International Journal of Agricultural Management and Development
Available online on: www.ijamad.iaurasht.ac.ir
ISSN: 2159-5852 (Print)
ISSN:2159-5860 (Online)
Research Paper

Efficient Harvesting of Saffron Using Integer Programming

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Received: 01 May 2018,
Accepted: 19 July 2019

Abstract

Among various products available in agriculture, saffron plays a major role in contributing to Iran's gross domestic product and per capita income growth. Due to shortage of workforce and short duration of harvesting, areas under cultivation of saffron in Iran will be declining in coming years. Thus, proper planning for optimum use of workforce is one of the most important techniques to access efficient harvesting. In this regard, an integer programming model is proposed to solve the problem in this paper. Number of working shift and working hours in each shift are among decision variables in the proposed model, which satisfy the objective function, i.e. minimizing the total cost of workforce, with constrains including number of working hours in each shift, speed of workforce, number of fields that should be harvested in each day and relationship between working hours of each worker and the cost allocated. To evaluate the proposed model, we employ the data collected from fields located in different areas of Qaen, South Khorasan province, Iran. By comparing the output of the proposed model to the real situation, the ability of the model is confirmed. Finally, concluding remarks and suggestions for future research are provided.

Keywords:
Integer programming; saffron harvest; workforce planning

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INTRODUCTION

By having about 15 to 20 percent of GDP, the agricultural sector in Iran is one of the largest sectors in industry. Among various products available in this sector, saffron is widely cultivated in water-scarce regions of Iran (Gohari et al., 2013; Maggi et al., 2009). Saffron is an Iranian native product with a history dating back to 700 years ago. The area under cultivation for this product in Iran is more than 60 thousand hectares with cultivation at least in eight provinces (Figure 1). By holding 95 percent of the area under cultivation, provinces of Khorasan Razavi and South Khorasan are the main areas for saffron cultivation; provinces of Fars and Kerman are also working in this field. More than 130 thousand families in Iran earn a living through saffron cultivation. Saffron cultivation does not require huge financial resources and/or specific expertise and has the potential to generate revenue, employment, and other welfare and social amenities (Melfou et al., 2015). Planting, growing, and harvesting saffron and its by-products can generate revenue and employment (Jalali-Heravi et al., 2009). Saffron is among the herbs, which can grow favorably in water-scarce lands. Moreover, as saffron has a high value added, it can contribute to economy growth in each country (Melfou et al., 2015).

By producing more than 250 tons of saffron in 2009, Iran has about 90 to 95 percent of global production of this product, which has made Iran the world's largest saffron producer (Melfou et al., 2015).

Saffron cultivation processes in Iran can be generally divided into three basic stages. The first stage is dedicated to planting saffron bulbs. For this purpose, lands are plowed and weeded in spring and early autumn, and saffron bulbs are planted. The second stage includes the growing process. At this stage, in early October, manure is added to the soil and a surface plow is performed. Irrigation and weeding are the requirements of this step. The third stage is related to harvesting saffron flowers. One year after planting saffron bulbs, saffron flowers are ready to harvest. The saffron blossoming period is usually in early November. Within 10 to 15 days, each saffron bulb gives an average of six flowers (Mirza in Rajabi et al., 2015). However, despite all its advantages, saffron cultivation

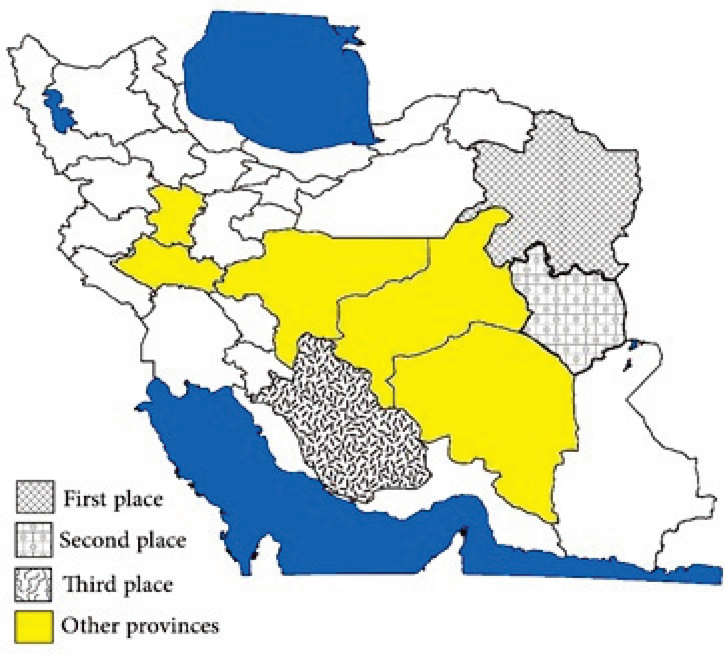

Figure 1. The location of Saffron planting in Iran

has its own agricultural issues. One of the main characteristics of this product is its short harvesting period. If a saffron flower is exposed to hot weather, wind, and sun for a long time, it loses its flavor and color, and its quality is reduced. Each type of saffron flower depending on bulb type, soil characteristics, and climatic conditions must be harvested within a maximum of two days; otherwise, the quality of the harvested saffron including color, taste and scent is reduced drastically. The best time to harvest saffron flowers is early in the morning before the sunrise. A high-quality saffron flower can remain unharvested for a maximum of 2 days. Saffron flowers ready for harvest should be gathered in the absence of sun radiation (Carmona et al., 2007).

Saffron harvest in Iran is done manually. Farmers usually either employ the existing workforce around them in shifts or rely on neighboring cities and provinces to employ workforce. In such circumstances, due to lack of information on available workers, harvest completion time of each land, and number of workers needed to harvest each land, harvesting is usually more prolonged than usual. This, in addition to reducing crop quality, causes to increase harvest costs for farmers. Saffron cultivation under such circumstances is not cost-effective, even for farmers who do not have large farms. Therefore, the need to plan for workforce employment is one of the requirements of saffron cultivation in Iran. If such a plan is developed for workforce employment, it will enable farmers to maximize saffron yields and quality during the flowering period. One of the methods for efficient use of labor is to offer mathematical programming. For this purpose, in this paper, the optimal allocation of workforce to agricultural lands is provided. This, in addition to solving the problems mentioned above, provides sufficient requirements to contribute to the growth of this sector in Iran.

Numerous studies have been conducted in the field of optimum allocation of workforce. Hytonen et al. (2008) carried out a study with the aim of developing a model for optimal allocation of a flexible workforce policy, where a team of workers assemble variable products on a short line. They conducted the study in a factory with diverse products and many workers in the assembly production line using discrete event simulation methods. In a study, Valls et al. (2009) examined the problem of planning skilled workforce in service organizations. The proposed model was used to obtain a feasible action plan, which satisfies maximum established dates and timetable constraints and also efficient assignment of workloads to workers. In their study, a genetic algorithm was presented to solve the workforce planning problem in real projects. Castillo et al. (2009) offered a model for workforce planning in a call center of a large manufacturing company in North America. The proposed model simultaneously reduced the cost and increased the service provision. The main aim of the model was to conduct a comprehensive workforce framework that can consider and analyze the relationship between cost and quality.

Li et al. (2012) used the hybrid goal programming and the meta-heuristic search approach to solve complex problems of workforce planning. Their study with multiple objectives, i.e. scheduling for weekends, avoiding any stand-alone shift, considering at least two consecutive holidays at a time, and planning for consecutive days, had two kinds of constraints including hard and soft constraints. While hard constraints must be satisfied under any circumstances, soft constraints are desirable. Othman et al. (2012) offered a multi-objective nonlinear programing model to minimize hiring, training, overtime costs, and layoffs of workers with high efficiency. To this end, some human aspects such as skill, training and workforce personality and motivation were considered. The proposed model was implemented in an industrial plant. Goel and Meisel (2013) offered a model for workforce planning to maintain the electricity network. By considering physical disconnection and reconnection of the power line from the network, their research objective was to allocate multiple tasks to workforce so that the network downtime and commuting of workers are minimized. In a study, Nah and Kim (2013) used mathematical programming to schedule workforce in a call center of a hospital, where there are multiple tasks for operators. The objective of their study was to reduce the total cost including operator labor costs, caller waiting cost and abandonment costs for lost calls.

Özgüven and Sungur (2013) offered five mathematical models using integer programming to solve problems of workforce hierarchical programming, including excessive days off and idle time of workers. In their study, a higher qualified worker can replace with a lower qualified one, worker requirements may vary, and each worker must have some off-days a week. Using mathematical modeling, Jennings and Shah (2014) offered a programing model that can be a strategic workforce planning for a large-scale technology installation scheme such as water and electricity. The objective of the model was to minimize total cost considering workforce costs, costs of maintaining and servicing technologies and customer costs related to technology. In a study, Silva et al. (2015) offered heuristic integer programming for maximum use of operating room capacity. In their study, a specialized workforce with unique skills and various working shifts was assigned to different surgeries. Jafari and Salmasi (2015) designed and implemented a mathematical model by taking into account several important factors including hospital policy, workforce laws, government regulations, and nurses' status. In their study, metaheuristic algorithms were used to schedule work shifts of nurses. Dewi and Septiana (2015) conducted a study to schedule workforce considering the workload of workers in a manufacturing industry. They used goal programming for this purpose. The results showed that the use of a two-shift system of working instead of three shifts could increase worker productivity and minimize factors that reduce productivity.

Kheybari and Salehpour (2015) conducted a study to optimize the irrigation schedule of paddy fields using mathematical programming. In their study, two mathematical models were presented to reduce the time period of plowing and transplanting operations as well as to determine optimal times of opening and closing valves. The results indicated that the planning done had a considerable impact on reducing water consumption. Jafari et al. (2016) considered the scheduling problem of nurses at the largest hospital of Iran. The aim of the study was to maximize nurses' preferences about shifts and minimize the surplus of nurses. For this purpose, they offered a fuzzy multi-objective mathematical programming model, and to determine the weight of each of the objectives, they used the analytic hierarchy process. Wahyudin et al. (2016) offered an integer linear programming optimization model with the purpose of better allocation of resources and workforce related to aircraft line maintenance. These resources included workforce and tools, and the relationship between stations was given due to analysis of the possibility of resource transferring amongst them.

According to the survey carried out, it can be concluded that the agricultural sector, despite its importance in development of economy, employment, and GDP, is an issue that has not been given enough attention. Since saffron harvest in Iran is done manually, due to limited workforce, the problem of optimum allocation of workforce to lands under cultivation is among the requirements for cultivation of this plant. The problem of workforce allocation is a complex optimization problem with a variety of limitations and variables, solving which requires using powerful optimization techniques. Integer programming is among the methods applicable for such problems. In this context, the present study attempted to use integer programming so that, while offering a planning for the efficient allocation of workforce to agricultural lands, it could provide the context to increase the area under saffron cultivation in the coming years. Accordingly, the present study attempted to provide an appropriate model so that, while solving the mentioned problem, it could pave the ground for future activities in this field.

Other parts of this study are organized as follows. In Section 2, some assumptions are presented to develop the mathematical model. In Section 3, an integer programming model is provided to solve the problem of workforce allocation to saffron fields. In Section 4, the mathematical model is applied in a real case and numerical analysis of the model is presented. Finally, conclusions and recommendations as well as potential future studies are summed up in Section 5.

Problem formulation

The conditions for harvesting in saffron fields in Qaen City were investigated to offer the model. Qaen City is located in the north of South Khorasan Province. This city is known as the heart of Iranian saffron due to having wide areas under saffron cultivation for several years. After conducting some field studies in a number of fields of this city, the following assumptions are considered to formulate the question of how to allocate workforce:

Assumption

1. The effective harvest time is six hours per day.

2. Each day is divided into two intervals of three hours for harvesting.

3. Workers need an hour to rest and move between the first and second three hours.

4. The power of each worker at the beginning of each working day is considered the same as the day before.

5. For each hour of idleness between the first and second three hours, some part of the lost energy is recovered.

6. For each hour of rest and idleness, the total energy loss for an hour of working is recovered.

7. The harvesting power of each worker during each hour is assumed to be constant.

8. Each worker works nonstop during each harvesting interval.

9. During the planning period, the number of workers is assumed fix.

10. Workers can be only transferred from one place to another between the two intervals.

11. Due to easier management, farmers tend to use the maximum power of workers who are working. Therefore, if workers cannot cope with the harvesting workload of lands under cultivation, farmers hire more workers.

12. All saffron flowers in each area have specific characteristics and can be harvested at a specified time.

13. Workers in the area are divided into two different categories in terms of harvesting power and cost.

The mathematical model

Sets, parameters, and decision variables used in the model are shown in Table 1. In the model below, the purpose is to allocate workers to saffron lands ready to harvest at different hours of a day so that, in addition to considering steps listed in the previous section, the cost paid by farmers to workers is minimized and the least number of workers is used with the highest workforce productivity.

Two types of costs are considered for the worker *i* on the land *f*. If total hours of working in two shifts for the worker *i* on the land *f* is less than three hours, the cost C_{if} is paid by the farmer *f* : otherwise, the cost C^{-}_{if} is paid. According to the explanation, if the land *f* requires the worker *i* for more than three hours, and if the worker *i* continues their activity on the land in the second shift, the harvesting cost will be far less than when there is a workforce shift.

Table 1
The Symbols Used in the Model

Symbol	Explaining the corresponding symbol
i	Index for each worker ($i = 1, ..., N$)
f	Index for agricultural lands under cultivation ($f = 1, ..., F$)
m	Index for the number of working hours per person workforce in the first working shift ($m = 0, ..., 3$)
n	Index for the number of working hours per person workforce in the second working shift ($n = 0, ..., 3$)
P_{mi}	The amount of harvesting that the *i*-th worker will have in m hours
W_i^{mn}	The amount of harvesting that the *i*-th worker will have in n hours of the second shift on the condition that they harvest m hours in the first round
V_f	Area of the land *f*
M	Large positive number
C_{if}	The worker *i* costs for one hour of working less than three hours
$\bar{C}_{if}$	The worker *i* costs for more than three hours
X_{if}^m	The binary decision variable so that if the worker *i* works on the land *f* for *m* hours (the first shift), its value is equal to one and otherwise zero
Y_{if}^n	The binary decision variable so that if the worker *i* works on the land *f* for *n* hours (the second shift), its value is equal to one and otherwise zero
g_{if}^{mn}	The binary decision variable so that if the worker *i* works on the land *f* in the second shift for *n* hours after w-orking in the first shift for *m* hours, its value is equal to one and otherwise zero
α_{if}	The binary decision variable so that if the worker *i* works on the land *f* for one shift, its value is equal to one and otherwise zero
β_{if}	The binary decision variable so that if the worker *i* works on the land *f* in the both shifts; its value is equal to one and otherwise zero

$$Min \sum_i \sum_f C_{if}\, \alpha_{if} + \sum_i \sum_f \bar{C}_{if}\, \beta_{if} \quad (1)$$

The objective function (1) refers to minimizing the total cost of workforce.

$$\sum_f \sum_m X_{if}^m \leq 1 \quad \forall\ i \quad (2)$$

$$\sum_f \sum_n Y_{if}^n \leq 1 \quad \forall\ i \quad (3)$$

Constraints 2 and 3 guarantee that each worker at each shift can work only on one farm, and in case of working on one land, at every shift, the worker can work for one, two, or three hours.

$$\sum_{n=1}^{3} Y_{if}^n \leq \left(1 - \sum_{m=1}^{2} X_{if}^m\right) \quad \forall\ i, f \quad (4)$$

If the worker *i* does not work on the land *f* for three hours, this means that either the harvest work is finished or the land owner is not satisfied with the work of the worker *i*. Thus, in the both cases, the worker will not be used in the second round. This condition is guaranteed by constraint 4.

$$\sum_f \sum_m \sum_n g_{if}^{mn} \leq 1 \quad \forall\ i \quad (5)$$

$$\sum_f g_{if}^{mn} = \left(\sum_f X_{if}^m\right)\left(\sum_f Y_{if}^n\right) \quad \forall\ i, n, m \quad (6)$$

$$Y_{if}^n \leq \sum_m g_{if}^{mn} \quad (7)$$

The speed of harvesting of a worker is dependent on working hours and rest time. Constraints 5, 6 and 7 refer to the relationship between these two factors and their impact.

$$V_f \leq \sum_i \sum_m P_{mi}\ X_{if}^m + \sum_i \sum_m \sum_n W_i^{mn}\, g_{if}^{mn} \quad \forall\ f \quad (8)$$

Constraint 8 points out that a certain level of saffron fields ready for harvest should be harvested by workers in each day.

$$\sum_m m\, X_{if}^m + \sum_n n\, Y_{if}^n \le 3\alpha_{if} + M\,\beta_{if} \quad \forall\ i,f \tag{9}$$

$$4\beta_{if} \le \sum_m m\, X_{if}^m + \sum_n n\, Y_{if}^n \le 6 \quad \forall\ i,f \tag{10}$$

$$\alpha_{if} + \beta_{if} \le 1 \quad \forall\ i,f \tag{11}$$

Constraints 9, 10 and 11 refer to the relationship between hours of activity of workers on each land and payment they receive. In other words, if a worker works half a day on one land (one shift or less), the cost allocated to the worker is more than that allocated to a worker who works all day on a land. Therefore, it is cost effective for a farmer to use the same worker on the same land for the second time.

$$X_{if}^m,\ Y_{if}^n,\ \alpha_{if},\ \beta_{if} \in \{0{,}1\} \tag{12}$$

Finally, Constraint 12 shows that the variables are integer. Among the used constraints, Constraint 6 is non-linear. Since solving the problem is much easier with linear constraints than with nonlinear ones, in this section, we attempted to convert constraint 6 as a linear one. Constraint 6 is obtained by multiplying two binary variables together. For linearization of such constraints, the following method is used.

Assume that z is the product of two binary variables ($z = x_1 . x_2$); here, z is one only when the both binary variables (x_1, x_2) have the value one; otherwise, the z value is zero. By utilizing the following auxiliary constraints, one can convert non-linear constraints in the model into linear constraints (Norouzi et al., 2012).

$$z \le x_1 \tag{13}$$

$$z \le x_2 \tag{14}$$

$$x_1 + x_2 \le 1 + z \tag{15}$$

Then, constraint 6 can be rewritten as follows:

$$\sum_f g_{if}^{mn} \le \sum_f X_{if}^m \quad \forall\ i,m,n \tag{16}$$

$$\sum_f g_{if}^{mn} \le \sum_f y_{if}^n \quad \forall\ i,m,n \tag{17}$$

$$\sum_f X_{if}^m + \sum_f Y_{if}^n \le 1 + \sum_f g_{if}^{mn} \tag{18}$$

It is noteworthy that the model structure is designed so that if working hours of workers in a region vary or they work more than two shifts, the model can be extended to the intended region only by changing the coefficients of a few constraints.

Numerical analysis of the model

Information on farms and workforce in Qaen City is used to assess abilities of the proposed model. Based on the investigations, one can divide workforce used on fields of this city into two types: Powerful and normal. To assess the ability of workers belonging to each of the two categories above at different harvesting times, more than 40 farmers were interviewed in Qaen City. During the interview with these farmers, first, they were asked to specify the most likely speed of harvesting during the first hour. After specifying the harvesting speed of each category of workers within an hour, their harvesting speed at other hours of the initial period was determined using the efficiency resulting from the farmers' views. Table 2 shows the harvesting speed of each group of workers at different hours and harvesting scenarios.

Information on several farms in different parts of Qaen City is used to evaluate the proposed model. Information on each of the examples is summarized in Table 3. It should be noted that the unit of harvesting in different conditions is Iranian toman. To solve the problem, the proposed model is implemented with the help of the ILOG OPL software (IBM Company) and solver CPLEX version 12.6. A computer with a core i5-2.30GHz CPU is used for this purpose.

Tables A to E in the appendix show the results of running the model separately for each sample. According to the results, the maximum cost to harvest fields is 1520 tomans in the sample 1, 3340 tomans in the sample 2, 4730 tomans in the sample 3, 9680 tomans in the sample 4, and 11970 tomans in the sample 5. By comparing the results of the model with the present circumstances, it is concluded that the proposed model is able to save harvesting costs significantly (Figure 2). As mentioned earlier, due to lack of proper planning, workforce is not usually used in an optimized way, as can be observed in the previous examples. The maximum harvesting time for the existing farms under real conditions is two days in the samples 1 and 2, three days in the sample 3 and four days in the samples 4 and 5. With the implementation of the mentioned model, acceptable reduction occurred in harvest time (Table 4). Therefore, with the help of this model, not only the costs of farmers are minimized, but also their lands are harvested in less time and in a planned way.

Table 2

Information on Each Type of Worker in Different Working Conditions

	Hours	First shift			Second shift		
		1	2	3	1	2	3
Powerful worker	Status	on	on	on	on	on	on
	Harvesting	0.074	0.067	0.06	0.063	0.048	0.043
	Status	on	on	off	on	on	on
	Harvesting	0.074	0.067	-	0.071	0.054	0.048
	Status	on	off	off	on	on	on
	Harvesting	0.074	-	-	0.074	0.067	0.06
	Status	off	off	off	on	on	on
	Harvesting	-	-	-	0.074	0.067	0.06
Normal worker	Status	on	on	on	on	on	on
	Harvesting	0.055	0.047	0.045	0.042	0.035	0.031
	Status	on	on	off	on	on	on
	Harvesting	0.055	0.047	-	0.05	0.038	0.034
	Status	on	off	off	on	on	on
	Harvesting	0.052	-	-	0.055	0.047	0.045
	Status	off	off	off	on	on	on
	Harvesting	-	-	-	0.055	0.047	0.045

Table 3
The Model Input

f	Sample 5			Sample 4			Sample 3			Sample 2			Sample 1						
	V_f	The number of normal workers	The number of powerful workers	V_f	The number of normal workers	The number of powerful workers	V_f	The number of normal workers	The number of powerful workers	V_f	The number of normal workers	The number of powerful workers	V_f	The number of normal workers	The number of powerful workers	The cost of three hours of working by normal worker	The cost of three hours of working by powerful workers	The cost of six hours of working by normal worker	The cost of six hours of working by powerful workers
1	0.5	12	10	0.5	46	9	2.5	50	25	2.5	45	30	1.5	56	37	40	50	60	80
2	1.2			1.5			2.5			3			2						
3	1			1			1			3.5			2.5						
4	2.2			3			3			2.5			1.5						
5	1.5			2.5			0.5			4.5			1						
6				2.5			1.5			0.5			2.5						
7				1			1			2			2						
8				0.5			0.5			2.2			1						
9				0.5			1			1.5			3						
10				1			2			2			1						
11							1			1.5			2						
12							0.5			2			0.5						
13							1.5			0.5			1						
14							1			1.5			3						
15							0.5			2			1						
16										3			5						
17										2			3						
18										1			2.5						
19										2			3.5						
20										1.5			2						
21													1.5						
22													2						
23													2						
24													1.5						
25													2						

Table 4

The Harvest Completion Time of Each Land

Land	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
	Model Output	Current conditions	Model Output	Current conditions	Model Output	Current conditions	Model Output	Current conditions	Model Output	Current conditions
1	1	1	1	1	1	2	1	1	1	2
2	1	1	1	1	1	2	1	1	1	2
3	1	1	1	2	1	1	1	1	1	1
4	1	2	1	1	1	1	1	1	1	3
5	1	1	1	1	1	3	1	1	1	3
6			1	1	1	2	1	2	1	2
7			1	2	1	1	1	4	1	2
8			1	1	1	3	1	2	1	3
9			1	1	1	1	2	2	1	1
10			1	2	1	1	2	2	1	3
11						1	2	3	1	2
12						3	2	2	1	3
13						1	2	2	1	3
14						1	2	4	1	1
15						2	2	3	1	4
16							2	4	2	1
17							2	3	2	1
18							2	3	2	1
19							2	3	2	1
20							2	3	2	4
21									2	2
22									2	2
23									2	4
24									2	3
25									2	4

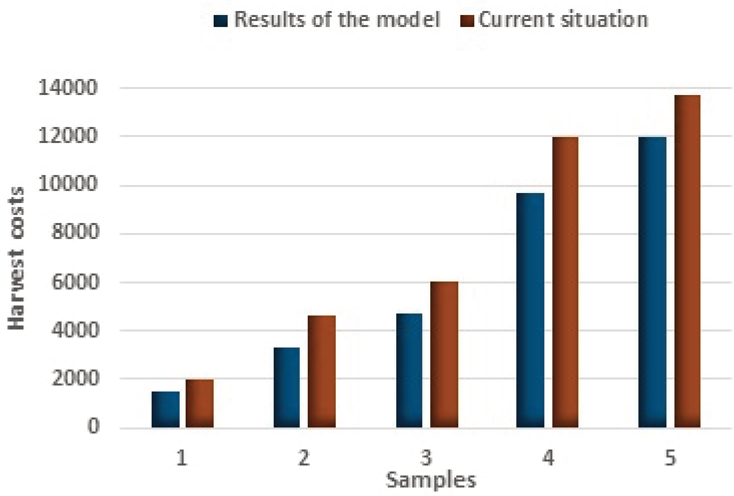

Figure 2. The cost of implementing each sample compared with the current situation

CONCLUSIONS AND RECOMMENDATIONS

In this paper, an integer programming model was proposed for workforce planning and reduction of the number of saffron-harvesting days. For this purpose, lands in South Khorasan, which are the most important areas for saffron cultivation in Iran, were studied and then some assumptions were considered for modeling. The objective of the suggested model was to reduce the harvesting cost. The decision variables were working of each worker during each shift or their continuous working, working hours of each worker during each three-hour shift and harvesting costs. Constraints of the model included amount of workforce available, minimum level of harvest, harvesting of each worker under different working conditions, and harvesting cost of each worker. The proposed model can offer a significant improvement in harvesting costs and time compared to the actual conditions. This planning can also increase the quality of harvested saffron as well as rounds of harvesting at different flowering times of saffron. By employing data gathered from Qaen City where saffron is mostly cultivated, the efficiency of the proposed model was evaluated. The results indicated the ability of the proposed planning. Based on the model suggested in this paper, a guideline is provided for public policy makers and farmers to both increase the amount of harvested saffron and provide the ground for cultivation of other similar products. Given that the proposed model examines input parameters in crisp terms, use of fuzzy logic to enhance the model accuracy and use of meta-heuristic methods to develop further planning assumptions for lands and workforce (due to the inability of the model presented for problems with large solution spaces) are suggested as future research in this field.

ACKNOWLEDGEMENTS

We would like to thank the anonymous reviewers for their constructive comments on the initial version of the paper.

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Appendix

Table A
The Output of the Sample 1

f	Total working hours of the first shift	Total working hours of the second shift	The number of normal workers in the first shift	The number of powerful workers in the first shift	The number of normal workers in the second shift	The number of powerful workers in the second shift	The number of fixed workers in both shifts of work	Total fixed workers working hours in both shifts	Harvesting costs	Harvesting costs in real terms
1	6	6	2	0	2	0	2	12	120	320
2	12	12	2	2	2	2	4	24	280	480
3	12	12	4	0	4	0	4	24	240	150
4	21	21	2	5	2	5	7	42	520	720
5	15	15	2	3	2	3	5	30	360	480

Table B
The Output of the Sample 2

f	Total working hours of the first shift	Total working hours of the second shift	The number of normal workers in the first shift	The number of powerful workers in the first shift	The number of normal workers in the second shift	The number of powerful workers in the second shift	The number of fixed workers in both shifts of work	Total fixed workers working hours in both shifts	Harvesting costs	Harvesting costs in real terms
1	6	6	2	0	2	0	2	12	120	200
2	18	18	6	0	6	0	6	36	360	600
3	12	6	4	0	1	1	2	12	240	440
4	33	33	9	2	9	2	11	66	700	720
5	30	30	10	0	10	0	10	60	600	720
6	30	27	9	1	8	1	9	54	600	720
7	12	12	4	0	4	0	4	24	240	360
8	6	6	2	0	2	0	2	12	120	200
9	6	6	2	0	2	0	2	12	120	200
10	9	8	0	3	0	3	3	17	240	440

Table C
The Output of the Sample 3

f	Total working hours of the first shift	Total working hours of the second shift	The number of normal workers in the first shift	The number of powerful workers in the first shift	The number of normal workers in the second shift	The number of powerful workers in the second shift	The number of fixed workers in both shifts of work	Total fixed workers working hours in both shifts	Harvesting costs	Harvesting costs in real terms
1	23	24	3	5	3	5	8	47	580	720
2	24	24	3	5	3	5	8	48	580	720
3	12	12	4	0	4	0	4	24	240	350
4	30	30	5	5	5	5	10	60	700	720
5	6	6	2	0	2	0	2	12	120	240
6	12	15	1	3	2	3	4	24	350	450
7	12	9	3	1	2	1	3	18	240	350
8	6	6	2	0	2	0	2	12	120	240
9	12	12	4	0	4	0	4	24	240	410
10	24	24	8	0	8	0	8	48	480	560
11	12	12	4	0	4	0	4	24	240	400
12	6	6	2	0	2	0	2	12	120	240
13	13	15	2	3	2	3	5	28	360	380
14	12	9	3	1	2	1	3	18	240	440
15	6	6	1	0	2	0	2	12	120	150

Table D
The Output of the Sample 4

f	Total working hours of the first shift	Total working hours of the second shift	The number of normal workers in the first shift	The number of powerful workers in the first shift	The number of normal workers in the second shift	The number of powerful workers in the second shift	The number of fixed workers in both shifts of work	Total fixed workers working hours in both shifts	Harvesting costs	Harvesting costs in real terms
1	24	24	3	5	3	5	8	48	580	750
2	30	30	5	5	5	5	10	60	700	720
3	33	33	4	7	4	7	11	66	800	1000
4	24	24	3	5	3	5	8	48	580	640
5	48	45	10	6	10	5	15	90	1050	1800
6	6	6	2	0	2	0	2	12	120	200
7	24	24	8	0	8	0	8	48	480	500
8	24	24	6	2	6	2	8	48	520	600
9	15	15	2	3	2	3	5	30	360	320
10	20	18	3	4	3	3	6	35	470	600
11	18	15	5	1	4	1	5	30	360	450
12	21	18	3	4	3	3	1	36	470	560
13	6	6	2	0	2	0	2	12	120	200
14	18	12	4	2	2	2	4	24	360	450
15	18	18	1	5	1	5	6	36	460	550
16	33	33	9	2	9	2	11	66	700	720
17	17	21	3	3	3	4	6	35	470	560
18	9	9	1	2	1	2	2	12	240	320
19	23	21	7	1	6	1	7	41	480	600
20	15	18	4	1	5	1	5	30	360	450

Table E
The Output of the Sample 5

f	Total working hours of the first shift	Total working hours of the second shift	The number of normal workers in the first shift	The number of powerful workers in the first shift	The number of normal workers in the second shift	The number of powerful workers in the second shift	The number of fixed workers in both shifts of work	Total fixed workers working hours in both shifts	Harvesting costs	Harvesting costs in real terms
1	18	18	6	0	6	0	6	36	360	400
2	23	21	6	2	6	1	7	41	490	600
3	24	24	3	5	3	5	8	48	580	720
4	15	15	2	3	2	3	5	30	360	250
5	12	12	4	0	4	0	4	24	240	250
6	24	24	3	5	3	5	8	48	580	720
7	24	17	5	3	5	1	6	35	480	600
8	11	9	2	2	1	2	3	17	260	250
9	29	30	5	5	5	5	10	59	700	720
10	12	9	3	1	2	1	3	18	240	250
11	18	18	1	5	1	5	6	36	460	600
12	6	6	2	0	2	0	2	12	120	200
13	9	12	2	1	3	1	3	18	240	250
14	30	33	7	3	7	4	10	60	710	720
15	10	9	2	2	2	1	3	16	250	250
16	51	54	11	6	11	7	18	104	1190	750
17	29	30	5	5	5	5	10	59	700	1440
18	30	29	10	0	10	0	10	59	600	720
19	36	36	7	5	7	5	12	72	820	800
20	21	18	3	4	3	3	6	36	470	500
21	15	12	1	4	1	3	4	24	350	480
22	18	18	1	5	1	5	6	36	460	500
23	21	21	4	3	4	3	7	42	480	700
24	18	15	5	1	4	1	5	30	360	480
25	20	18	3	4	3	3	6	35	470	600

How to cite this article:
Kheybari, S., Bokaeyan, A., & Naji Nasrabadi Yazd, S.A. (2020). Efficient harvesting of saffron using integer programming. *International Journal of Agricultural Management and Development, 10*(3), 307-321.
URL: http://ijamad.iaurasht.ac.ir/article_674761_d2246e347682292ffd9ea0000911c4b8.pdf