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Evaluation of the economic changes of planting pattern resulted from sugar beet planting area variation (case study: Qazvin plain)

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ABSTRACT

Sugar beet is one of the main products in Qazvin plain which has allocated most of the planting areas to itself after wheat, barley, and corn. In recent years, restriction of water resources has decreased sugar beet planting area in this plain. Therefore, in this study, the effects of increase in sugar beet planting area on planting pattern, grower's income, and input utilization under water shortage was investigated. To achieve this goal, positive mathematical programming model and products yield function based on water requirement was used. Data were collected from the questionnaires completed by 127 growers in 2012-13 and analyzed using SPSS and GAMZ software. Results showed that increase in sugar beet planting decreased wheat, barley and canola planting area and increased the grower's income. It also resulted in the reduction of input utilization such as water, capital, and machines in large fields and increase in the utilization of the aforesaid inputs for small and medium fields. In conclusion, increasing sugar beet planting area which resulted in the reduction of fertilizer and pesticide application is recommended as a proper solution for reducing environmental pollution in southern regions of Qazvin plain.

Keywords: Cropping pattern; positive mathematical programming; sugar beet; water shortage

INTRODUCTION

Sugar beet is a crop with a strategic importance in the agricultural sector. The high importance of sugar in the commodity basket of Iranians on the one hand and the role of sugar import in meeting a great part of its demand on the other hand show the importance of adequate sugar supply and increasing sugar beet acreage in Iran. Furthermore, undeniable need for efficient use of scarce resources like water may challenge the production of many crops such as sugar beet which requires plentiful water (Mohammadi et al. 2013). The problem of water crisis has been quite evident in recent years, especially in southern parts of Qazvin plain (Buin Zahra) locatd among fertile plains of the country for the production of strategic crops. Recent reports show that annually over 200 million m^3 extra water is extracted from the groundwater resources of this plain. In fact, the aquifers of this plain are altogether fed with 1260.5 million m^3 water whilst their total discharge rate amounts to 1458.66 million m^3. The average annual precipitation of this province is 234.1 mm (about 8% less than average precipitation rate of Iran) (Parhizkari and Sabuhi 2013). Despite the excessive discharge of underground water tables in Qazvin Province and the negative water balance of its plains (the plains of Qazvin, Zaran of Saveh, Mah Neshan, and Taleqan-Alamut) in recent years, this province has played a remarkable role in sugar beet crop production so that it has the fifth rank after the

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West Azerbaijan, Razavi Khorasan, Fars, and Kermanshah provinces. Qazvin Province accounts for about 4% of the total sugar beet planting area in Iran. Even in terms of acreage, sugar beet is the main crop of Qazvin Plain so that its planting area is 2568 ha and sugar beet is the fourth most important crop of the plain after wheat, barley, and maize (Ministry of Agriculture-Jahad 2012).

The farmers in Qazvin Province become reluctant to increase sugar beet planting area in recent years due to some problems such as water scarcity, spatially and temporally inadequate rainfall as well as the increasing demand for extending other crops planting area (Parhizkari 2012). Recent reports show that the planned planting area of sugar beet in Qazvin Province was supposed to be 4,500 ha in 2012-2013 with an expected production of 170,000 t beets, but in practice, only 1,900 ha were planted with only about 90,000 t beets harvested, which is indeed only 40%. In addition, the cost of sugar beet production in Qazvin Plain is estimated at 3.9 million IRR/ha including transportation and mechanization (13%), land lease (16%), labor (29%) and other inputs including water, seed, fertilizer, herbicide, and pesticide (42%) (Qazvin Agricultural Jihad Organization, 2012).

Therefore, it is imperative to explore the challenges, production condition, and the increase in sugar beet acreage in Qazvin Plain. At first step, the effect of increasing sugar beet acreage in terms of farmers' response after the implementation of policies in the agricultural sector is investigated. Obviously, the result of this policy and its effectiveness in the agricultural sector mostly depend on the response of the farmers to the policies. The response of the farmers, in turn, is dictated by farm condition, their attitudes, and personal characteristics. Since it is not feasible to test policies in real-world, the policymakers in the agricultural sector need to reliably be aware of the results of the policies and the response of the environments (He et al., 2006). Presently, this has been made possible by the positive mathematical programming (PMP) model. Currently, the PMP model is widely used for agricultural policies analysis. The advantage of the model is its capability to go into the details of the policies impact at the farm level (Nigel, 2005). The model has recently been used in a plethora of empirical studies on different policies of the agricultural sector, some of which are reviewed in the next few paragraphs.

Schmid et al. (2007) used the PMP model to analyze the environmental impacts of phasing out the policy of supporting farmers in Austria. The results showed that the policy change would reduce the production cost of farmers, improve environmental condition in terms of water and soil, and decrease the emission of greenhouse gas. Cortignani and Severini (2009) focused on deficit-irrigation policies in the Mediterranean region using the PMP model. According to their results, the policies of limiting water availability and increasing water price may cause the reduction of water usage and would encourage farmers to use these policies under water deficiency. Howitt et al. (2009) focused on the economic impacts of crop yield variations with climatic conditions in 26 regions in California using the PMP model. It was found that farmers' income was influenced by climate change in all regions with decreasing trend under adverse climate. Medellan-Azuara et al. (2011) used the PMP model to explore the response of farmers to irrigation water price and rationing and the phase-out of subsidies on agricultural input in California. They reported that the technology subsidy was efficient and water rationing might have a slight impact on the land usage and water. Similarly, in Iran, Mohseni and Zibaee (2009) employed the PMP model to analyze the consequences of the increased acreage of canola in Namdan Plain of Fars Province. According to their results, the increase in canola acreage would bring about the loss of wheat and bean acreages and the increase in the expected income of the representative farms. Bakhshi (2009) used the PMP approach to address the environmental impacts of abolishing subsidy on chemical fertilizers in North- and Razavi-Khorasan provinces of Iran in the context of several scenarios. They reported that the increased price of fertilizers due to the phase-out of subsidy would reduce stability indices and surface balance and would increase N and P efficiency. Moinodini (2010) focused on farmers' response to water pricing and rationing policies in Kerman Province using the PMP model. He reported that increasing water pricing and reducing water availability would be effective in adopting the deficit-irrigation practice. Using the PMP model, Parhizkari et al. (2012) examined the effects of water sharing policy on irrigated cropping patterns in the Shahrood river watershed. They found that the application of water sharing policy was a proper approach for water allocation in the studied watershed so that it increased the acreage of the irrigated crops by 9-37%.

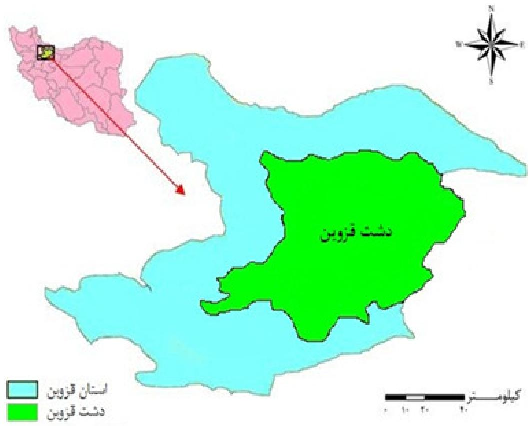

Figure 1. The geographical location of Qazvin Plain in Qazvin Province

The literature shows that PMP is a suitable method to explore the impacts of different policies in the agricultural sector. Therefore, the present study focused on economic analysis of the effects of increase in sugar beet acreage on planting pattern, input use, and farmers' gross profit in Qazvin Plain under low water condition.

MATERIALS AND METHODS

Study site

Qazvin Plain is the largest watershed of Namak Lake in Iran and a proper plain for crop production, however its water balance is negative like all other plains in Iran (Sabuhi and Parhizkari 2013). Given the crucial role of this plain in producing strategic crops and supplying the raw material to the sugar factory of Qazvin Province, it seems imperative to give a serious attention to the sustainability and development of sugar beet acreage. Figure 1 depicts the location of the studied region.

Positive mathematical programming (PMP) model

The positive mathematical programming (PMP) model was first introduced by Howitt in 1995. The model was developed to tackle the problems of normative mathematical programming (NMP) model (Parhizkari and Sabuhi 2012). The rationale of the PMP model is to use the information of dual variables of calibration constraints which confine the solution of the linear programming problem to the current activity level. In fact, the dual values are used to assert the nonlinear objective function to reconstruct the observed activity level again through the optimum solution of a new programming problem that does not have the calibration constraint (Meyer et al., 1993). Determining the spatial aggregation level is crucial for defining the application domain of the PMP model and analyzing the agricultural policies. In fact, by determining this level, the PMP model considers local features with smaller datasets, instead of analyzing the policies at a wider level, and explores the policies at the determined local levels (Parhizakri et al. 2012). The calibration of the PMP model is described as follows:

Step 1: Solving linear programming model and determining shadow price

At this step, a linear programming model was solved to maximize the farmers' gross profit with respect to resource and calibration constraints, and the shadow price of the model constraints were obtained (Howitt et al. 2012). The mathematical form of this step in the PMP for the study site is as follows:

$$Max\Pi = \left(\sum_{i=1}^{5} \sum_{h=1}^{3} \left(price_{ih} * yield_{ih} - \sum_{j=1}^{5} a_{ihj} \cos t_{ihj} \right) \right) Area_{ih} \quad (1)$$

Subject to:

$$\sum_{i=1}^{5} a_{ihj} Area_{ih} \le b_j \qquad \forall jh \qquad \left[\lambda_{ih}^{j} \right] \quad (2)$$

$$Area_{ih} \le \tilde{A}rea_{ih} + \varepsilon \qquad \forall ih \qquad \left[\lambda_{ih}^{c} \right] \quad (3)$$

$$Area_{ih} \ge 0 \qquad \forall ih \quad (4)$$

Equation (1) is the objective function of the linear programming model which includes the maximization of farmer gross profit. In this equation, *Π* is the farmer's gross profit, *i* is the number of crops (irrigated wheat, irrigated barley, grain maize, sugar beet, and canola), *j* is the number of inputs (land, water, labor, machinery, and capital), and *h* is the irrigation technique (full irrigation, 5% deficit-irrigation, and 10% deficit-irrigation). $Price_{ih}$, $yield_{ih}$, and $Area_{ih}$ represent the market price, yield, and acreage of the crop as produced under irrigation technique *h*, respectively. Also, $cost_{ihj}$ is the production cost of crop *i* using input *j* irrigated by technique *h*. a_{ihj} represents Leontief coefficients which shows the ratio of a production factor use to the land estimated by Equation 5 (Howitt et al. 2012):

$$a_{ihj} = \frac{\tilde{A}rea_{ih}}{\tilde{A}rea_{ih,Land}} \qquad \forall ihj \quad (5)$$

Equation 2 shows the resource limitations in which b_j is the total available resources of the region for the production of selected crops.

Equation 3 is the model calibration constraint in which $\tilde{Area}_{ih}$ denotes observed value of activity *i* in the base year under irrigation technique *h*. Also, *ε* is a small positive value that is used to inhibit the linear dependency of the structural constraints and calibration constraints. λ_{ih}^{j} in Equation 2 denotes the shadow price of the systemic constraint, and λ_{ih}^{c} in Equation 3 is the shadow price of the calibration constraint. Also, Equation 4 represents the non-negative constraint of the activity levels (Medellan-Azuara et al. 2011).

Step 2: Estimating exponential cost function and water requirement-based yield function

This step of the PMP model includes estimation of the exponential or logarithmic cost function and then estimation of crop yield function based on water requirement. The general form of the exponential function is as follows:

$$TC_i(Area_{ih}) = \delta_{ih} e^{\gamma_{ih} Area_{ih}} \qquad \forall ih \tag{6}$$

in which TC_i is the total cost of farming to produce crop *i*, δ_{ih} is the tracing parameter, and γ_{ih} is the gamma parameter which is a function of the elasticity supply of the crop *i* (η_{ih}) (Medellin-Azuara et al. 2010). For a certain price of crop *i* irrigated by technique *h*, the gamma parameter of the exponential cost function (γ_{ih}) is defined as

$$\gamma_{ih} = \frac{p_{ih}}{\eta_{ih} Area_{ih}} \qquad \forall ih \tag{7}$$

By having parameter γ_{rh} (Equation 7) and assuming equality of final cost with total average costs and the values of dual variables of land constraint (Equation 8), parameter δ_{rh} (delta) can be defined as Equation 9:

$$MC_{ih} = AC_{ihj} + \lambda_{ih}^{land} \qquad \forall rhj \tag{8}$$

$$\delta_{ih} = \frac{AC_{ihj} + \lambda_{ih}^{land}}{\gamma_{ih} e^{\gamma_{ih} Area_{ih}}} \qquad \forall ihj \tag{9}$$

To explore the effect of increasing sugar beet acreage under water deficit conditions, a yield function which is based on crop water requirement is needed. The present study used the yield function presented by Qureshi et al. (2013). The general form of the function is as follows:

$$Yield_{ih} = f(ET_{ih}^{R}) = a + b \times ET_{ih}^{R} + c \times (ET_{ih}^{R})^2 \qquad \forall ih \tag{10}$$

in which $Yield_{ih}$ and ET_{ik}^{R} are yield and water requirement of crop *i* under irrigation technique *h*, *a* is the *y*-intercept, *b* is the slope, and *c* is the quadratic coefficient of yield function (Qureshi et al. 2013). Crop water requirement in this function is estimated by the amount of available water, precipitation during crop growth period, and irrigation efficiency in each irrigation technique. Equation 11 expresses this concept mathematically:

$$ET_{ih}^{R} = (IW_{ih}^{R} + IEff_{ih}) + ERain_i \qquad \forall ih \tag{11}$$

in which ET_{ih}^{R} is the water requirement of crop *i* under irrigation technique *h*, IW_{ih}^{R} is the amount of water available to crop *i* under irrigation technique *h*, $IEff_{ih}$ is the efficiency of the irrigation technique *h* for crop *i*, and $ERain_i$ is the mean rainfall during the growth period of the crop *i* (Qureshi et al. 2013).

Step 3: Determining the final calibrated PMP model

At this step, as the final step of the PMP model, a nonlinear programming model is derived from the calibrated exponential cost function, yield function based on crop water requirement and a set of the constraints (except for the calibration constraint) as follows:

$$Max\Pi = \sum_{i=1}^{5}\sum_{h=1}^{3}\left(price_{ih} * \left[a + b \times ET_{ih}^{R} + c \times (ET_{ih}^{r})^2\right]\right)Area_{ih}$$

$$- \sum_{i=1}^{5}\sum_{h=1}^{3}\delta_{ih} e^{\gamma_{ih} Area_{ih}} - \sum_{i=1}^{5}\sum_{h=1}^{3}\sum_{j \neq Land}^{5} a_{ihj} cost_{ihj} \tag{12}$$

Subject to:

$$\sum_{i=1}^{5}\sum_{h=1}^{3} Area_{ih} \le TArea \tag{13}$$

$$\sum_{i=1}^{5}\sum_{h=1}^{3} ETArea_{ih}.Area_{ih} / \theta_{water} \le TW \tag{14}$$

$$\sum_{i=1}^{5}\sum_{h=1}^{3} k_{ih}.Area_{ih} \le TK \tag{15}$$

$$\sum_{i=1}^{5}\sum_{h=1}^{3} La_{ih}.Area_{ih} \le TLa \tag{16}$$

$$\sum_{i=1}^{5}\sum_{h=1}^{3} Ma_{ih}.Area_{ih} \le TMa \tag{17}$$

$$Area_{ih} \ge 0 \qquad \forall ih \tag{18}$$

Equation 12 represents the nonlinear objective function of the PMP model. Equation 13 displays the acreage constraint and shows that the total acreage of the selected crops at different irrigation conditions ($Area_{ih}$) is always smaller than or equal to the total arable lands of the region (*TArea*). Equation 14 represents the constraint of

Table 1. Distribution of samples, growers, and acreage of representative users

Studied components	Growers in Qazvin Plain			Sum
	Small-sized farms	Medium-sized farms	Large-sized farms	
Total percentage of growers	51.9	36.5	11.7	100
Number of sample	78	35	14	127
Farm size of the representative user	09.33	16.7	26.5	-

water input in which $ETArea_{ih}$ is the water requirement of crop *i* under irrigation technique *h*, ϑ_{water} is the irrigation efficiency, and *TW* is the total available water resources in the region. Equation 15 expresses capital constraint in which k_{ih} is the technical coefficient of cost per unit area of crop *i* under irrigation technique *h*, and *TK* is the total available capital in the region. Equation 16 is related to labor constraint in which La_{ih} denotes labor number required for producing crop *i* under irrigation technique *h* and *TLa* is total available labor in the studied region. Equation 17 shows machinery constraint in which Ma_{ij} is the machinery required for producing crop *i* under irrigation technique *h* and *TMa* is a total available machinery in the studied region. Finally, Equation 18 represents the constraint that the activity level cannot be negative and ensures that the applied method is physically feasible.

After distribution a number of samples, the present study used its interaction to examine the effect of increasing sugar beet acreage on planting pattern, input use, and farmer gross profit under water deficit conditions in Qazvin Plain. This means that sugar beet acreage was excluded from planting pattern of the representative users instead of its increase (i.e. their acreage was reduced to 0), and then the presented PMP model was employed to study the consequences of this variation under full irrigation, 5% deficit irrigation (DI), and 10% deficit irrigation (DI).

The statistical population was composed of all farmers in Qazvin Plain. Data were collected from the representative farmers by a regulatory questionnaire in 2012-13. In addition to farmers' demographic information, data were related to other parameters such as crop acreage, yield and price, input use and price, production cost, as well as farmers' income. Given the high number of users and the impossibility of filling regulatory questionnaires by users separately, data were collected from a sample that was taken by a random stratified method and the size was determined by Cochran's formula. The advantage of this sampling technique is that it is representative of different features of the population and the low variability of the studied features within each stratum is related to their variability within the whole population. It also improves the sampling accuracy in terms of estimating the population parameters remarkably. Accordingly, the sample size for the study site was first estimated at about 127 users by the general Cochran's formula. Then, users were classified into homogeneous strata in terms of acreage and a representative user was taken from each homogenous stratum. It should be noted that there is no single method to categorize users in homogenous strata and to select the representative user, different methods have been used in different studies. However, three methods are commonly employed: (1) mean resources method; (2) the most limiting production factor method; and (3) resource ratio method. In the first technique, users are categorized according to the 'size'. Acreage is a good criterion of the size of users in Iran. In this research as well, the farmers of Qazvin Plain were divided up into users with small-sized farms (<10 ha), medium-sized farms (10-20 ha), and large-sized farms (>20 ha) in terms of acreage based on the analysis of data derived from the regulatory questionnaires in SPSS (ver. 21) software. Table 1 presents the distribution of the estimated sample and Table 2 presents information on representative farmers in the studied region.

RESULTS AND DISCUSSION

Table 3 presents the consequences of removing sugar beet from the planting pattern of the representative user from the first group (small-sized fields). It is evident that the calibration of the PMP model gives exactly the same data of the base year (i.e. the present status of the planting pattern) Also, it was observed that after sugar beet is removed from the planting pattern, total acreage of wheat, barley, and canola increased from 2.59 to 3.53 ha, from 2.22 to 3.16 ha, and from 1.21 to 1.41 ha, respectively whereas for grain corn decreased from 1.4 to 1.23%. Therefore, it can concluded that sugar beet is the main substitute for wheat, barley, and canola.

In fact, the PMP model reveals that under

Table 2. growers' characteristics in the studied sample

Studied variables	Studied range/level	Growers in Qazvin Province		
		Small-sized fields	Medium-sized fields	Large-sized fields
Age (%)	<30 years	35.4	26.5	32.8
	30-47 years	26.1	27.3	36.0
	>47 years	38.5	46.2	31.2
Work experience (%)	<10 years	31.5	13.4	13.2
	10-18 years	19.2	30.3	19.3
	>18 years	49.3	64.3	67.5
Educational level (%)	Illiterate	31.5	18.3	14.5
	Elementary school	27.4	41.6	34.0
	Intermediate school	23.7	28.9	25.7
	Diploma and associate degree	11.2	7.4	14.6
	Higher than associate degree	6.3	3.8	11.2

Table 3. Effect of sugar beet elimination from planting pattern, input use, and gross profit of growers under water deficit conditions in the field of the first group representative (small-sized farm)

Selected crops	Yield decrease (%)	Planting pattern Base year (ha)	Calibration model of PMP* (ha)	Planting pattern after sugar beet elimination (ha)
Wheat		1.25	1.25	1.08
5% deficit irrigation	2.45	0.83	0.83	1.47
10% deficit irrigation	3.38	0.51	0.51	0.98
Barley		1.06	1.06	1.37
5% deficit irrigation	1.32	0.72	0.72	1.08
10% deficit irrigation	2.27	0.44	0.44	0.71
Grain maize		0.83	0.83	0.64
5% deficit irrigation	3.29	0.57	0.57	0.59
Sugar beet		0.90	0.90	0
5% deficit irrigation	1.08	0.63	0.63	0
10% deficit irrigation	1.24	0.38	0.38	0
Canola		0.79	0.79	0.83
5% deficit irrigation	2.46	0.42	0.42	0.58
Total acreage		9.33	9.33	9.33
Model gross profit (000 IRR)		132700	132700	118500
Water use (m^3)		58491	58491	46754
Labor requirement (person-day)		236.7	236.7	209.3
Capital use (kg**)		5565.2	5565.2	5509.4
Machinery use (operating hour)		396.75	396.75	378.41

* The equality of calibration model with base year model (columns 3 and 4) validate the results of the PMP model.

** Capital means total seed, fertilizer and pesticide that farmer require before planting.

water deficient conditions, when sugar beet is eliminated from the planting pattern, smallholders tend to allocate more land to wheat (by 36.3%), barley (by 42.3%) and canola (by 16.5%). Thus, if sugar beet is included in the planting pattern and its planting area is increased, farmers will reduce the planting areas allocation to wheat, barley, and canola. However, the decrease in planting area will be more for wheat and less for canola. Another important conclusion is that when sugar beet is eliminated, the acreages of the crops that have different irrigation requirements during their growth stages do not change similarly. Variation in the planting pattern after the elimination of sugar beet causes remarkable decline in the gross-profit of the field to about 10.7% from 132,700 thousand IRR (in the base year) to 118,500 thousand IRR. This decline has two reasons; first, the removal of sugar beet from the planting pattern results in the loss of total gross profit of the field as sugar beet generates higher income than other crops, and second, the amount of irrigation in the field and the use of DI methods during the growth period of the alternative crops. The application of DI reduces the yield of the alternative crops, causing the gross-profit loss of the field. These results lead us to the conclusion that the inclusion of sugar beet in the planting pattern of small-sized fields improves gross-profit of the grower. In addition, since sugar beet is a crop with high water requirement, it is expected that less water is used in fields after its removal or its substitution with wheat and barley which have low water requirements. Results of the PMP

Table 4. Effect of sugar beet elimination from planting pattern, input use, and gross profit of growers under water deficit conditions in the field of the first group representative (medium-sized field)

Selected crops	Yield decrease (%)	Planting pattern Base year (ha)	Calibration model of PMP* (ha)	Planting pattern after sugar beet elimination (ha)
Wheat		2.38	2.38	2.30
5% deficit irrigation	2.45	1.57	1.57	2.16
10% deficit irrigation	3.38	0.95	0.95	1.63
Barley		1.83	1.83	2.46
5% deficit irrigation	1.32	1.30	1.30	1.73
10% deficit irrigation	2.27	0.84	0.84	1.52
Grain maize		1.44	1.44	1.36
5% deficit irrigation	3.29	0.97	0.97	0.82
Sugar beet		1.69	1.69	0
5% deficit irrigation	1.08	1.04	1.04	0
10% deficit irrigation	1.24	0.73	0.73	0
Canola		1.14	1.14	1.49
5% deficit irrigation	2.46	0.82	0.82	1.23
Total acreage		16.7	16.7	16.7
Model gross profit (000 IRR)		236420	236420	211860
Water use (m^3)		98069	98069	84326
Labor requirement (person-day)		405.1	405.1	376.0
Capital use (kg**)		9967	9967	9844
Machinery use (operating hour)		709.4	709.4	689.8

* The equality of calibration model with base year model (columns 3 and 4) validate the results of the PMP model.

** Capital means total seed, fertilizer and pesticide that grower require before planting.

model confirm these points.

In addition to these findings, Table 3 shows that 58,491 m^3 of water is used in the present pattern whilst the removal of sugar beet reduces it to 46,754 m^3, showing 20% less water use versus the base year. It can be observed that elimination of sugar beet from the planting pattern reduces the capital use (total seed, fertilizer, and pesticide use) and machinery in the first group (small-sized fields), too. This is related to higher demand of sugar beet crop for chemical fertilizers and pesticides (580 kg ha^{-1}) for better growth as well as pest control and its higher demand for machinery and mechanized implements (64 operation hours per ha) during sowing, cultivation and harvest compared with other crops in the planting pattern. Thus, when sugar beet is not planted in small-sized fields and it is replaced with such crops as wheat, barley and canola which require more chemical fertilizers and pesticides (385, 380 and 410 kg ha^{-1}, respectively) and less machinery operation hours (46, 43, and 51 operation hours per ha, respectively), a reduction happens in the use of capital inputs and machinery as compared with the status quo.

Table 4 shows results of removing sugar beet from the planting pattern for medium-sized fields (the representative field of the second group).

Table 4 shows that results of the PMP model for the representative user of the second group (medium-sized field) indicate how to reach data of the base year for planting pattern and input use (comparison of the third and fourth columns in Table 4). Furthermore, it is observed that when sugar beet is withdrawn from the planting pattern, total acreage of irrigated is increased from 4.9 to 6.09 ha. This is about 24.3% higher than that of the base year. After eliminating sugar beet, the total acreage of barley and canola is increased from 3.97 to 5.71 and from 1.96 to 2.72 ha, respectively. These are 43.8 and 38.7% higher than those of the base year, respectively. Also, it is seen that the users in the second group (medium-sized fields) tend to replace sugar beet with barley (by 43.8%), canola (38.7%) and wheat (24.3%). This is different from what we observed in the users of the first group (small-sized fields). According to the results, it can be said that sugar beet is the main substitute for barley, canola, and wheat in medium-sized fields. Like small-sized fields, the acreage of grain maize is reduced after elimination of sugar beet in medium-sized fields from 1.44 to 1.36 ha (a 5.54% reduction versus the base year).

In addition, Table 4 indicates that in medium-sized fields, after sugar beet is removed, the acreage of irrigated wheat under full irrigation treatment is not extended and even it is decreased by 3.36% from 2.38 to 2.30 ha as compared to the base year, whereas in small-sized farms, the acreage of irrigated wheat shows an increase versus the base year in all irrigation

Table 5. Effect of sugar beet elimination from planting pattern, input use, and gross profit of growers under water deficit conditions in the field of the first group representative (large-sized field)

Selected crops	Yield decrease (%)	Planting pattern Base year (ha)	Calibration model of PMP* (ha)	Planting pattern after sugar beet elimination (ha)
Wheat		3.69	3.69	3.91
5% deficit irrigation	2.45	2.37	2.37	2.95
10% deficit irrigation	3.38	1.41	1.41	2.10
Barley		2.95	2.95	3.45
5% deficit irrigation	1.32	1.80	1.80	2.37
10% deficit irrigation	2.27	1.14	1.14	1.89
Grain maize		2.38	2.38	2.91
5% deficit irrigation	3.29	1.85	1.85	2.34
Sugar beet		2.48	2.48	0
5% deficit irrigation	1.08	1.93	1.93	0
10% deficit irrigation	1.24	1.35	1.35	0
Canola		1.89	1.89	2.65
5% deficit irrigation	2.46	1.26	1.26	1.93
Total acreage		26.5	26.5	26.5
Model gross profit (000 IRR)		386920	386920	345680
Water use (m^3)		158127	158127	165370
Labor requirement (person-day)		647.9	647.9	597.6
Capital use (kg**)		15437.6	15437.6	15860.2
Machinery use (operating hour)		1071.3	1071.3	1142.6

* The equality of calibration model with base year model (columns 3 and 4) validate the results of the PMP model.

** Capital means total seed, fertilizer and pesticide that grower require before planting.

regimes. When sugar beet is removed from the planting pattern, the gross profit of the medium-sized farms exhibits a decrease of 10.4% from 236,420 to 211,860 thousand IRR. This is only slightly different from the change of gross profit in small-sized farms. So, it can be said that when sugar beet is included in the planting pattern and its acreage is increased, an enhancement happens in the gross profit of the medium-sized farms. After the elimination of sugar beet from the planting pattern, total water use of the users in the second group changes from 98,069 to 84,326 m^3, reflecting a 14.03% saving in water use. This is related to the 43.8% increase in irrigated barley planting area after the withdrawal of sugar beet planting given that irrigated barley requires less water than other selected crops. Also, we see in Table 4 that after the elimination of sugar beet, the rate of labor use is decreased from 405.1 to 376 person-days, capital use is decreased from 9967 to 9844 kg and machinery use is decreased from 709.4 to 689.9 hr, showing 7.18, 1.23, and 2.76% decline as compared to the base year. The results lead us to the conclusion that the inclusion of sugar beet in planting pattern increases the use of water, fertilizer, capital, and machinery in medium-sized farms.

Table 5 presents the impacts of sugar beet elimination from the planting pattern on the use of inputs and gross profit of the third group (large-sized farms).

It can be observed that the calibration model of the PMP model yields exactly the same data of the base year (the planting pattern under the status quo) (compare columns 3 and 4 in Table 5). Also, Table 5 shows that when sugar beet is removed from the planting pattern, the acreage of all selected crops is increased for the representative user of the third group. The total increase in the acreage of irrigated wheat, irrigated barley, canola, and grain maize is from 7.47 to 8.96 ha, from 5.89 to 7.71 ha, from 3.15 to 4.58 ha, and from 4.23 to 5.25 ha, respectively. It should be noted that the acreage of the grain maize is reduced in small and medium-sized fields. In this group of users, when sugar beet is eliminated, growers tend to extend the planting area of canola (by 45.3%), barley (by 30.9%), grain maize (by 24.1%), and wheat (by 19.9%). In total, according to the results of the third group, it can be said that sugar beet is the main substitute for all selected crops so that after its full elimination from the large-sized field pattern, the highest substitution percentage is related to canola and the lowest to wheat. As a result of the variations in planting pattern after the elimination of sugar beet, the gross profit of large-sized field s declined from 386,920 to 345,680 IRR (a 10.6% reduction vs. the base year). It can be observed that the planting of sugar beet contributes to higher income of growers with large-sized fieldss. Interestingly, water use is slightly increased after the elimination of sugar beet crop from the planting pattern. According to Table 5, we see that after sugar beet was removed, the acreage of grain maize (with high water requirement) increased along with other crops. Therefore, by replaceing the sugar beet planting area with otrher crops, more water was consumed as compared with base year. Results indicate that water use was increased from 158,127 to 165,370 m^3, showing a 4.58% increase vs. base year. On contrary to the first and second groups, sugar beet planting in large-sized fields contribute to less water use. In fact, when sugar beet is included in the planting pattern of large-sized fields, the acreage of wheat and barley (which have lower water requirement) as well as grain maize (which has higher water requirement) decreased. The final result was water saving. Furthermore, it can be observed that when sugar beet is eliminated from the planting pattern of large-sized fields, the use of capital and machinery is influenced differently from the small and medium-sized fields. Table 5 shows that when sugar beet is removed from the planting pattern of large-sized fields, although labor use is reduced similar to small and medium-sized fields, an increase happened in the use of capital and machinery vs. the base year (unlike the small and medium-sized fields) so that the use of capital (total seed, fertilizer and pesticide) was increased from 15,437.6 to 15,860.2 kg and also the use of machinery from 1071.3 to 1142.6 hr, showing 2.73 and 6.65% increase in capital and machinery use as compared with the base year, respectively. It can be observed that when sugar beet is included in the planting pattern of large-sized fields, a reduction happens in the acreage of grain maize which needs more fertilizer and pesticide (625 kg ha^{-1}) and machinery operating hours (71 hr ha^{-1}) than sugar beet. The replacement of grain maize with sugar beet results in the use of capital and machinery saving and increase in the use of labor in large-sized fields.

CONCLUSIONS

According to the results, it can be observed that farmers' preferences about the substitution of the crops for sugar beet vary with the group they belong to (small, medium or large-sized fields). But, it should be noted that when sugar beet is removed from the planting pattern, all local growers (small, medium or large-sized field) tend to increase the acreage of other selected crops. But, the amount of area allocated to the selected crops varies among small, medium or large-sized growers, and growers with large-sized fields show the greatest tendency as compared with growers with small or medium-sized fields. In addition, it was found that the preferred patterns, i.e. the acreages increased by growers are influenced by the extent to which the long-term crop yields are affected by deficit irrigation and finally, the substitution of other selected crops with lower water requirement than sugar beet. As well, the results showed that the ratio of land used for the planting of the selected crops differed among the representative small, medium and large-sized fields after the elimination of sugar beet from the planting pattern, but the variations in the acreage of grain maize as an alternative crop is higher in representative large-sized fields than in small or medium-sized fields.

RECOMMENDATIONS

The study of the effect of increasing sugar beet acreage on planting pattern, farmers' gross profit, and input use under water deficit conditions in Qazvin Plain led us to the following recommendations:

1. After sugar beet is harvested from the planting pattern, wheat is always an alternative crop in all representative user groups (small, medium and large-sized fields) and its planting area was increased. So, when sugar beet is included in the planting pattern, wheat acreage is reduced and this can challenge wheat self-sufficiency. To tackle this problem, it is recommended to develop policies to increase wheat yield per unit area when sugar beet is included in the planting pattern or its acreage is increased.
2. It was found that when sugar beet is included in the planting pattern of the large-sized fields, the acreage of grain maize is decreased and water was saved. But, this substitution does not work in small or medium-sized fields and it cannot be adopted as a policy for water sustainability and conservation. So, it is recommended to adopt policies for water demand management when sugar beet is included in the planting pattern (of small or medium-sized fields).
3. Given the fact that when sugar beet is included in the planting pattern of the large-sized fields, a reduction happens in the use of capital (seed, fertilizer, and chemical

pesticide), so this policy can be adopted to alleviate environmental pollution, especially in southern regions of Qazvin Plain (where the pollution of water and soil resources is worse due to the high rate of chemical pesticide and fertilizer use).

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