Journal of Sugar Beet
http://jsb.sbsi.ir/
Journal of Sugar Beet 2014, 29(2)

Optimal cropping pattern of sugar beet growers with emphasis on price and yield risk: the case of Fasa district

H. Mohammadi[(1)]*, M. Ahmadpour Borazjani[(1)], S. Ziaee[(1)], B.A. Fakheri[(2)] and M. Ramrodi[(3)]

[(1)] *Assistant Professor of Economics Group, Department of Agricultural Economics, University of Zabol, Zabol, Iran.*
[(2)] *Associate Professor of Biotechnoligy Group, Department of Agricultural Economics, University of Zabol, Zabol, Iran.*
[(3)] *Instructor of Department of Agronomy, University of Zabol, Zabol, Iran.*

Mohammadi H, Ahmadpour Borazjani M, Ziaee S, Fakheri BA, Ramrodi M. Optimal cropping pattern of sugar beet growers with emphasis on price and yield risk: the case of Fasa district. J. Sugar Beet. 2014; 29(2): 123-129.

Received March 13, 2011; Accepted December 16, 2013

ABSTRACT

The main objectives of this study were to develop an optimal cropping pattern for sugar beet growers in Fars district (Fars province) and to investigate sugar beet importance in cropping pattern. Regarding the effect of risk on producer's decision, two risk sources including price and yield were considered. Data were obtained from Fasa district growers in 2008. In this study multi-objective mathematical programming was used. Results showed 7% difference between current income and optimal cropping pattern. However, they had difference in crop composition. In current pattern, 3.8 hectares out of 6.8 hectares belonged to sugar beet, while in optimal pattern, it reduced to 0.2 hectares. In general, in introduced cropping patterns, sugar beet and wheat cultivation is replaced by bean. This replacement meets the goal of water use reduction up to 33% in addition to provide current efficiency. Results showed that farmers pay more attention to price risk in cropping pattern formulation. It was also determined that sugar beet inefficiency for water usage, as a restricting input, has lowered its ranking in cropping pattern.

Keywords: optimal cropping pattern, risk, sugar beet, water

INTRODUCTION

Sugar beet has a strategic importance in Iran by supplying sugar needs. However, water crisis may challenge its production. Water shortage is critical in regions such as Fars province in which uncontrolled water exploitation is performed. Statistics show that the volume of groundwater exploitation is more than its capacity which has resulted in annual decrease of water (Bagheri and Bakhshoodeh 2010). Fars province has a remarkable role in sugar beet production which has been placed it as the third province in sugar beet production (after Khorasan Razavi and West Azerbaijan) by producing 8% of total sugar beet production (2 million tons). It also has 10.9 % of sugar beet planting area (Iranian Ministry of Agriculture 2008) which indicates its lower yield compared with national average production. Thus, it is necessary to improve sugar beet production. Income as a small object had got great attention by growers and sustainable use of water resources has been considered as a target by policy makers. However, sustainable water usage policy should be taken to action beside growers' preferences. It is especially important since their activity's results is observable after a cultivation period. In other words, it's a risky activity which characterizes more attention to growers preferences. A study results indicated that growers avoid risk facing (Torkamani 1996). Therefore, growers preference's to earn favourable income should be considered together with risk phenomenon. Moreover, as a policy recommendation, it is essential to pay attention to sustainable water resource usage or in other words to water consumption reduction compared with current

*Corresponding author's email: hamidmohammadi1378@gmail.com

©2014 Sugar Beet Seed Institute, PO Box 4114-31585, Karaj, I.R. Iran
All rights reserved.

situation. This study aimed to make operational pattern for water use reduction and risk. Using mathematical programming models for introducing an optimal pattern in accordance to capabilities such as growers' behaviour against risk phenomenon has always been considered. Using primary basic models such as Motad in recent studies confirms this fact. This study reviews some national and international researches which used mathematical programming models. Chizari and Ghasemi (1999) evaluated optimal cropping pattern in 40 hectares in Eqlid, Fars province. Based on the results, wheat and sugar beet were placed in optimal pattern and other crops such as bean, pea, and lentil were excluded. Bayat (1999) evaluated optimal cropping pattern under the utilization of surface and groundwater in Borazjan. Results showed that optimal cropping pattern utilization resulted in 33 and 21% efficiency increase for six and less than six hectares, respectively compared with current cropping pattern. Keramatzadeh *et al*. (2005) evaluated optimal water allocation to the fields under Barzu and Shirvan dam (Khorasan) and observed that excluding some crops from current cropping pattern and extending other crops cultivation increased region profit. Mohammadi *et al*. (2006) showed that in fish farms in Fars province, chemical fertilizers and machines had negative effect on production risk, while manure and water had positive effect on fisheries production. Naghshinefard *et al*. (2006) showed that in Fars province, vegetables and field crops had higher risk compared with horticultural crops particularly citrus. Burton *et al*. (1987) suggested different marketing strategies for beef cattle farm in West Virginia, US, using almost optimal programming. Among various options, desired options were selected based on risk level, cash, and labour cost. Torkamani and Sedaghat (1999) determined optimal agronomy and horticulture pattern based on creating alternative programming. Results showed that using normal water, pistachio sowing area in optimal and semi-optimal pattern had no significant difference but using saline water, the area extended more than normal sowing. In risk model development, Motad and Target Motad models have more application due to the ease of changing and acceptable replications. Kumar (1995) compared Motad and Target Motad methods in 12.3 hectares in Harayana state, India and observed that both methods were similar. Doppler *et al*. (2002) introduced optimal pattern via combining water allocation and cropping and also using the risky Motad programming approach in Jordan valley. Results showed that with risk consideration in the model, due to the lack of fluctuations in cereal price in the risk model, cereal contribution may be increased. Torkamani and Kalaei (1999) compared mathematical programming methods combined with Motad risk, Target Motad, and conventional linear programming. Results showed that at the highest risk level, all three models were similar and also with increase in risk, programming patterns combined with risk tended to replace high efficiency products by other crops in the cropping pattern. Mohammadian *et al*. (2006) evaluated the effects of agricultural commodity market stock on rice sowing area using Motad pattern in Golestan province. Stock market impact was considered as a price fluctuation reduction from 5 to 50%. Results showed that price fluctuation reduction resulted in rice planting area increase but with more fluctuation reduction, rice planting area was decreased again. Suresh and Mujumdar (2004) evaluated agricultural production risk using fuzzy programming in India. In their study, water was supplied by reservoir, stimulation patterns were used, and yield was stimulated for different water level based on evapotranspiration. Performance risk was considered as uncertainty or fuzziness. Results showed that optimal pattern changed greatly in fuzziness mode compared with absolute mode. Francisco and Mubarik (2006) evaluated the effects of potential interaction among different production technologies, activities, and limitations on vegetable growers in Manila, Taiwan. They used minimal variance pattern for risk assessment. Results showed that irrespective of high earning potential by some technologies, they were not accepted by growers owing to their high risk. As pointed out earlier, the aim of this study is to develop operational patterns for selective growers based on providing several objectives including a clear programming, water consumption and also risk reduction. Separate analysis of price risk and yield are unique characteristics which distinguishes this study from similar studies.

MATERIALS AND METHODS

Multi-objective programming

In this study multi-objective programming was used which allows multi-objective optimization with consideration of resource limitation. In this method, instead of an optimal solution, a set of solutions was obtained which makes it possible to exchange among solutions. The multi-objective mathematical programming model can be written as follows (Francisco and Mubarik 2006):

$$MaxZ(x) = (Z_1(x), Z_2(x), \ldots Z_h(x), \ldots Z_k(x)),$$

$$Z_1(x) = Z1(x_1, x_2, \ldots, x_n)$$

.

.

.

$$Z_h(x) = Zh(x_1, x_2, \ldots, x_n)$$

.

.

$$Z_k(x) = Zk(x_1, x_2, \ldots, x_n)$$

$$Subject\ to: \quad X \in F, X \geq 0$$

where $Z = (Z_1, Z_2, \ldots, Z_K)$ is the objective function vector with (i=1,2,…,k) Z_i components as individual objective function and (i=1,2,…,n) X_i as sowing area of the i^{th} crop. In general, there are three methods to solve multi-objective models including weighing method, constraint method, and simplex method. Constraint method is more used than other methods (Francisco and Mubarik 2006). In constraint method, the h^{th} objective function is optimized and the remaining k-1 objectives are included in limitation frame. Minimization condition was as follows:

$$MinZ(x) = (Z_1(x), Z_2(x), \ldots Z_h(x), \ldots Z_k(x)),$$

$$Subjet \quad to:$$

$$Z_1(x_1, x_2, \ldots, x_n) \leq b1$$

.

.

$$Z_{(h-1)}(x_1, x_2, \ldots, x_n) \leq b_{(h-1)}$$

$$Z_{(h+1)}(x_1, x_2, \ldots, x_n) \leq b_{(h+1)}$$

.

.

.

.

$$Z_{(h)}(x_1, x_2, \ldots, x_n) \leq b_{(h)}$$

$$X \in F,$$
$$X \geq 0$$

where b_i is the constraint set for each restriction in the improvement of desired constraint. Numerous solutions were obtained in constraint method. Cluster analysis can be used for solution selection (Raju and Kumar 1999).

Risk

Agricultural risk may affect farmer's decision and causes technical inefficiency in production factors application (Torkamani 1996). Therefore, it is necessary to consider risk issue in introduction of decision making patterns. The idea of using variance as a measure of income risk has been used for a long time. In this study we used income variance to introduce a pattern that aims to provide a minimum risk objective. The income variance of the i^{th} crop with gross efficiency (R_i) was as follows (Francisco and Mubarik 2006):

$$V(I) = \sum\sum \sigma_{ij} X_i X_j \qquad i, j = 1,2, \ldots, n$$

where variance-covariance matrix of the i and X_i products is the i^{th} product activity. In the studied pattern, objective function was defined as the minimization of above equation. Using multi-objective programming approach, risk objective reduction was evaluated beside gross efficiency and water use reduction. Some economical and social considerations were not included in the restriction frame inside pattern. For example, if the aim was to increase the production of a special product based on strategic programming, then it might be affected by the optimal pattern derived from simple or routine program. Solutions suggested by conventional mathematical programming had firmness and rigidity. Therefore, efforts were made to increase solutions efficiency introduced by mathematical programming techniques. These include using Modelling to Generate Alternatives (MGA) method in which objective function has a small bias to optimal solution. MGA is performed through several forms but the most common technique is Hop-Skip-Jump (HSJ) which is the best model in the case of zero variable maximization in simple or routine optimal programming pattern (Willis and Willis 1993):

$$\max: X_i, \quad X_i = 0$$

$$Subject\ to: \quad C_i X_i \geq (1-j)Z^*$$

$$A_i X_i \leq b_j$$

$$X_i \geq 0$$

where Z^o is the optimal solution obtained from solving conventional programming model

Table 1. Sowing area and the efficiency of the current pattern in Eqlid

Crop	Sugar beet	Wheat	bean	Total	Gross efficiency (million Rials)
Sowing area	3.8	2.4	0.6	6.8	83.87
Sowing area contribution (%)	56	35	9	100	-
Gross efficiency contribution (%)	62.4	28.2	9.4	-	100

Table 2. Planting area and efficiency of the current, optimal, and semi-optimal patterns in Eqlid

Crop	Current pattern	Optimal pattern		Semi-optimal pattern	
		Planting area	Change compared to current pattern (%)	Planting area	Change compared to current pattern (%)
Sugar beet	3.8	0.2	-98	0.3	-92
Wheat	2.4	-	-	0.8	-67
Bean	0.6	6.6	1100	5.6	833
Gross efficiency (million Rials)	83.87	89.48	6.69	86.81	3.5

(simple), *j* is the negligible deviation from the optimal value of the objective function (conventional programming pattern), C_i is the objective function coefficient vector, X_i is the activities vector, *A* is the restriction coefficient matrix, and b_i is the resource vector. In this study, objective function is defined as the variance minimization or programming efficiency risk and two objectives including certain level of program efficiency and water use reduction within restriction frame along with other restrictions were considered. Programming efficiency and water use data were placed on the right side of inequality. Pattern restrictions included land restriction, water, labour, investment, crop rotation, risk, and constraint solution method restrictions (including constraint specified output level and certain amount of water). The amount of available water and also the amount of water needed for different months varied, thus water restriction was placed within nine restrictions. Groundwater resources were used for water supply. Labour was used with seven restrictions consideration. In order to improve land restriction, crop sowing calendar was prepared and was considered within five restrictions. In the case of capital restriction, planting variables coefficients (crops) were considered as equal to crop variable cost and available capital as equal to total variable cost of current pattern. Objective function was used on the left side of the specified limited output. In the case of water restriction, the above coefficients were considered as water consumption coefficient. Water technical coefficients and the amount of available water were obtained via questionnaire. For the values on the right side, two recent restrictions were illustrated in the analysis description. Required information was prepared through interviews and questionnaires from 90 selective growers in 2008 in Fasa. The sample was selected randomly. Data related to the price and yield of selected products including sugar beet, wheat, and bean were extracted from statistical calendars of Fars province.

RESULTS AND DISCUSSION

In the use of mathematical programming models, owing to the impracticability of providing a proper model for all individual units, a grower was appointed as representative of a group of growers. This effort should also be made according to the growers' similarity. Growers were selected from a region and cluster analysis showed that they could be placed in one group. Table 1 shows the current pattern of the growers. Selected growers had an average of 6.8 hectares land and only produced three crops including sugar beet, wheat, and bean. The contribution of sugar beet, wheat, and bean in sowing area was 56, 35, and 9%, respectively and for gross efficiency was 62.4, 28.2, and 9.4%, respectively.

Optimal pattern was developed using conventional or simple mathematical programming pattern. However, this pattern implies the highest risk (Torkamani 1996). As shown in Table 2, 0.6 hectares out of 6.8 hectares were devoted to bean cultivation which included more than 97% of the representative grower's sowing. Only 0.2 hectares were allocated to sugar beet sowing. Therefore, despite favourable contribution of sugar beet to gross efficiency, it could not be placed in optimal pattern (because of high water volume need). Based on the results obtained from the modil, water restriction especially in June and July resulted in such conditions. Therefore, to keep sugar beet inside pattern, water use efficiency of this crop should be increased. According to Table 2, in the

Table 3. Results of the variance minimization price risk and yield in Eqlid

					Objective function (10^4)		Variance changes (%)	
		Sugar beet	wheat	bean	Price variance	Yield variance	price	Yield
	Current income	0.42	1.73	4.64	6650	787	2895	-95.6
Objective income level (million Rials) in price variance minimizing patterns	85	0.37	1.39	5.04	7695	717	3366	-96
	86	0.33	1.08	5.39	8688	670	3814	-96.3
	87	0.29	0.77	5.74	9743	635	4289	-96.5
	88	0.25	0.46	6.08	10862	609	4793	-96.6
	Optimal pattern income	0.2	-	6.6	12639	571	5593	-96.7
	Current income	-	0.65	5.89	10231	416	4509	-97.7
Objective income level (million Rials) in price variance minimizing patterns	85	-	0.66	5.97	10512	427	4635	-97.6
	86	-	0.66	6.04	10758	438	4746	-97.6
	87	-	0.67	6.11	11009	448	4859	-97.5
	88	-	0.42	6.38	11920	460	5269	-97.4
	Optimal pattern income	0.2	-	6.6	12639	571	5593	-96.8

Table 4. Results of the gross efficiency variance reduction and water use in Eqlid

	Current pattern	Sugar beet	wheat	bean	Objective function (10^9)	Pattern number
					32561	1
Objective income (million Rials)	Current income	-	-	6.4	7123	2
	85	-	-	6.47	7316	3
	86	-	-	6.54	7489	4
	87	-	-	6.61	7664	5
	88	-	-	6.69	7842	6
	Optimal pattern income	0.2		6.6	8374	7
Objective water consumption (m^3)	Current consumption (67184 m^3)	-	-	6.4	7123	8
	6000 m^3	-	-	6.4	7123	9
	55000 m^3	-	-	6.4	7123	10
	50000 m^3	-	-	6.4	7123	11
	45000 m^3	-	-	6.4	7123	12
	Optimal water consumption (40578 m^3)	-	-	6.4	7123	13

terms of gross efficiency, only 6.7% difference was observed between optimal pattern and current pattern. Using optimal pattern, only less than 7% of the gross efficiency could be increased. In the case of water consumption reduction, too much difference was found between two models. Using optimal pattern led to 33% decrease in water consumption.

The aim of semi-optimal pattern was to maximize wheat planting based on gross efficiency increase to above 86.8 million Rials. In other words, semi-optimal pattern was allowed to have small deviation from maximum income which was equal to 86.8 million Rials. In order to support wheat market, semi-optimal pattern has got more superiority. Therefore, to increase practical capability using alternative technique, increase in wheat planting area was also considered. Using this pattern, gross efficiency decreased to 3% compared with current pattern and 0.8 hectare of planting area was allocated to wheat. In semi-optimal pattern, sugar beet planting was increased to 0.1 hectare compared with optimal pattern. Since in semi-optimal pattern, all crops had non-zero planting area, no other patterns were used. Owing to the importance of risk in pattern development, in the next section, production patterns were considered with minimum risk. In risk pattern, two risk resources including price (market) and yield were considered separately. Also according to multi-period programming approach and water use reduction goal, models which provide both water use reduction and gross efficiency risk (based on providing current income level) were also improved. For this purpose, water level was minimized within separate pattern contingent on a current income. Then, water consumption level was selected in the range of current consumption to minimize consumption pattern. This method is similar to objective function coefficient range determination in fuzzy pattern (Kumar *et al*. 2006). Tables 3 and 4 show the results of these patterns. In Table 3, results are divided into two separate sections; at the top of the table, the results of price variance minimization model and at the lower part, the results of minimum variance performance are presented. For each pattern, the variance variation compared with current pattern is brought in two last columns. In all patterns, compared with current pattern, price variance increased and yield variance decreased. However, price variance variation was higher than yield variance which indicates that the current pattern superiority is owing to its ability to deal with price variance especially for wheat in which guarantee of purchase removes market risk. In first group in which objective function is defined as yield variance reduction based on different income level, with increase in income level, price variance, and yield, wheat and sugar beet planting area was replaced by bean. Change in crop planting increased the distance from current pattern. Finally, in the last pattern of both groups, the optimal pattern of price variance minimization and yield become equal to optimal programming pattern. Only with the acceptance of high price risk, wheat can be removed from the pattern which confirms that the lack of risk in the market or price made wheat popular among growers. Sugar beet had similar situation compared to wheat but with decrease in planting area, income increased and income variance was lower than wheat. Reduction in sugar beet planting area compared with wheat is due to its favouring to income. In the case of low income fluctuation due to the guaranteed price, sugar beet had analogous situation to wheat but it had higher contribution to income in pattern. Wheat and sugar beet cultivation replacement by bean is due to higher income earning by increasing bean planting area. Another important point is that in patterns including the minimum price risk, with increase in objective income level and as a consequence increase in price risk, the minimum yield risk decreased. There is an exchange between two risk resources in different patterns (Table 3).

To evaluate the effects of price risk and yield on sowing pattern, patterns decreasing efficiency variance were introduced. Similar to patterns in Table 3, different income levels were selected and for each level, reducing efficiency risk pattern was introduced and also patterns with the minimum risk level were presented. In patterns introduced for water consumption reduction, in addition to water consumption reduction, the minimum efficiency supply equal to current level was also included. By comparing Tables 3 and 4, it can be concluded that there is a high similarity between risk efficiency reduction pattern and yield. All efficiency variance minimizing patterns included bean except pattern 7. Thus, comparing two tables indicated that current growers pattern is closer to risk price reduction pattern meaning that in the development of the pattern, growers paid more attention to price risk than yield. In other words, if there is more stability in bean market, it is expected that its superiority increases and in addition to marker risk decrease, income increase will be provided. Another advantageous of this model is water consumption decrease. In all water use reduction levels until optimal level, which derived from a linear programming pattern based on income level, only bean remained in the pattern.

CONCLUSION

Despite the advantageous of programmed patterns, they may not include outside crop effects. For example, sugar beet has a remarkable place in job creation after harvest in field until becoming as a final product by consumers which was not considered in pattern designing in the region. As it was discussed before, the most important restricting factor in the development of this crop and its priorities in the pattern is water scarcity. Wheat support in the market and price risk elimination is the main goal of its usage in the pattern. Therefore, crop support in the market, not only affects crop production pattern but also influences price and resource composition. Water use efficiency in sugar beet planting and sugar beet support in the market are the main factors influencing its market place. Other crops condition, their compatibility with resource structure, region production situation, and the effects of optimal pattern on market are the main terms which should be cared by the patterns presented via mathematical programming. Based on the above results, following items are recommended:

1. According to the sugar beet importance in job creation and higher usage of labour in field, price support and market risk reduction is more desirable.
2. Regarding the strategic importance of sugar beet, water use efficiency improvement is inevitable in order to prioritize sugar beet crop in growers pattern.
3. Owing to the lack of growers attention to yield risk, risk reduction activities may lead to the improvement of resource use.

REFERENCES

Bagheri M, Bakhshoodeh M. External cost of ground water over withdraw and determining affecting factor in Mamasani district. Journal of Agricultural Economics. 2010.

4(1): 79-99. (in Persian, abstract in English)

Bayat P. Determining optimal cropping pattern for integrated use of ground and flowing water: Case study of Borazjan basin (MSc. thesis). Shiraz University; 1999. (in Persian, abstract in English)

Burton RO, Gidley, JS, Baker BS, Red-Wilson, KJ. Nearly optimal programming solutions: Some conceptual issues and a farm management application. American Journal of Agricultural Economics. 1987; 69: 813-818

Chizari AH, Ghasemi A. Application of mathematical programming for agricultural optimal cropping pattern. 1999. 28: 61-76. (in Persian, abstract in English)

Doppler W, Salman AZ, Al-Karablieh EK, Wolf HP. The impact of water price strategies on the allocation of irrigation water: The case of the Jordan Valley. Agricultural Water Management. 2002; 55: 171-182.

Francisco SR, Mubarik A. Resource allocation trade-offs in Manila's peri-urban vegetable production systems: An application of multiple objective programming. Agric. Sys. 2006; 87: 147–168.

Iranian Ministry of Agriculture. Production Statistical Yearbook. 2008; http://dbagri.maj.ir/zrt/.

Keramatzadeh A, Chizari AH, Mousavi H. Water resource management using optimal allocation of water in the basin of Barzoo dam of Shirvan. The Iranian 5th Conference of Agricultural Economics. Sistan and Baloochestan University; 2005. (in Persian, abstract in English)

Kumar B. Trade-off Between Return and Risk in Farm Planning: MOTAD and Target MOTAD Approach. Indian Journal of Agricultural Economics. 1995; 50: 193-199.

Mohammadi H, Kafilzadeh F, Pishbin S, Torabi M, Ameri A. Financial analysis of investment projects and impacts of production risk on aquaculture products in Fars province. Journal of Insurance and Agriculture. 2006. 11: 69-106. (in Persian, abstract in English)

Mohammadian M, Chizari AH, Mortazavi, SA. Impact of rice price risk control under commodity exchange market on optimal cropping pattern: Case of Golestan province, Gonbad-Minoodasht district. Journal of Agricultural Economics and Development. 2005. 49: 168-194. (in Persian, abstract in English)

Naghshinefard M, Mohammadi H, Ghaderi Kh, Yaali M, Ejraei A, Pishbin S. application of risk programming models in determining optimal cropping pattern of horticultural and agronomy crops in Fars province. Journal of Insurance and Agriculture. 2006. 12: 109-128. (in Persian, abstract in English)

Raju KS, Kumar DN. Multicriterion decision making in irrigation planning. Agricultural System. 1999; 62: 117–129.

Suresh KR, Mujumdar PP. A fuzzy risk approach for performance evaluation of an irrigation reservoir system. Agricultural Water Management. 2004; 69: 159-177.

Torkamani J, Kalaei A. impact of risk on agricultural farmers' optimal pattern: comparison of MOTAD and Target MOTAD risk programming approaches. Journal of Agricultural Economics and Development. 1999. 25: 7-28. (in Persian, abstract in English)

Torkamani J, Sedaghat R. Determining optimal plan of integrated horticultural and agronomy activities: Application of modeling to generate alternatives. Journal of Agricultural Economics and Development. 1999. 28: 7-34. (in Persian, abstract in English).

Torkamani J. Using mathematical risk programming in farmers' efficiency analysis. Journal of Iranian Agricultural Sciences. 1996. 27(4): 95-104. (in Persian, abstract in English)

Willis C, Willis MS. Multiple criteria and nearly optimal solutions in greenhouse management. Agricultural System. 1993; 41: 289-303.