhance farmers' profit by as high as 38%. Falkenmark (2007) studied the management and improvement of water efficiency and listed water efficiency improvement by reducing water wastage, the application of modern irrigation techniques, and the development of rain-fed farming as the most important approaches for water optimization. Azadegan et al. (2014) to determine the crop plan of Sabzevar city using fuzzy planning. The results showed that farmers use efficiently in three groups of small farms (less than 6.5 hectares), moderate (6.5 to 13 hectares) and large (more than 13 hectares) by changing the existing cropping pattern. They can measure their gross margin Increase and out of available resources. Kavand et al. (2014) in a study to determine the agronomic program using a mathematical programming model in Boroujerd city. The results showed that there is a significant difference between the current culture pattern and the cultivar pattern using deficit planning. Also, according to the findings, the cultivated area of wheat, corn, alfalfa and barley increased and the area under cultivation of sugar beet and bean decreased. Bahrami Nasab et al. (2016) Determine optimal crop pattern of Esfarayne city by fuzzy model. The results of their study showed that forage crops, red beans and wheat are the optimal and economical products for cultivation in most scenarios, and the optimal profit benefit should be increased by decreasing the uncertainty of water resources. Mirzaie and Ziyaie (2017) to determine the agro economic program of cultivating the model for the stability and preservation of the environment using the

West Atlantic Alborz Rudbar Almanac's priority programming model. The results showed that the current pattern of cultivation in this region is not optimal both economically and environmentally. Therefore, wheat and barley products were eliminated from the current pattern due to low gross yields and tomato and alfalfa products due to high levels of fertilizer and poison.

It is well known that water scarcity is a major challenge faced by most countries in the world, especially the countries with growing population. Since the available water resources are limited, the only solution to this crisis is the optimal use of water resources and their productivity improvement and the determination of an agronomic plan for the agricultural sector. In this respect, linear programming models can be a very helpful tool for water optimization and management. By examining the research background, it was determined that the suggestion of the crop pattern and the final value of agricultural products were considered by many researches which illustrate the importance of this topic in agricultural research. In this research for the first time, this issue has been investigated and the final value of products and planting pattern of selected products in Kerman province has been evaluated with emphasis on water scenarios.

## 4. Research Methodology

Optimizing is a method by which the best possible solution is figured out for a problem with certain objectives and constraints that are all recognized with mathematical functions and relationships. Optimizing problem has a target function and probably several constraints that generally include the characteristics of the system. The main programming techniques for optimizing are linear programming, non-linear programming, dynamic programming, integer programming, and zero-one programming. Since we applied linear programming, its theoretical framework is reviewed below.

Linear programming is one of the simplest and widely applied optimization models. A linear programming model is constructed through these steps: (i) the formation of target function, (ii) the formation of a set of equations and non-equations (constraints), (iii) the consideration of non-negative constraint. A general linear programming problem for maximizing and minimizing a linear function is delineated as below:

$$
\begin{aligned}
&Z = f\left(x\right) = C_1x_1 + C_2x_2 + \ldots + C_nx_n \\
&S.\mathrm{t}: \\
&\quad a_{11}a_1 + a_{12}a_2 + \ldots a_{1n}a_n \le,=,\ge b_1 \\
&\quad a_{21}a_2 + a_{22}a_2 + \ldots a_{2n}a_n \le,=,\ge b_2 \\
&\qquad\qquad \ldots \\
&\quad a_{m1}a_1 + a_{m2}a_2 + \ldots a_{mn}a_n \le,=,\ge b_m \\
&\quad x_1 \ge 0 \ldots x_n \ge 0
\end{aligned}
\tag{1}
$$

In which $x_i$ is the decision variable, and $a_{ij}$ and $b_i$ are constraints. The problem can be written in the following matrix form:

$$
\begin{aligned}
&Z = CX \\
&S.t: \\
&\quad AX \le,=,\ge B \\
&\quad X \ge 0
\end{aligned}
\tag{2}
$$

In which $C$ denotes an $n$-dimensional vector from the coefficient of the target function, $X$ denotes an $n$-dimensional vector from decision-making variables, and $B$ represents an $m$-dimensional vector from the factors on the right side that show the available resources.

Linear programming is associated with optimizing (maximizing or minimizing) a dependent variable that is related to a set of independent variables linearly in which a number of linear constraints formed of independent variables is taken into account. Independent variables are the variables whose values are determined by decision maker (or by the model after it solution). They determine the value of dependent variables that are presented as the model outputs. Dependent variables are usually presented in target function that expresses economic concepts like profit, cost, income, production, sale, distance, time, etc. Independent variables are considered in linear programming as variables whose values are unknown and decision maker should derive their values after solving the problem (Mehdipour et al., 2006).

In the present research that is based on Nazer et al. (2009), the objective function of the model maximizes total net profit of irrigation considering the constraints of available land, available water, and consumption requirement in five agricultural regions (Kerman, Baft, Bardsir, Bam, and Jiroft) and five crops (wheat, barley, potato, onion, and tomato) in Kerman Province. The target function of the optimizing model is as below:

$$TP = \sum_{j=1}^{j=z}\sum_{i=1}^{i=x} P_{ij} \times A_{ij} \times Y_{ij} - \sum_{j=1}^{j=z}\sum_{i=1}^{i=x} Cc_{ij} \times A_{ij} - \sum_{j=1}^{j=z}\sum_{i=1}^{i=x} Wc_{j} \times A_{ij} \times Wd_{ij} \tag{3}$$

In which *TP* denotes total profit of cropping, $P_{ij}$ represents farm-gate crop price in IRR $kg^{-1}$, $A_{ij}$ shows crop planning area in ha, $Y_{ij}$ is the crop yield in kg $ha^{-1}$, $Cc_{ij}$ is crop planting cost in the region in IRR $ha^{-1}$, $Wc_j$ denotes water cost in the region in IRR, and $Wd_{ij}$ represents the quantity of water consumed for crop production in $m^3$ $ha^{-1}$.

**Constraints:**

1) Land constraint:

$$\sum_{j=1}^{j=z}\sum_{i=1}^{i=x} A_{ij} \le A_{\mathrm{a}} \tag{4}$$

2) Water constraint:

$$\sum_{j=1}^{j=z}\sum_{i=1}^{i=x} Wd_{ij} A_{ij} \times \le W_{\mathrm{a}} \tag{5}$$

3) Local consumption constraint:

$$\sum_{j=1}^{j=z}\sum_{i=1}^{i=x} A_{ij} Y_{ij} \ge TD \tag{6}$$

4) Positive constraint:

$$\sum_{j=1}^{j=z}\sum_{i=1}^{i=x} A_{ij} \ge 0 \tag{7}$$

In which $A_a$ is total agricultural area in the regions (ha), $W_a$ is total water devoted to local agriculture (m$^3$), and *TD* is total domestic demand for agricultural crops (t). As well, total cost of the variable is estimated by the following equation:

$$Coct_{to} = Cc_{ij} + Wc_j \times Wd_{ij} \quad (8)$$

Profit accomplished from each crop in each region is estimated by:

$$Pr_{ij} = P_{ij} \times Y_{ij} - Cost_{to} \quad (9)$$

The data for the calculation and estimation of the models were related to the 2015-2016 growing season. Data were collected from the relevant organizations including Agriculture Research and Education Center and Jihad-e Agriculture Organization of Kerman Province. Also, supplementary data were collected by administering a questionnaire among 200 farmers in the five studied regions (Kerman, Baft, Bardsir, Bam, and Jiroft). The farmers were sampled by simple randomization, and they provided such data as cropping cost, water cost, farm-gate crop price, and the quantity of water used for the crops in the region. Data were analyzed by *WINQSB* Software Package.

## 5. Results and Discussion

Given the research objectives, after data were solicited from the relevant organizations and farmers, the constraints and factors were specified, and linear programming model was applied to estimate the profit at optimum conditions. Analysis was carried out at three scenarios: (i) current planting conditions, (ii) profit maximization considering the constraints of required water and land, and (iii) profit maximization considering the constraints including land and local consumption constraint. The results of the model in these scenarios are summarized below.

**Table 1: Results of Modeling under Different Scenarios**

| City | | | Tomato | Onion | Potato | Barley | Wheat |
|---|---|---|---|---|---|---|---|
| Kerman | Scenario | 1 | 265 | 250 | 145 | 2500 | 5000 |
| | | 2 | 365 | 350 | 295 | 0 | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | 365 | 349 | 295 | 0 | 4070.186 |
| Baft | Scenario | 1 | 50 | 100 | 650 | 6000 | 8800 |
| | | 2 | 100 | 250 | 850 | 0 | 0 |
| | | 3 | 100 | 250 | 850 | 0 | 7650 |
| Bardsir | Scenario | 1 | 19 | 362 | 3200 | 6000 | 1000 |
| | | 2 | 122 | 600 | 3700 | 0 | 0 |
| | | 3 | 122 | 600 | 3700 | 0 | 8760 |
| Bam | Scenario | 1 | 20 | 40 | 10 | 2000 | 4000 |
| | | 2 | 110 | 159 | 80 | 0 | 0 |
| | | 3 | 110 | 159 | 80 | 0 | 5721 |
| Jiroft | Scenario | 1 | 16970 | 1983 | 6036 | 1866 | 46401 |
| | | 2 | 5766.39 | 5000 | 10000 | 0 | 0 |
| | | 3 | 14987.4 | 5000 | 10000 | 0 | 0 |

**Source**: Research Findings (Values are in Ha)

With respect to the results and scenarios, it is concluded that the application of water and land constraints (Scenario 2) in Kerman region renders wheat and barley production uneconomical, resulting in their elimination from the planting pattern. But, the planting area of potato, tomato and onion is increase. When all constraints are applied (Scenario 3), barley is removed from the planting pattern. In Baft region, water and land constraints removes wheat and barley from our planting pattern and the planting area of other crops increases. Under Scenario 3, the planting area of wheat is decreased and barley is removed from the model, but the planting area of other crops does not change. Scenarios 2 and 3 in Bardsir region result in the loss of planting area of all crops. Scenario 2 in Bam region is related to the decrease in total planting area, but Scenario 3 does not change it. In Jiroft, when Scenarios 2 and 3 are applied, wheat and barley lose their planting area in exchange for potato and onion that gain more planting area. The planting area of tomato is reduced in both scenarios.

**Table 2: Agronomic Value and Shadow Price for the Studied Regions under the Scenarios with Land Constraint**

| *Land Constraint* | Scenario 2 | Scenario 3 |
|---|---|---|

| | Final Value (ha) | Shadow Price (ha.IRR$^{-1}$) | Final Value (ha) | Shadow Price (ha.IRR$^{-1}$) |
|---|---|---|---|---|
| Kerman | 1010 | 0 | 5080.186 | 0 |
| Baft | 1200 | 0 | 6538.296 | 184489 |
| Bardsir | 4422 | 0 | 4422 | 371070 |
| Bam | 249 | 371970 | 6070 | 371070 |
| Jiroft | 72666.39 | 0 | 29987.4 | 0 |

**Source**: Research Findings

**Table 3: Agronomic Value and Shadow Price for Different Regions under the Scenarios with Water Constraint**

| *Water Constraint* | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|
| | Final Value (ha) | Shadow Price (ha.IRR$^{-1}$) | Final Value (ha) | Shadow Price (ha.IRR$^{-1}$) |
| Kerman | 45195520 | 0 | 45195520 | 5 |
| Baft | 82135550 | 39.4713 | 142314700 | 4 |
| Bardsir | 106224900 | 39.4713 | 167228000 | 5 |
| Bam | 56092650 | 0 | 56092650 | 0 |
| Jiroft | 645086300 | 52.7602 | 24293800 | 0.1923 |

**Source**: Research Findings

In Scenario 2, the shadow price of the crop planting area was the highest (371,970 ha) in Bam region. Thus, for one ha increase in planting area, the profit is enhanced by 371,970 IRR. In other regions, the expected profit does not change equally with planting area increase, because the shadow price is zero. If decision makers are to enhance the collected profit, they should devote more lands for agriculture in Bam, because it has high shadow price. In Scenario 2, the highest shadow price with respect to water constraint is 52.7602 IRR in Jiroft region and Baft and Bardsir regions have shadow price of 39.4713 IRR. Therefore, for each unit increase in available water in these regions (Jiroft, Baft, and Bardsir), the profit will be increased by 52.7602 and 39.4713 IRR, respectively. Since the shadow price is zero in Bam and Kerman, available water increase cannot be a sound decision in these regions. The shadow prices associated with water balance constraint is of importance to decision makers because they provide the final value of water that is dependent on consumption value. On the other hand, it can be useful in determining regions where water has a high value and the demand for water is valuable in those regions.

## 6. Suggestions

Since the resources are deficient in the studied region and the agricultural sector is the biggest water user, it is unavoidable to change the attitude in crop planting pattern and water allocation to this sector. Optimization models can be used as appropriate tools for curbing water use and improving production in the schemes of water resources management community. In this study, evaluation of final value and planting pattern has been considered for selected agricultural products of Kerman province in different scenarios.

According to the results, it can be said that although farmers are very concerned about maximizing their income and income, they tend to cultivate the products that have the most revenue for them, but given the lack of water in the studied area in the planning of crops, more attention should be paid to water-intake products. Therefore, agricultural planners can provide appropriate cropping patterns based on available water availability. On the other hand, farmers in the region, based on the results of the sampled farms, should better change their cultivation pattern, taking into account their goals and the results of different scenarios.

It is recommended to use the agricultural program of this research, in which the emphasis is on the management of water use and profit maximization, in the studied region.

Given that the Mathematical programming technique, for sustainable agriculture purposes, can provide a new perspective for analyzing agricultural activities. Farmers are usually looking for maximize crop yields While agriculture officials, in addition to addressing this issue, are pursuing other goals such as increasing employment, sustainable development of agriculture, reducing fertilizer use and agricultural pesticides. Therefore, it is suggested that using the promotional strategies, the policy of supplying this goal to the farmers was transferred.

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