

# Economic analysis of saffron production

Naser Shahnoushi<sup>1</sup>, Leili Abolhassani<sup>1</sup>, Vida Kavakebi<sup>1</sup>, Michael Reed<sup>2</sup> and Sayed Saghaian<sup>2</sup>

<sup>1</sup>Department of Agricultural Economics, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Iran, <sup>2</sup>Department of Agricultural Economics, College of Agriculture, Food and Environment, University of Kentucky, Lexington, KY, United States

## Chapter Outline

<b>21.1 Introduction</b>	<b>337</b>	<b>21.7 Economic performance of saffron</b>	<b>346</b>
<b>21.2 World's main exporters of saffron</b>	<b>337</b>	21.7.1 Return on investment	346
<b>21.3 Price of saffron</b>	<b>338</b>	21.7.2 Ratio of return to cost	346
<b>21.4 Saffron production around the world</b>	<b>339</b>	<b>21.8 Efficiency</b>	<b>346</b>
21.4.1 Iran	340	21.8.1 Energy use efficiency	346
21.4.2 India	341	<b>21.9 Economic comparative advantage</b>	<b>349</b>
21.4.3 Greece	341	21.9.1 Revealed comparative advantage	349
21.4.4 Spain	342	21.9.2 Policy analysis matrix	349
21.4.5 Afghanistan	342	21.9.3 Nominal protection coefficient	352
21.4.6 Summary	343	21.9.4 Effective protection coefficient	352
<b>21.5 Production function in economics</b>	<b>343</b>	21.9.5 The domestic resource cost	352
21.5.1 Production function of saffron	344	21.9.6 Based on unit costs	353
<b>21.6 Economic productivity of saffron</b>	<b>344</b>	<b>21.10 Some economic advantages of saffron production</b>	<b>353</b>
21.6.1 Water productivity of saffron	345	<b>21.11 Conclusion</b>	<b>353</b>
21.6.2 Labor productivity of saffron	345	<b>References</b>	<b>354</b>
21.6.3 Land productivity of saffron	345		

## 21.1 Introduction

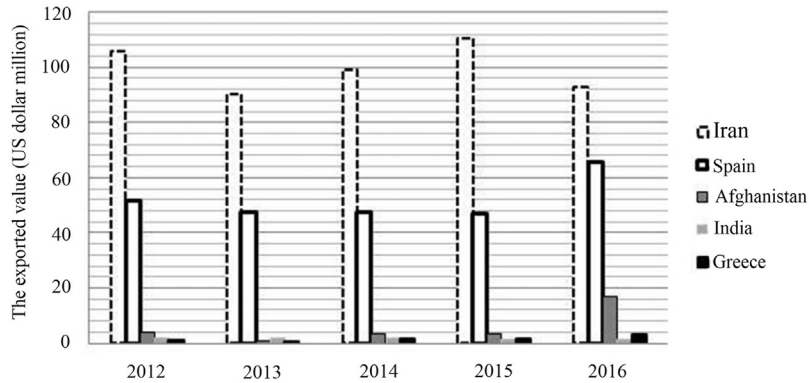
The purpose of this chapter is to examine and analyze the cultivation of saffron using simple economics to look at overall trends, followed by more technical analysis at the end. Most of the data provided for the analysis in this chapter are related to Iran. There are two reasons for this. One is that data and information related to other countries were not accessible for us. The second is that Iran, as we will see in the following section, is the major producer and exporter of saffron.

We start this chapter by identifying the major exporters and describing the way saffron is priced, then we discuss saffron production in Iran. We end the chapter by applying some technical tools to analyze the economics of the saffron production process.

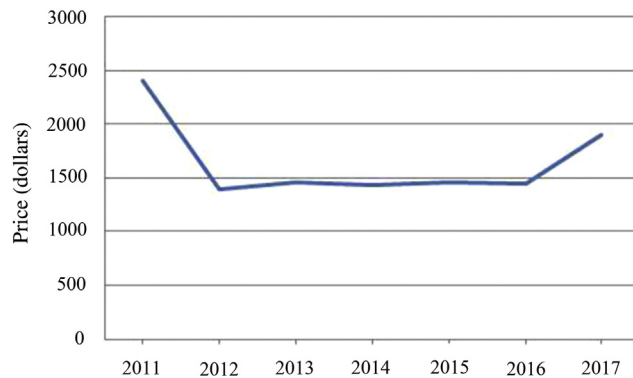
## 21.2 World's main exporters of saffron

For many decades, Iran, Spain, and Greece have been the world's major exporters of saffron. However, since 2000, the entry of other countries such as Afghanistan, China, the Netherlands, and Portugal into the world market has increased and influenced saffron export values. Fig. 21.1 presents the value of saffron exports from Iran, Spain, Greece, and Afghanistan during 2012 and 2016.

Between 2012 and 2016, Iran and Spain held the first and second positions in saffron exporting. In most years, Greece has held the third position. In 2016 Afghanistan moved ahead of Greece into third place.



**FIGURE 21.1** Exported values of the major exporting countries of saffron. Data from Trademap, 2017. Trade statistics for international business development. Available from: <<https://www.trademap.org/Index.aspx>>.



**FIGURE 21.2** Price per kg of Iranian saffron in the world market (2011–17). Data from Trademap, 2017. Trade statistics for international business development. Available from: <<https://www.trademap.org/Index.aspx>>.

Iran is the main source of saffron in the world with 111,000 ha of saffron farms and about 404 tons of production in 2018 (Donya-e-Eqtesad, 2019). About 60% of the cultivated area is located in the three provinces of Khorasan (UNIDO, 2016). However, due to the lack of a packaging industry, proper marketing, and production of edible products with saffron, much of Iran's saffron is sold to the world by other countries. The marketing process is that the saffron from Iran is sold to other countries, such as Spain, where it is appropriately packed and marketed to other countries at a high price.

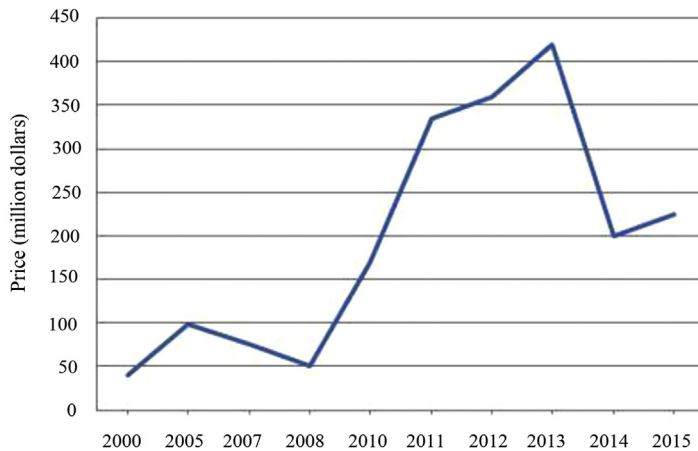
### 21.3 Price of saffron

The price of saffron varies markedly by year. Fig. 21.2 shows the world price of Iranian saffron between 2012 and 2017.

The highest price for saffron during the 2011–17 period was in 2011 at \$2400 kg<sup>-1</sup>. The lowest price was in 2012 at \$1400 kg<sup>-1</sup>. During 2013–16, the price of saffron remained relatively stable, but it jumped by \$500 kg<sup>-1</sup> in 2016. The sudden drop in the Iranian saffron price in 2012 was mainly due to an increase in saffron supply. Fig. 21.3 shows the value of Iranian saffron exports.

As can be seen, there was a dramatic increase in exports of saffron during 2008–12. Iran is the major producer of saffron, and while more than 90% of the world's saffron is produced there, a significant portion of saffron's value-add belongs to other countries due to Iran's poorly developed processing sector (Karbasi, 2006). If Iran prioritized saffron processing in its development plans and suitably packaged saffron, it would be able to increase its value-add by more than 16 times (Resistance Analysts, 2016).

Saffron price fluctuations not only influence producers, but also affect local economies where saffron is cultivated. According to a study conducted by Filipowski et al. (2017) in the Taliouine–Taznakht region of Morocco, increasing saffron price by 77% over the years 2007–09 allowed improvements in production technology, such as drip irrigation,



**FIGURE 21.3** Export price of Iranian saffron (2000–15). Data from Trademap, 2017. Trade statistics for international business development. Available at <<https://www.trademap.org/Index.aspx>>.

**TABLE 21.1** Saffron production in the world's main saffron-producing countries in 2016.

Country	Area (ha)	Production (tons)	Yield (kg ha <sup>-1</sup> )	Share in the world (%)
Iran	105,270	336	3.3	88.8
India	5707	22	3.9	5.8
Greece	1800	7.2	4	1.9
Afghanistan	2811	6	2.1	1.58
Morocco	200	2.6	3.2	0.68
Spain	165	2.3	14	0.6
Italy	500	1	2	0.26
China	500	1	2	0.26
Azerbaijan	35	0.23	6.6	0.06
Total	116,988	378.33	–	100

Source: Data from Iranian Ministry of Agriculture, 2017. Report of saffron. National plan of herbal medicine. Available from: <[http://si.torbath.ac.ir/resource/file\\_book/8.pdf](http://si.torbath.ac.ir/resource/file_book/8.pdf)>; UNIDO, 2016. Saffron industry value chain development. Available from: <<https://open.unido.org/projects/IR/projects/120595>>.

which led to increased productivity of saffron flowers. This study showed that a 100% increase in saffron price brings a 133% increase in wages of a typical female employed for the harvesting stage, and a 36% increase in wages for a male employed for the cultivation stage.

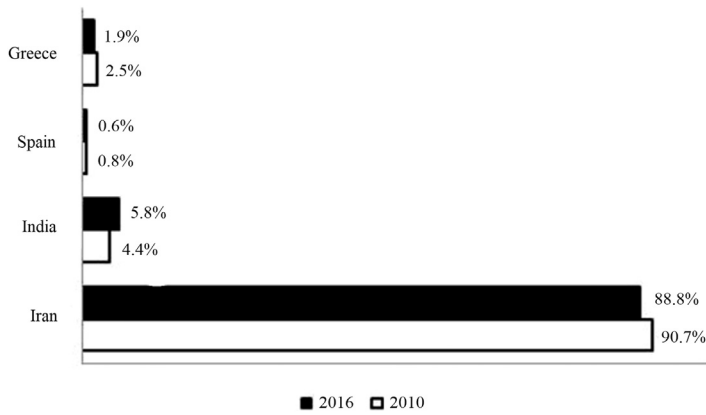
The price of saffron within the country, and most likely in the international market, is affected by its end use. Saffron used in food preparation and as a spice is more expensive than saffron used for medical purposes.

## 21.4 Saffron production around the world

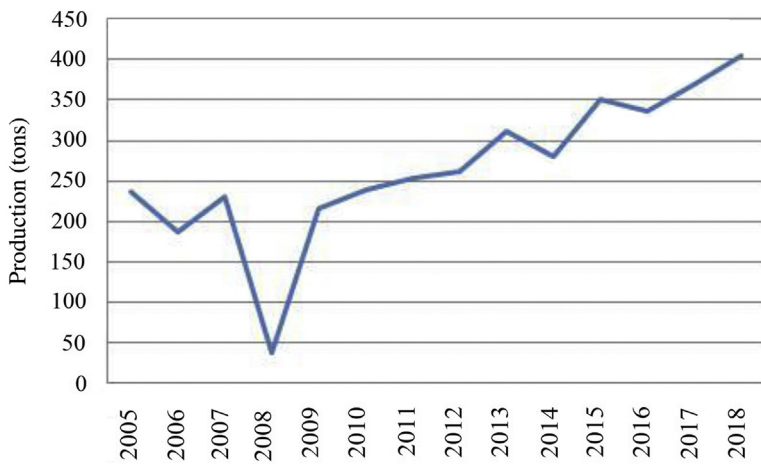
As saffron grows under specific climate conditions, very few countries produce it and data are not available for all producing countries. Table 21.1 shows the area, amount, and yield of saffron production in the world's main saffron-producing countries.

Iran, Greece, Spain, and India have traditionally been the major saffron-producing countries (UNIDO, 2016). Fig. 21.4 shows the share of each country in world saffron production.

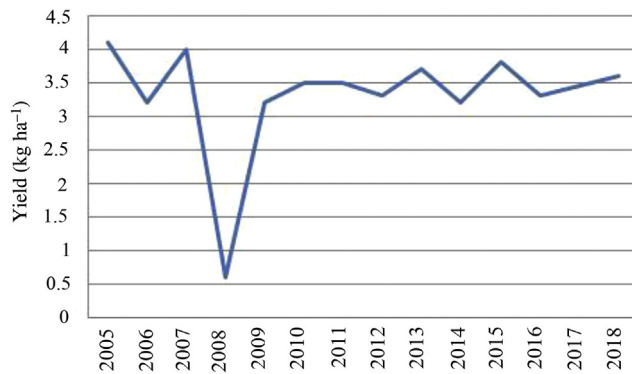
Market shares by country have dramatically changed during the years, in particular after 2010, due to the increased demand for saffron. For instance, Afghanistan, which only started producing saffron in the late 1990s, accounted for 1.6% of world saffron production in 2016.



**FIGURE 21.4** The share of Iran, India, Spain, and Greece in world saffron production. Data from UNIDO, 2016. Saffron industry value chain development. Available from: <<https://open.unido.org/projects/IR/projects/120595>>.



**FIGURE 21.5** The amount of saffron production in Iran during 2005–18. Data from Khorasan Razavi Agricultural directorate, 2019.



**FIGURE 21.6** Saffron yield in Iran during 2005–18. Data from Khorasan Razavi Agricultural directorate, 2019.

### 21.4.1 Iran

Saffron is a major agricultural product for Iran. Figs. 21.5–21.7 show the amount of production, yield, and land area during 2005–18.

The year 2008 was the worst year in recent memory for saffron production in Iran. In that year, saffron production fell to less than 50,000 kg. The average yield was only 0.6 kg ha<sup>-1</sup> (the lowest in 10 years). The highest yield was obtained in 2005 at 4.1 kg ha<sup>-1</sup>. Saffron yields since 2005 have averaged about 3.7 kg ha<sup>-1</sup>. The land area of saffron cultivation has been increasing by about 6% annually since 2008.

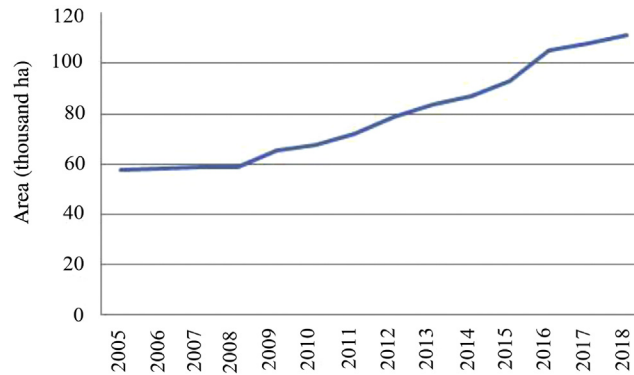


FIGURE 21.7 Saffron area in Iran during 2005–18. Data from Khorasan Razavi Agricultural directorate, 2019.

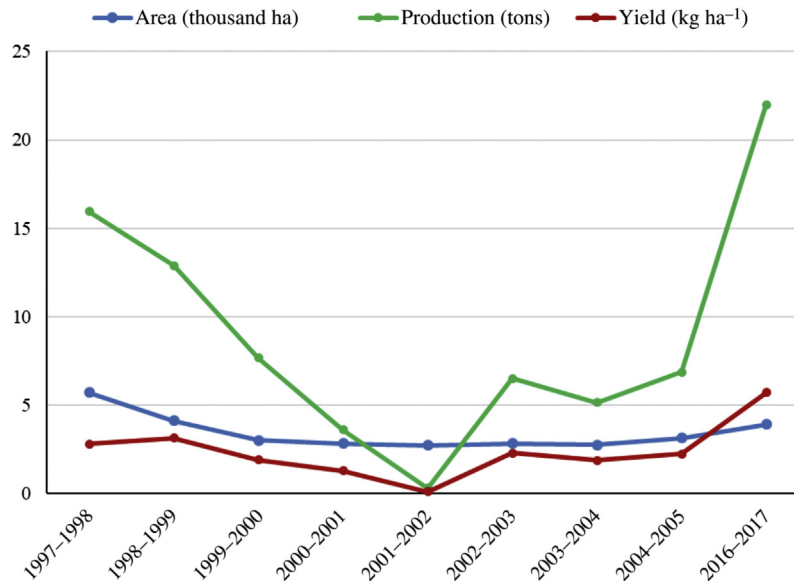


FIGURE 21.8 Cultivated area, amount of production, and yield of saffron in India during 1997–2017. Data from UNIDO, 2016. Saffron industry value chain development. Available from: <<https://open.unido.org/projects/IR/projects/120595>>.

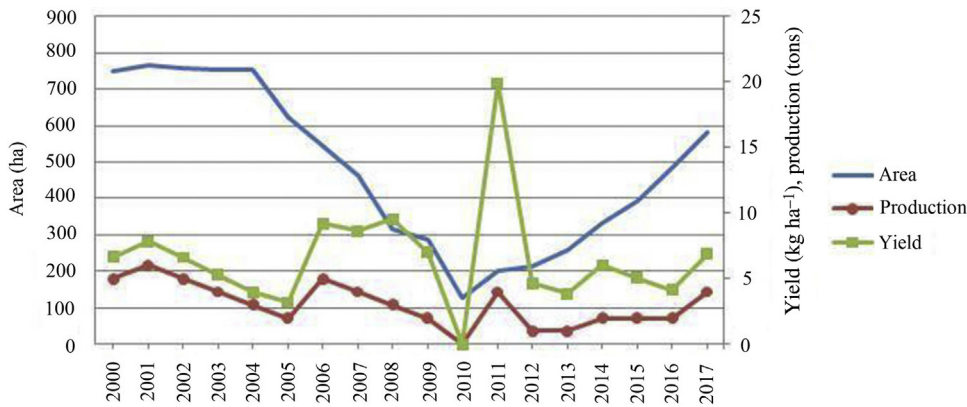
## 21.4.2 India

In India, most saffron is produced in the state of Jammu & Kashmir (Kafi and Showket, 2007). Fig. 21.8 shows cultivated area, production, and yield of saffron in India during the years 1997 and 2016. Reliable information for the years between 2005 and 2015 is lacking.

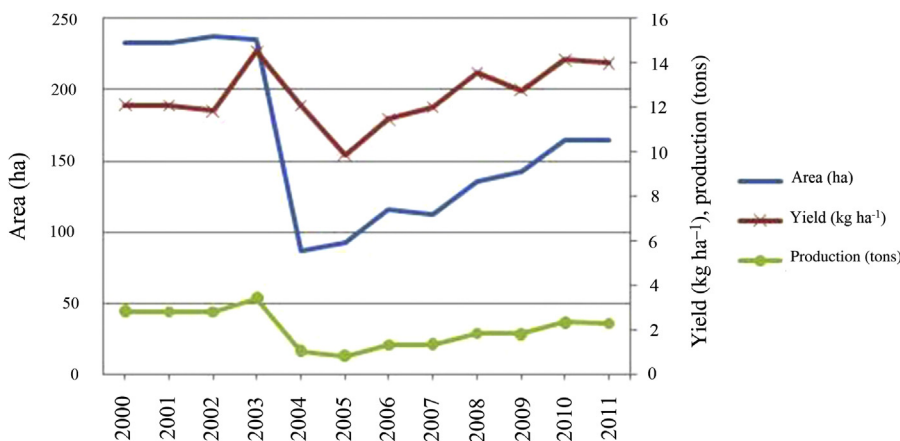
India produces 15–20 tons of saffron per year but has tended to increase its production due to economic improvements. In order to protect its domestic consumption, the country has set a 35% tariff on imported saffron. In spite of the country's intention to expand saffron farms, the cultivated area has only slightly increased from the 2010s—from 3143 ha in 2005 to 5707 ha in 2016. According to the evidence (UNIDO, 2016), Indian saffron is known as a low-quality product because of its high moisture content and dark color. Arab countries are the major exporters of saffron from India.

## 21.4.3 Greece

Greece, with more than 5 and 7 tons of saffron production, was the second- and third-leading producer in 2004 and 2016, respectively. The major region of saffron cultivation in Greece is Kozani. The amount of saffron production in Greece, however, has markedly fallen since 2006 due to the country's economic fluctuations and droughts. Fig. 21.9 presents cultivated area, production, and yield of saffron in Greece during the years of 2000–17.



**FIGURE 21.9** Cultivated area, amount of production, and yield of saffron in Greece during 2000–17. Data from the Ministry of Agriculture, Greece, 2019.



**FIGURE 21.10** Cultivated area, amount of production, and yield of saffron in Spain during 2000–11. Data from UNIDO, 2016. Saffron industry value chain development. Available from: <<https://open.unido.org/projects/IR/projects/120595>>.

After 5 years of significant reductions in Greece saffron production, the country has focused on expanding saffron cultivation. Some regions of Greece that abandoned saffron cultivation started to replant, and saffron cultivation increased by fourfold between 2010 and 2017.

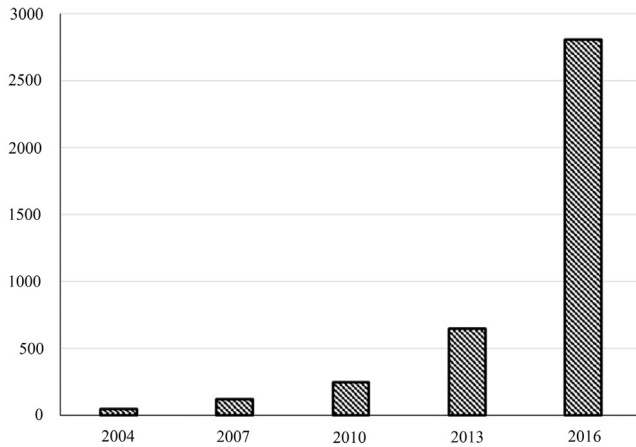
#### 21.4.4 Spain

By 1970, Spain, with 60 tons of saffron production, was the leading producer. Cultivation, harvesting, and processing of saffron are very labor-intensive. Since 1990, production cost increases, particularly for wages, has decreased cultivation of saffron dramatically (Katawazy, 2013; UNIDO, 2016). For instance, production dropped to 3.4 tons in 2003, while it was 21.8 tons in 1990. Fig. 21.10 shows cultivated area, production, and yield of saffron in Spain in the years 2000–16.

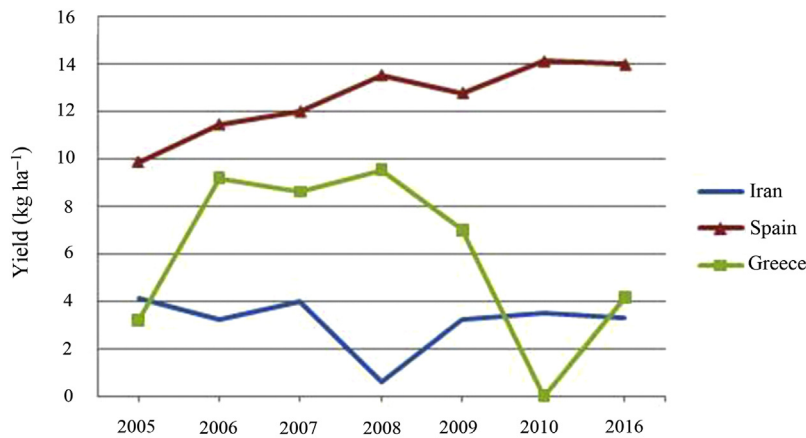
Since 2006, increases in the world price of saffron as well as the economic crises in Europe have encouraged farmers in Spain to cultivate saffron (UNIDO, 2016). In 2006, 116 ha of Spain lands were cultivated for saffron, while this area reached 165 ha in 2016. Spain, however, has the highest production yield in the world. In 2016, the average yields were 14 and 9 kg ha<sup>-1</sup> for irrigated lands and drylands, respectively. The saffron yield on irrigated lands is 19–20 kg ha<sup>-1</sup> (UNIDO, 2016).

#### 21.4.5 Afghanistan

In 1998, some Afghan NGOs in cooperation with local farmers started to produce saffron in the semiarid villages of Pashtun Zarghun district of Herat province. Saffron cultivation has expanded widely because of positive results. In 2002, the Ministry of Agriculture in Afghanistan began to distribute saffron corms to farmers in the provinces of Herat, Mazar-i Sharif, Baghlan, Kabul, Wardak, Bamyan, and Logar. Since 2003 the National Control Drug Strategy has been adopted, and saffron is expected to be an alternative cultivation to poppy (Wyeth and Malik, 2008; Mollafilabi et al., 2009).



**FIGURE 21.11** Areas cultivated (ha) by saffron in Afghanistan during 2004–16. Data from Katawazy, A.S., 2013. *A comprehensive study of Afghan saffron. The report of Afghanistan Investment Support Agency (AISA); Iranian Ministry of Agriculture, 2017. Report of saffron. National plan of herbal medicine.* Available from: <[http://si.torbath.ac.ir/resource/file\\_book/8.pdf](http://si.torbath.ac.ir/resource/file_book/8.pdf)>.



**FIGURE 21.12** Saffron yield production in Iran, Spain, and Greece during 2005–16. Data from UNIDO, 2016. *Saffron industry value chain development.* Available from: <<https://open.unido.org/projects/IR/projects/120595>>.

By 2011, more than 1300 farmers were growing saffron in these provinces (Katawazy, 2013; UNIDO, 2016). Fig. 21.11 shows the areas under saffron cultivation during the years 2004–16.

According to Katawazy (2013), there are 7000–10,000 ha in Afghanistan that are suitable for saffron production and these areas could produce 50,000–70,000 kg of saffron.

#### 21.4.6 Summary

In summary, Iran's share of saffron production has been decreasing since 2008. Newcomers with low wages, such as Afghanistan, have increased their share of production. Furthermore, even though production yield has been increasing for major saffron producers over the years, Spain has been often been the leader. Fig. 21.12 shows yields in Iran, Greece, and Spain. Saffron yield in Spain increased from 10 to 14 kg ha<sup>-1</sup> from 2005 to 2016, a 42% increase in growth. Greece is in second place with an average yield of about 6 kg/ha. Among the three countries, Iran has the lowest yield with an average of 3.13 kg ha<sup>-1</sup>. The large reduction in yield for 2008, as compared to that in the previous year, was due to frostbite weather in the two major saffron-producing provinces of South and Razavi Khorasan in 2007 (Iranian Ministry of Agriculture, 2017).

### 21.5 Production function in economics

The production function is the relationship between physical output of a production process and physical inputs or production factors. The main purpose of estimating a production function is to determine whether goods and services are produced in the most efficient and economical way. Indeed, the production function is the output obtained from the most combination of inputs.

The production function is practically applied by valuing the physical outputs and inputs using their prices. By comparing the economic value of the last unit of production with the cost incurred to produce it, we can determine if the use of more production inputs leads to more economic benefits. If the economic value obtained from the last unit of production is higher than the production cost, it is economically beneficial for the producer to use more units of the inputs. Alternatively, if the production cost of the last unit is higher than the benefits obtained from producing it, economic benefit is increased by reducing input use. Therefore, the most economic benefit is obtained at the point where the economic benefit of the last unit of production equals its production cost.

### 21.5.1 Production function of saffron

In saffron cultivation, the main production inputs are land, labor, irrigated water, manure, chemical fertilizer, saffron corm, agricultural machinery, and herbicide. Studies on the production function for saffron cultivation normally use a Cobb–Douglas production function:

$$Y_i = A X_{ij}^{\beta_j} + e_i \quad (21.1)$$

where  $Y_i$  is the yield of saffron for the  $i$ th farmer,  $X_{ij}$  is the  $j$ th input used by the  $i$ th farmer,  $\beta_j$  is coefficients for inputs estimated by the model, and  $e_i$  is the error term. To simplify the model estimation, it can be linearized as

$$\ln Y_i = \ln A + \beta_j \ln X_{ij} + e_i \quad (21.2)$$

The results of estimating a Cobb–Douglas function of saffron cultivation show that the economic importance of production inputs varies across various cultivation regions (Golkaran-Moghadam, 2014; Jalali et al., 2015, 2016; Khanali et al., 2016). In the Torbat-e-Heydarieh county, expansion of the farming area (Golkaran-Moghadam, 2014; Jalali et al., 2015, 2016), an increase in labor per hectare (Golkaran-Moghadam, 2014; Jalali et al., 2016), corm density (Golkaran-Moghadam, 2014), manure use (Golkaran-Moghadam, 2014), chemical fertilizer use (Golkaran-Moghadam, 2014), agricultural machinery use (Jalali et al., 2016), and water irrigation use (Jalali et al., 2016) increase economic benefits obtained from saffron cultivation, while an increase in herbicide use per hectare will decrease the economic benefit (Golkaran-Moghadam, 2014). In the two counties of Ghaen and Gonabad, four inputs—land, labor, chemical fertilizers, and irrigated water—increase economic benefits, but the use of more herbicides and manures are expected to decrease economic benefits (Golkaran-Moghadam, 2014; Khanali et al., 2016). Putting all these results together, while labor and irrigated water inputs had a significantly positive impact on the economic benefits obtained from saffron cultivation (Bakhtiari et al., 2015), herbicides had a negative impact in all three regions. The negative impact is due to the overuse of herbicides due to the lack knowledge about their use.

## 21.6 Economic productivity of saffron

Productivity is an economic tool used to compare some alternative economic activities in terms of their obtained benefits. Productivity is a measure of output per unit of input. Table 21.2 shows the inputs used for saffron cultivation in Torbat-e-Heydarieh, the major area for saffron production in Iran. Data in the table are based on a questionnaire

**TABLE 21.2** The amount of inputs used to produce 1 kg of saffron.

Inputs	Amount	Inputs	Amount
Nitrogen fertilizer (kg)	20.2	Gasoline (kg)	18.99
Phosphorus fertilizer (kg)	12.84	Electricity (kW h <sup>-1</sup> )	18.84
Potash fertilizer (kg)	14.07	work force (people)	21
Manure (tons)	4.76	Irrigation (h)	3.46
Micronutrient (L)	0.26	Machinery (h)	2.55
Herbicide (kg)	0.09	Corn (tons)	0.18

Source: Data from Nezamoleslami, A., 2018. The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions. Case Study: Torbat-e-Heydarieh Region (M.Sc. thesis). Ferdowsi University of Mashhad, Iran (in Persian).

completed by 57 farmers who cultivated saffron in 2017. Table 21.2 shows the average of each input used by the farmers to produce 1 kg of saffron.

The main inputs of saffron cultivation are water, land, and labor, so we analyze the productivity of these inputs in the rest of this chapter.

### 21.6.1 Water productivity of saffron

One of the most important factors in determining suitable agricultural systems for arid and semiarid regions (e.g., water-scarce countries) is water productivity or the value of production per a unit of water used. Many sources (Amirteymouri and Khaliliyan, 2008; Khavarinezhad, 2014; Shamsabadi et al., 2016) define water productivity as the ratio of product yield to the amount of water used in production. With this aim, studies on various agricultural products measured the amount of production per cubic meter of water used. For instance, 1 m<sup>3</sup> of water can generate 1 g of saffron, 1 kg of wheat, 6 kg of potatoes, and 6.5 kg of sugar beets (Koocheki et al., 2017), as reported by the Iranian Students News Agency (ISNA, 2017). According to Zwart and Bastiaanssen (2004), a cubic meter of water can be used to produce 0.99 kg of wheat, 1.9 kg of rice, 0.65 kg of cotton, and 1.80 kg of corn. While this information is helpful for farmers and policymakers to know the amount of water required for planting each product, from an economic viewpoint it is necessary to determine the monetary value of product per 1 m<sup>3</sup> of water used. This allows an economic comparison among different types of products.

It is instructive to compare the income generated per cubic meter of water in its various uses. Each cubic meter of water used for saffron production generates 9 times more income than wheat, 10 times more than sugar beet, 6 times more than potato and 2.5 times more than apple (Sadeghi, 2012). Another study (Tabatabaei and Shahidi, 2017) analyzed a scenario of eliminating cultivation of wheat, barley, and alfalfa, and replacing these crops with saffron. This study shows that reallocating water to saffron from barley increased net income by 5.8 times. This study also showed that removing wheat, barley, and alfalfa production and allocating the water consumed to saffron could increase the area under saffron cultivation by 6.8 ha (reaching 46.8 ha) based on traditional irrigation (e.g., 4500–5000 m<sup>3</sup> of water for a hectare of saffron). Drip irrigation would save 1000 m<sup>3</sup> of water per hectare. In a summary, the survey of existing studies and reports shows that low water requirements, high tolerance to drought/water shortage, soil fertility, and high levels of economic productivity of water in saffron cultivation make saffron a suitable product for arid and low water areas.

### 21.6.2 Labor productivity of saffron

The economic productivity of labor is the amount of income generated by a unit of labor. Labor productivity shows how much a laborer produces in output value. Although saffron production is very labor-intensive, especially the planting and harvesting stages, the high level of income produced from this crop yields high labor productivity in comparison with other crops. Labor productivity for saffron is 2.4 times more than wheat, 3.6 times more than barley, 4.6 times more than cotton, and almost 10 times more than a vine crop (Monazam-Esmaeilpour and Kordovani, 2010). As a result, the production of this product (in comparison with other agricultural products) creates high income for employees in this sector. The high income generated by saffron can have even more positive effects on the status of poor workers. Increased wages are expected to positively affect school enrollment and birth rates (Becker, 1992). Nevertheless, saffron is not economically suitable for regions with high labor wages. For instance, in New Zealand high labor costs limit saffron production even though its yield is high (up to 24.3 kg ha<sup>-1</sup>; more than three times the yield of traditional producing countries) (McGimpsey et al., 1997).

### 21.6.3 Land productivity of saffron

Saffron cultivation is also high in terms of land productivity. Saffron yields differ by country due to climatic conditions and cultivation methods. But studies show that the value-added generated by saffron cultivation is several times higher than wheat, beets, and other crops (Kouzegaran et al., 2013; Tabatabaei and Shahidi, 2017). The results of the study by Monazam-Esmaeilpour and Kordovani (2010) show that the net income of 1 ha of saffron is 16 times more than wheat, 24 times more than barley, 19 times more than cotton, 31 times more than wheat, 7 times more than grapes, and 45 times more than pistachio.

## 21.7 Economic performance of saffron

We use some economic indicators to analyze the economic performance of saffron production.

### 21.7.1 Return on investment

Return on investment (ROI), sometimes known as rate of return, is the percentage change in the value of an investment over a certain period of time. The following formula is used to measure it:

$$\text{ROI} = \frac{V_f - V_i}{V_i} * 100 \quad (21.3)$$

where  $V_f$  is the value of the investment at the end period of time and  $V_i$  is the initial value of investment. The average ROI for saffron cultivated in Torbat-e-Heydarieh, the major saffron region in Iran, is about 500%. In other words, a saffron field, which lasts 5–7 years, generates income that is five times more than its establishment costs.

### 21.7.2 Ratio of return to cost

The ratio of return to cost (RRC) is another economic indicator used to evaluate the efficiency of an economic activity and investment. This ratio is calculated using annual income from an investment divided by the cost of the investment. The result is either a ratio or percentage. In Torbat-e-Heydarieh, the average RRC for saffron production is 2.1, while the ratio is 1.2, 1.12, and 1.41 for wheat, barley, and alfalfa production, respectively. The RRC for sugar beets is estimated between 1.02 and 1.56, depending on the production scale (Gholami-Ghajlou et al., 2014). Saffron's RRC is about two times more than this ratio for the mentioned products (Salehi and Karimiyan, 2017).

## 21.8 Efficiency

In evaluating the ecological performance of a human activity, we may take various perspectives. One of the most common notions used is “efficiency,” which is the distance between what is actually performed and what can be ideally achieved (Sherman and Zhu, 2006). However, the challenging point on the concept of efficiency is that experts and researchers in different areas of research conceptualize “ideal achievement” differently. For an ecological scientist, the achievements are considered based on energy produced during a plant's growing period (Sherman and Zhu, 2006). However, the produced energy can be measured in different forms such as assimilation, known as assimilation efficiency (Jahan et al., 2012), and consumer production, known as production efficiency (Khavarinezhad, 2014). From an economic perspective, “ideal achievement” is generally defined by the economic benefits obtained from the production process (Sherman and Zhu, 2006). Nevertheless, the economic benefit can be analyzed from different perspectives such as input combination (Sherman and Zhu, 2006) or production scale (Sherman and Zhu, 2006). From a social point of view, “ideal achievement” is usually in terms of resource distribution. Indeed, maximum efficiency in a society is achieved when making one person better off requires someone else to be worse off (Barr, 2004). Nevertheless, the value associated with efficiency, in any of its forms, is between 0 and 1.

In many studies of ecological performance (Abdshahi et al., 2013; Taki et al., 2011), energy efficiency is used to assess how energy moves in the production process. The following sections describe energy efficiency in saffron producing.

### 21.8.1 Energy use efficiency

Energy efficiency is how energy is consumed as the product moves from raw material to final product during the production process. Indeed, energy efficiency is energy delivered by the product compared to the energy consumed to produce it.

The following formula measures energy efficiency:

$$\text{Energy use efficiency} = \frac{\text{Energy in the output (MJ ha}^{-1}\text{)}}{\text{Total energy in the inputs (MJ ha}^{-1}\text{)}} \quad (21.4)$$

To calculate energy use efficiency, four stages are followed:

Stage 1: Specify the inputs used for the production cycle (which lasts 5–7 years for saffron) per hectare. For conventionally produced saffron, the main production inputs are fossil fuels used for machinery, fuels used to generate electricity, different types of fertilizers (such as farmyard manure), other chemicals such as herbicides and pesticides, human labor, irrigation water, and corms (Bakhtiari et al., 2015; Khanali et al., 2016; Khoramdel et al., 2016; Yaghoubi et al., 2015).

Stage 2: Convert the physical quantities of the inputs used during the production cycle per hectare into energy values. To quantify the energy values, most studies (Bakhtiari et al., 2015; Elhami et al., 2016; Ghorbani-Birgani and Dibaei, 2010; Heidari-Soltanabadi, 2014; Khanali et al., 2016) use energy coefficients drawn from the literature. For each input an energy coefficient indicates the energy used to produce one unit of the input from the beginning of the production process to the end user (Mousavi-Avval et al., 2011a,b). One has to consider the technique used to produce the inputs applied in the production process (Mousavi-Avval et al., 2011a,b). Table 21.3 presents energy coefficients for the main inputs required for saffron production under conventional methods.

Stage 3: Specify the production outputs. In this context, various levels of outputs are distinguished. However, since the efficiency term refers to the human benefits gained, studies (Karunarathna and Wilson, 2017; Maia et al., 2016) only consider parts of the plant that benefit humans as “economic output.” In saffron, the economic output is stigma and corms, with leaves and flowers as byproducts (Bakhtiari et al., 2015).

Stage 4: Convert the physical quantities of the outputs produced over the production cycle per hectare into energy values. Studies have used two techniques for the quantification of output energy. Similar to the input energy quantification, some studies (Khanali et al., 2016; Mehrabadi-Basharabadi and Pourmoghadam, 2012; Mirhosein et al., 2005; Mousavi-Avval et al., 2011a,b) use energy coefficients calculated by other studies (FAO, 2000). Other studies (Bakhtiari et al., 2015; Ghaderpour and Rafiei, 2016; Ziyaei et al., 2013) use laboratory methods to calculate energy output of agricultural products.

The efficiency is the ratio between the caloric useful products and the total energy used to produce inputs (Esmaeili-Dastjerdipour and Mehrabi-Basharabadi, 2011). This clarifies whether the production process is a net producer or consumer of energy (Khanali et al., 2016).

**TABLE 21.3** Energy coefficients of different inputs and outputs used in agricultural production.

Inputs	Units	Energy coefficients (MJ unit <sup>-1</sup> )	Reference
1. Human labor	h	1.96	Beheshti-Tabar et al. (2010), Mohammadi et al. (2008)
2. Machinery	h	62.7	Mobtaker et al. (2010), Nabavi-Pelesarai et al. (2014)
3. Diesel fuel	L	56.31	Mobtaker et al. (2010)
4. Electricity	kWh	11.93	Mobtaker et al. (2010), Mohammadi et al. (2014)
5. Chemical fertilizers	kg		
a. Nitrogen (N)		66.14	Esengun et al. (2007), Mousavi-Aval et al. (2011)
b. Phosphate (P <sub>2</sub> O <sub>5</sub> )		12.44	Esengun et al. (2007), Mousavi-Aval et al. (2011)
c. Potassium (K <sub>2</sub> O)		11.15	Esengun et al. (2007), Mousavi-Aval et al. (2011)
6. Water for irrigation	m <sup>3</sup>	0.63	Erdal et al. (2007)
7. Farmyard manure (FYM)	kg	0.3	Demircan et al. (2006)
8. Chemicals	kg		
a. Pesticides		199	Ozkan et al. (2004)
b. Herbicides		238	Helsel (1992)
c. Fungicide		92	Ozkan et al. (2004)

Source: Data from Bakhtiari, A.A., Hematian, A., Sharifi, A., 2015. Energy analyses and greenhouse gas emissions assessment for saffron production cycle. Environ. Sci. Pollut. Res. 22 (20), 16184–16201.

### 21.8.1.1 Energy use efficiency of saffron cultivation

All published studies on the energy efficiency of saffron cultivation have been conducted in Iran; we did not find studies conducted in other countries. Having reviewed these studies, the following points can be noted:

1. The first published study on the energy efficiency of saffron cultivation was conducted by [Jami-Al-Ahmadi et al. \(2010\)](#) for the Southern Khorasan province. In this study, energy efficiency was calculated at 0.006. The two other studies reported energy efficiency for saffron of 0.0026 for the provinces of Khorasan Razavi and Southern Khorasan ([Bakhtiari et al., 2015](#)) and 0.0044 for Southern Khorasan province ([Khanali et al., 2016](#)). The three studies confirmed low energy efficiency for saffron cultivation compared to other agricultural products. The main reason for the low energy efficiency of saffron is that only a small part of the plant (the stigma) is an economic output. The ratio of usable yield or economic yield to the total amount of the above ground biomass is 0.5% for saffron, while it is usually between 30% and 60% for most agricultural products ([Kafi, 2006](#)).
2. Farm-level energy consumption in Iran varies tremendously. This indicates that the production process varies widely from farm to farm.
3. Fertilizers, in particular N-based fertilizers, constitute most of the energy consumption. As a result, managing fertilizer consumption in saffron should be given priority. Other studies ([Mohammadi et al., 2014](#); [Mousavi-Avval et al., 2011a,b](#); [Sefeedpari et al., 2014](#)) also indicate that chemical fertilizers, in particular N-based fertilizers, are excessively employed in Iran.
4. Land preparation consumes most of the energy input during the saffron production cycle. This is because fuel used in machines and most fertilization takes place when the soil is being prepared for planting.

### 21.8.1.2 Economic efficiency

Economic efficiency measures whether resources are allocated to produce the desired outputs in the most economical way. Economic efficiency is obtained when a product is produced at the lowest possible cost. Therefore, at the point of economic efficiency, any change made to improve a part of the production process would harm another part. When economic efficiency is achieved, nothing can be improved without something else being hurt ([Farrell, 1957](#)). Economic values of consumed inputs and produced outputs are the main determinants of economic efficiency.

Estimating the degree of a firm's efficiency shows how the firm can improve economically by either reducing its inputs without changing its production or expanding production without changing its inputs. Economic efficiency compares firm operations that produce under a common technology. Efficiency falls in a range between 0 and 1. A value of 1 indicates the firm is an efficient unit and a value less than one denotes the firm is inefficient. An inefficient unit can improve in two ways:

1. By reducing its input consumption while output remains constant
2. By expanding its output while inputs remain constant

The efficiency comparison can be conducted in two forms—input-based efficiency and output-based efficiency ([Bogetoft and Otto, 2011](#)). The input-based efficiency under a certain technology “*T*” is:

$$E = \min\{E > 0 | (Ex, y) \in T\} \quad (21.5)$$

where *E*, *x*, and *y* are the efficiency, the inputs, and the outputs, respectively. This input-based efficiency presents the maximum reduction of inputs that allows the firm to continue producing a given output. On the other hand, the output-based efficiency under a certain technology “*T*” is:

$$F = \max\{F > 0 | (x, Fy) \in T\} \quad (21.6)$$

where *F*, *x*, and *Fy* are the efficiency, the inputs, and the outputs, respectively. This output-based efficiency denotes the maximum increase in output that is feasible consuming the given inputs.

#### 21.8.1.2.1 Economic efficiency of saffron cultivation

Studies on the economic efficiency of saffron cultivation have been mainly conducted in Iran. The main findings are:

1. Saffron is mainly cultivated in the two neighboring provinces of Khorasan Razavi and Southern Khorasan located in northeastern Iran. The two counties of Torbat-e-Heydarieh and Gonabad from Khorasan Razavi and the county of Ghaen from Southern Khorasan are the major regions of saffron production in Iran. Findings from different studies

on economic efficiency for saffron production in those regions show average economic efficiency between 80% and 90%, indicating that production can increase more than 10% without increasing inputs (Golkaran-Moghadam, 2014; Kavand et al., 2014). More specifically, among these three regions, Torbat-e-Heydarieh, with an average of economic efficiency of 86%, is the most efficient area in producing saffron, and Ghaen, with an economic efficiency of 63%, is the lowest one (Golkaran-Moghadam, 2014).

2. Jalali et al. (2016) found that the benefit efficiency of saffron (61.4%) was significantly less than the economic efficiency (86%) in Torbat-e-Heydarieh. This indicates that the net benefit from saffron production can be raised on average by 38.6% without any change in the production scale. The results of this study revealed that saffron producers were not able to make the most efficient decisions about inputs due to fluctuating input prices and input price uncertainty.
3. In the Kozani area of western Macedonia, the main Greek area for saffron cultivation, the economic efficiency of saffron was estimated at 63% under constant returns to scale indicating that the production inputs can decrease by 37% while leaving production unchanged (Melfou et al., 2015).
4. Firm-level economic efficiencies varied significantly among firms due to management and input use (Golkaran-Moghadam, 2014; Kavand et al., 2014).
5. Some socioeconomic characteristics, such as age, education, number of farms, and off-farm income sources, were the main determinants of economic performance for saffron farms. Two farmer characteristics, age and education, have positive effects on farm efficiency of saffron production. Older and more educated farmers have higher farm efficiency, indicating better management of resources.

## 21.9 Economic comparative advantage

### 21.9.1 Revealed comparative advantage

Revealed comparative advantage (RCA), also known as the Balassa index, is a trade index used to analyze the comparative advantage or disadvantage of a certain country in producing and exporting a product or service. The Balassa index is based on Ricardo's theory that countries allocate their resources to produce products in which they have comparative advantages. Therefore, a product with a larger share in a country's exports has a comparative advantage for that country.

The RCA compares a country's export pattern relative to the world. The RCA of a country for a given product is:

$$RCA_{ij} = \frac{\left[ \frac{X_{ij}}{\sum_{j=1}^m X_{ij}} \right]}{\left[ \frac{\sum_{i=1}^n X_{ij}}{\sum_{j=1}^m \sum_{i=1}^n X_{ij}} \right]} \quad (21.7)$$

where  $X$  is exports,  $i$  denotes the country,  $j$  denotes the product,  $m$  is a set of countries, and  $n$  is a set of commodities. Comparative advantage is revealed when  $RCA > 1$ .

The Balassa's index has been used in many studies (Amirnezhad and Alipour, 2013; Mehrabadi-Basharabadi and Pourmoghadam, 2012) to calculate the comparative advantages of a country's products.

### 21.9.2 Policy analysis matrix

The theory of comparative advantage developed by David Ricardo (Ruffin, 2002) indicates that a country will reach higher economic growth by promoting industries in which it has the greatest comparative advantage. Comparative advantage is present if a country produces goods and services that have a low opportunity cost. It shows if the benefits of producing a good or service outweigh the costs.

The comparative advantage of a particular product can be analyzed using the PAM in which two sets of prices, private and social, are considered. Private prices are determined by the market; indeed, traders face private prices directly in the market. Social prices are opportunity costs for outputs and inputs, so they reflect externalities from production. International prices are normally thought of as social prices (unless there are externalities), but domestic resource values are determined in local markets. A PAM, shown in Table 21.4, can be used to analyze economic comparative advantage, efficiency of using production inputs, and differences between social and private costs.

**TABLE 21.4** Policy analysis matrix.

Values	Revenue	Cost		Profit
		Tradable inputs	Domestic inputs	
At private prices	<i>A</i>	<i>B</i>	<i>C</i>	<i>D<sup>a</sup></i>
At social prices	<i>E</i>	<i>F</i>	<i>G</i>	<i>H<sup>b</sup></i>
Differences	<i>I<sup>c</sup></i>	<i>J<sup>d</sup></i>	<i>K<sup>e</sup></i>	<i>L<sup>f</sup></i>

<sup>a</sup>Private profits,  $D = A - (B + C)$ .

<sup>b</sup>Social profits,  $H = E - (F + G)$ .

<sup>c</sup>Output transfers,  $I = A - E$ .

<sup>d</sup>Input transfers;  $J = B - F$ .

<sup>e</sup>Factor transfers,  $K = C - G$ .

<sup>f</sup>Net policy transfers,  $L = D - H$ .

Source: Data from Monke, E.A., Pearson, S.R., Akrasanee, N., 1976. Comparative advantage, government policies, and international trade in rice. Food Res. Inst. 15 (2), 1–27.

**TABLE 21.5** Inputs consumed and output produced during 1 year (per hectare).

Input	Average	Input	Average	Input	Average
Nitrogen fertilizer (kg)		Micronutrient (L)		Corm (tons)/seeder (h)	
First year	115.78	First year	1.82	Corm (first year)	7.55
Second and years after	119.29	Second and years after	0.85	Seeder (first year)	11.54
Phosphorus fertilizer (kg)		Herbicide (L)		Tillage (h)	
First year	78.07	First year	0.72	Second and years after	14.85
Second and years after	79.82	Second and years after	0.71		
Potash fertilizer (kg)		Labor (person)		Irrigation (h)	
First year	83.33	First year (person)	77	Each year	5.94
Second and years after	87.71	Second and years after	177		
Manure (tons)		Fossil fuel (L)		Yield (kg)	
First year	29.01	Second and years after 199.38		Yearly except the 1th year	7.21
Second and years after	13.23				

Source: Data from Nezamoleslami, A., 2018. The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions. Case Study: Torbat-e-Heydarieh Region (M.Sc. thesis). Ferdowsi University of Mashhad, Iran (in Persian).

Yields, inputs, output, and market and social prices of inputs and outputs are the main information required to calculate a PAM. Table 21.5 presents the average amount of inputs consumed for 1 ha of saffron located in the Torbat-e-Heydarieh region (Nezamoleslami, 2018).

The determination of social prices is the most important part of PAM calculations. To estimate social costs, the study (Nezamoleslami, 2018) divided inputs into tradables, such as machinery, herbicide, fertilizer, and corm that can be exported or imported, and nontradables, such as labor, land, and water that cannot be exported or imported. For tradable inputs, cost, insurance, and freight (CIF) prices are used as social costs, and an opportunity cost (the highest market price) is used for nontradable inputs. The fob (free on board) price of saffron is used for social income (Table 21.6). Fig. 21.13 shows the market and social (shadow) prices for each input used to produce saffron.

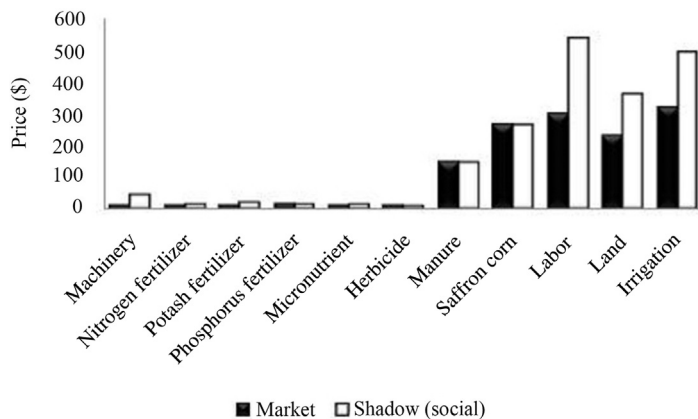
Table 21.7 shows a PAM estimated for saffron production in Torbat-e-Heydarieh in 2017.

During a 7-year cycle of saffron cultivation, the income earned for 1 ha based on shadow prices is 217,500,000, which is 21,750,000 rials more than the market income for the same amount of saffron. This implies that there is an implicit 10% tax on saffron production because market prices in Iran are lower than international prices for saffron.

**TABLE 21.6** Income, the cost of tradable and nontradable inputs at shadow, and market price for a hectare of saffron farm (in dollars).

Items	Unit	Market	Shadow
Income	1 kg of saffron	375	416.67
<b>Tradable inputs</b>			
Rental of machinery	Used during a year	4.02	40.43
Nitrogen fertilizer	Used during a year	8.10	10.95
Potash fertilizer	Used during a year	0.01	17.04
Phosphorus fertilizer	Used during a year	11.57	13.93
Micronutrient	Used during a year	8.65	10.25
Herbicide	Used during a year	0.79	8.97
Manure	Used during a year	141.59	141.59
Saffron corm	Used in the first year	262.35	262.35
<b>Nontradable inputs</b>			
Labor	Used during a year	293.8	536.46
Rental of land	Used during a year	224.63	356.73
Irrigation	Used during a year	312.35	490.87

Source: Data from Nezamoleslami, A., 2018. The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions. Case Study: Torbat-e-Heydarieh Region (M.Sc. thesis). Ferdowsi University of Mashhad, Iran (in Persian).



**FIGURE 21.13** Input prices at market and social levels (dollars per hectare). Data from Nezamoleslami, A., 2018. The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions. Case Study: Torbat-e-Heydarieh Region (M.Sc. thesis). Ferdowsi University of Mashhad, Iran (in Persian).

For nontradable inputs, the difference between market prices and shadow prices is Rs 40,200,000, indicating that saffron producers receive an indirect subsidy for nontradable inputs. Thus government programs and policies reduce private production costs by 68%.

The value of tradable inputs calculated based on market prices is Rs 426,626, which is less than the value based on social prices. This indicates that saffron producers are receiving a subsidy of about 2% on tradable inputs.

According to the profit calculations, producing saffron is profitable at both market prices (Rs 81,449,439) and shadow prices (Rs 62,572,813). Since the profit at market prices is greater than the profit at shadow prices, there is a net subsidy to saffron producers.

The PAM provides three indicators of comparative advantage: Nominal Protection Coefficient (NPC), Effective Protection Coefficient (EPC), and Domestic Resource Cost (DRC). In the next section, we present the comparative advantage indices obtained by our study and the results from other studies.

**TABLE 21.7** Policy analysis matrix for saffron crop, rials per hectare, for a 7-year period, Torbat-e-Heydarieh, 2017.

Value	Income	Costs		Profit
		Tradeable inputs	Nontradable inputs	
At market price	195,750,000	29,943,544	84,357,018	81,449,439
At shadow prices	217,500,000	30,370,170	124,557,018	62,572,813
Deviations	- 21,750,000	- 426,626	- 40,200,000	18,876,626

Source: Data from Nezamoleslami, A., 2018. The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions. Case Study: Torbat-e-Heydarieh Region (M.Sc. thesis). Ferdowsi University of Mashhad, Iran (in Persian).

### 21.9.3 Nominal protection coefficient

The NPC is the ratio of domestic price to social price. The domestic price can be a farm-gate price, while the social price is the international price adjusted for transportation, marketing, and processing costs. This indicator measures external policies including tariffs, subsidies, or other distortions causing a divergence between the two prices. For a given good, an NPC with a value higher than one shows that national policies push the domestic price higher than the international price. On the other hand, an NPC less than one indicates that national policies reduce the market price compared to its international price.

The indicator can be calculated for both inputs (NPCI) and outputs (NPCO). The NPCI addresses how much the domestic prices of inputs differ from their social prices. If the domestic input cost is higher than the international price ( $NPCI > 1$ ), there is net taxation. If the domestic input cost is lower than the international price ( $NPCI < 1$ ), there is net subsidization. The NPCO can be analyzed in the same way; an  $NPCO > 1$  implies subsidization (private price above social price for output) and an  $NPCO < 1$  implies taxation.

In our study, the NPCI is estimated at 0.99. The index was estimated at 0.53 by (Najarzadeh et al., 2010). Both results indicate that farmers receive subsidies for their production factors. The NPCO was estimated at 0.9, and was 0.62 from Aghai and Rezagholizadeh (2011), indicating that the international price of saffron is higher than the domestic market price, and therefore saffron production is taxed indirectly.

### 21.9.4 Effective protection coefficient

The EPC is a relative comparison of value added in private cost ( $A-B$  in Table 21.5) to value added in social cost ( $E-F$  in Table 21.5).

$$EPC = \frac{A - B}{E - F} \quad (21.8)$$

The EPC shows the impact of protective policies on input and output prices, and reveals the level of protection for the value added. If the EPC is higher than one ( $EPC > 1$ ), the value added at market price is higher than it would be at social cost, so the domestic market is protected. If the  $EPC < 1$ , the domestic market is taxed, so producers are discouraged.

In our study, we estimated EPC at 0.89, while Najarzadeh et al. (2010) estimated saffron's EPC at 0.63. Both results show that saffron production is not protected, but taxed, so policies are discouraging producers.

### 21.9.5 The domestic resource cost

The DRC is the most useful and common indicator to analyze economic comparative advantage for agricultural commodities. The indicator is computed using the ratio of nontradable factors used to produce the output per unit of tradable value added:

$$DRC = \frac{G}{E - F} \quad (21.9)$$

The DRC shows the shadow value of nontradable factors per unit of tradable value added. The rationale for using DRC is that there are commonly many domestic distortions in input markets. If  $DRC > 1$ , the use of domestic resources is not socially profitable. If  $DRC < 1$ , domestic resources are socially profitable.

The DRC of producing saffron on farms located in the Khorasan Razavi and Southern Khorasan is estimated at more than 0.8 (Aghai and Rezagholizadeh, 2011; Karbasi and Rastegaripour, 2014; Najarzadeh et al., 2010), indicating that generating one unit of income from the international market costs about 0.8 units. In Table 21.5 the DRC of producing saffron in Torbat-e-Heydarieh is estimated at 0.67. This implies that Iran has a comparative advantage in producing saffron.

### 21.9.6 Based on unit costs

The UC is an alternative to DCR in which all costs are considered and the classification error of the DRC is avoided (Masters and Winter-Nelson, 1995). The indicator is:

$$UC = \frac{F + G}{E} \quad (21.10)$$

A  $UC < 1$  shows that the production process generates a surplus over costs and a  $UC > 1$  indicates that the production process is not profitable.

The UC for the Khorasan Razavi and Southern Khorasan were estimated at 0.88 (Aghai and Rezagholizadeh, 2011; Najarzadeh et al., 2010). For the area we studied (Torbat-e-Heydarieh presented in the Table 21.5), the UC was estimated at 0.71. Both results imply that saffron production is profitable at current social prices.

## 21.10 Some economic advantages of saffron production

**Small-scale production:** An important economic advantage of producing saffron is the possibility of planting on a small scale. The crop can be produced easily under land constraints. In this regard, farmers can cultivate saffron in spaces among trees for more productive use of water and land.

**Employment opportunities:** Saffron is a labor-intensive product and is dependent on manual work, like handicrafts. The saffron harvest is similar to making handicrafts in that it uses only labor to extract the stigma from the flower. In general, saffron production requires 200–205 man days per hectare. Wheat, barley, and vine crops require 32, 69, and 58 man days per hectare, respectively (Monazam-Esmaeilpour and Kordovani, 2010). Of the total labor required for saffron production, 10% is needed for the planting stage, 25% for the cropping stage, and 65% for the harvesting stage. Saffron production provides a great wage/work opportunity for females. The employment opportunities in saffron cultivation have moved areas that have great potential for other crops toward production of saffron. There are also many job opportunities in the agribusiness sector beyond the harvesting stage to the final sale and even export for saffron. Product processing and the production of quality packaging are among the most important issues that must be addressed if the agribusiness sector is to expand for saffron. Considering the importance of saffron in the world market, and the employment needs in rural Iran, improved saffron production and marketing can generate many employment opportunities.

**Nonadvanced equipment and facilities:** Saffron cultivation does not require sophisticated machines and equipment. This makes it possible for most farmers, even those with low income and little financial capital, to produce saffron. Since saffron production generates more income compared to other agricultural products with limited investment, the expansion of saffron production has the potential to reduce poverty. However, when the cultivated area expands beyond the market demand, competition may change these results, so producers must keep in mind that large increases in production may lower price.

## 21.11 Conclusion

Saffron is a unique crop with a very high economic value compared with the other agricultural products. Its price is mainly affected by climatic conditions, in particular drought spells, and global economic factors such as economic crisis. Political and environmental factors have only a small influence on the saffron trade. However, the usable yield (e.g., the part of product that is used for human purposes, mainly stigma) in terms of energy or amount of production is very low. Due to the high price, productivity of the inputs used in production is very high. Saffron has a comparative advantage in regions with water shortage, nonadvanced agriculture, and low labor wage.

## References

- Abdshahi, A., Taki, M., Golabi, M., Hadad, M., 2013. Investigation of energy efficiency of wheat crop by data envelopment analysis (case study: mahyar plain of shahreza city). *Agric. Econ.* 7, 57–74 (in Persian).
- Aghai, M., Rezagholizadeh, M., 2011. Iranian comparative advantages in saffron production. *Agric. Econ. Dev. J.* 25, 121–132 (in Persian).
- Amirnezhad, H., Alipour, A., 2013. Comparative advantage and stability of export performance of forest products in Iran. *Iranian J. Forest Poplar Res.* 21, 690–701 (in Persian).
- Amirteymouri, S., Khaliliani, S., 2008. Calculation and analysis of productivity factors of production in agricultural sector of Iran. *Agric. Econ.* 2, 93–113 (in Persian).
- Bakhtiari, A.A., Hematian, A., Sharifi, A., 2015. Energy analyses and greenhouse gas emissions assessment for saffron production cycle. *Environ. Sci. Pollut. Res.* 22 (20), 16184–16201.
- Barr, N., 2004. *Economics of the Welfare State*. Oxford University Press, New York.
- Becker, G., 1992. Fertility and the economy. *J. Popul. Econ.* 5, 185–201.
- Beheshti-Tabar, I., Keyhani, A., Rafiee, S., 2010. Energy balance in Iran's agronomy (1990–2006). *Renew. Sust. Energy. Rev.* 14, 849–855.
- Bogetoft, P., Otto, L., 2011. *Benchmarking with DEA, SFA, and R*. Volume 157 of International Series in Operations Research and Management Science. Springer Science and Business Media, New York.
- Demircan, V., Ekinci, K., Keener, Hm, Akbolat, D., Ekinci, C., 2006. Energy and economic analysis of sweet cherry production in Turkey: a case study from isparta province. *Energy Convers. Manag.* 47, 1761–1769.
- Donya-e-Eqtasad, 2019. *Donya-e-Eqtasad Newspaper*. No. 4562. Available from: <<https://donya-e-eqtasad.com/>> (in Persian).
- Elhami, B., Akram, A., Khanali, M., 2016. Optimizing energy consumption and greenhouse gas emissions in lentil production using data envelopment analysis. *Iran Biosyst. Eng.* 47, 1–10 (in Persian).
- Erdal, G., Esengun, K., Erdal, H., Gunduz, O., 2007. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. *Energy* 32, 35–41.
- Esengun, K., Gunduz, O., Erdal, G., 2007. Input-output energy analysis in dry apricot production of Turkey. *Energy Convers. Manag.* 48, 592–598.
- Esmaili-Dastjerdipour, A., Mehrabi-Basharabadi, H., 2011. Surveying the relationship between agricultural products trade and virtual land in Iran. *Agric. Econ.* 5 (2), 1–20 (in Persian).
- FAO, 2000. *The Energy and Agricultural Nexus*. Environment and Natural Resources Working Paper No. 4. Rome.
- Farrell, M.J., 1957. The measurement of productive efficiency. *J. Royal Stat. Soc. Series A* 120, 253–290.
- Filipski, M., Aboudrare, A., Lybbert, T.J., Taylor, J.E., 2017. Spice price spikes: simulating impacts of saffron price volatility in a gendered local economy-wide model. *World Dev.* 91, 84–99.
- Ghaderpour, O., Rafiei, S., 2016. Analysis and modeling of energy and yield of chickpea production in Boukan. *Iran Biosyst. Eng.* 47, 711–720 (in Persian).
- Gholami-Ghajlou, J., Ghanbariyan, D., Maleki, A., Torki Harchegani, M., 2014. Investigating energy efficiency and economic analysis of sugar beet production fields in Miandoab county, west Azarbaijan province. *Sugar beet* 31, 109–122 (in Persian).
- Ghorbani-Birgani, M., Dibaei, M., 2010. Economic and energy evaluation of greenhouse cultures of sweet peppers in northern Khuzestan province. In: *Fifth National Conference on New Ideas in Agriculture*, 27–28 February 2010, Islamic Azad University, Khorasgan Branch, Isfahan, Iran (in Persian).
- Golkaran-Moghadam, S., 2014. Comparison and analysis of economic efficiency of saffron producers in the selected counties of the Razavi Khorasan. *Agric. Econ. Dev. J.* 84, 79–101 (in Persian).
- Heidari-Soltanabadi, M., 2014. Investigation and determination of energy consumption in two methods of production of onion. *Iran J. Energy* 18, 17–28 (in Persian).
- Helsel, Z.R., 1992. Energy and alternatives for fertilizer and pesticide use. In: R.C. Fluck (Ed.), *Energy in Farm Production* 6, pp. 177–210.
- Iranian Ministry of Agriculture, 2017. Report of saffron. National Plan of Herbal Medicine. Available from: <[http://si.torbath.ac.ir/resource/file\\_book/8.pdf](http://si.torbath.ac.ir/resource/file_book/8.pdf)>.
- ISNA, 2017. A brief look at the opportunities and threats of saffron. Available from: <<http://www.isna.ir/news/96060100140>>.
- Jahan, M., Amiri, M., Ehyaei, H., 2012. Efficiency of absorption and consumption of sesame seeds under the influence of biological fertilizers in a low input system. *Iran. J. Field Crop. Res.* 10, 435–447 (in Persian).
- Jalali, A., Esfanjari-Kenari, R., Shirzadi-Laskookalayeh, S., 2015. Estimating profit efficiency of saffron cultivation in the Torbat-E Heydarieh county. *Saffron Agron. Technol.* 4, 51–62 (in Persian).
- Jalali, A., Kenari, R., Laskookalayeh, S., 2016. Estimating profit efficiency of saffron cultivation in the Torbat-E Heydarieh county. *Saffron Agron. Technol.* 4 (1), 51–62 (in Persian).
- Jami-Al-Ahmadi, M., Behdani, M.A., Akbarpour, A., 2010. Analysis of agronomic effective factors on yield of saffron agroecosystems in southern Khorasan. In: *Third International Symposium on Saffron: Forthcoming Challenges in Cultivation, Research and Economics*. 31 January 2010, Kozani, Greece, pp. 123–129.
- Kafi, M., 2006. Saffron ecophysiology. In: Kafi, M., Koocheki, A., Rashed-Mohassel, M.H., Nassiri, M. (Eds.), *Saffron, Production and Processing*. Science Publishers, New Hampshire, pp. 39–59.
- Kafi, M., Showket, T., 2007. A comparative study of saffron agronomy and production systems of Khorasan (Iran) and Kashmir (India). *Acta Hort.* 739, 123. Available from: <https://doi.org/10.17660/ActaHortic.2007.739.16>.

- Karbasi, A., 2006. Economic aspects of saffron. In: Kafi, M., Koocheki, A., Rashed-Mohassel, M.H., Nassiri, M. (Eds.), *Saffron, Production and Processing*. Science Publishers, New Hampshire, pp. 139–154.
- Karbasi, A., Rastegaripour, F., 2014. Evaluation of comparative advantage on production and export of saffron. *Asian J. Res. Bus. Econ. Manag.* 4, 173–183.
- Karunaratna, M., Wilson, C., 2017. Agricultural biodiversity and farm level technical efficiency: an empirical investigation. *J. Forest Econ.* 29, 38–46.
- Katawazy, A.S., 2013. *A Comprehensive Study of Afghan Saffron*. The Report of Afghanistan Investment Support Agency (AISA).
- Kavand, H., Kalbali, E., Sabuhi, M., 2014. Application of data envelopment analysis to evaluate the efficiency of saffron growers (Case study: Qaen county). *Saffron Agron. Technol.* 2, 17–30 (in Persian).
- Khanali, M., Movahedi, M., Yousefi, M., Jahangiri, S., Khoshnevisan, B., 2016. Investigating energy balance and carbon footprint in saffron cultivation—a case study in Iran. *J. Clean. Prod.* 115, 162–171.
- Khavarinezhad, A., 2014. *Agricultural Productivity Indicators*. National Productivity Organization of Iran (in Persian).
- Khoramdel, S., Abolhassani, L., Azam Rahmati, E., 2016. Environmental impacts assessment of saffron agroecosystems using life cycle assessment methodology: (Case study: Torbat-e Heydarieh and Ghaen counties). *J. Saffron Res.* 4, 229–248 (in Persian).
- Koocheki, A., Karbasi, A., Seyyedi, S., 2017. Some reasons for saffron yield loss over the last 30 years period. *Saffron Agron. Technol.* 5, 107–122 (in Persian).
- Kouzegaran, S., Mousavibaygi, M., Sanaeinezhad, H., Behdani, M., 2013. Investigation and recognition of susceptible areas of saffron cultivation in terms of rainfall and relative humidity in southern Khorasan using GIS. *J. Saffron Res.* 2, 85–96 (in Persian).
- Masters, W.A., Winter-Nelson, A., 1995. Measuring the comparative advantage of agricultural activities: domestic resource costs and the social cost-benefit ratio. *AM. J. Agr. Econ.* 77 (2), 243–250.
- Maia, R., Silva, C., Costa, E., 2016. Eco-efficiency assessment in the agricultural sector: the Monte Novo irrigation perimeter, Portugal. *J. Clean. Prod.* 138, 217–228.
- McGimpsey, J.A., Douglas, M.H., Wallace, A.R., 1997. Evaluation of saffron (*Crocus Sativus* L.) production in New Zealand. *N. Z. J. Crop Hortic. Sci.* 25 (2), 159–168.
- Mehrabadi-Basharabadi, H., Pourmoghdam, A., 2012. Effective factors on the relative advantage of Iranian raisins export. *Agric. Econ. Res.* 4, 161–177 (in Persian).
- Melfou, K., Loizou, E., Oxouzi, E., Papanagiotou, E., 2015. Economic performance of quality labeled saffron in Greece. *Procedia Econ. Finance* 24, 419–425.
- Mirhosein, P., Rouhi, R., Alizade, M., 2005. Determination of energy consumption in traditional and semi-mechanized methods for rice production (case study in Guilan province). *J. Agric. Eng. Res.* 6, 67–80 (in Persian).
- Mobtaker, H.G., Keyhani, A., Mohammadi, A., Rafiee, S., Akram, A., 2010. Sensitivity an analysis of energy inputs for barley production in hamedan province of Iran. *Agric. Ecosyst. Environ.* 137 (3–4), 367–372.
- Mohammadi, A., Tabatabaefar, A., Shahan, S., Rafiee, S., Keyhani, A., 2008. Energy use and economical analysis of potato production in iran a case study: ardabil province. *Energy Convers. Manag.* 49, 3566–3570.
- Mohammadi, A., Rafiee, S., Jafari, A., Keyhani, A., Mousavi-Avval, S.H., Nonhebel, S., 2014. Energy use efficiency and greenhouse gas emissions of farming systems in north Iran. *Renew. Sust. Energ. Rev.* 30, 724–733.
- Mollafilabi, A., Aslami, M. H., Shoorideh, H., 2009. Replacement of saffron (*Crocus sativus* L.) with poppy (*Papaver somniferum* L.) and its socio-economic results in Afghanistan. In: *Third International Symposium on Saffron: Forthcoming Challenges in Cultivation, Research and Economics*, 31 January 2010, Kozani, Greece, pp. 299–302.
- Monazam-Esmaeilpour, A., Kordovani, P., 2010. Role of agricultural products with emphasis on saffron in rural development in Kashmar (High Districts) province. *Geograph. Quart.* 7, 31–51.
- Monke, E.A., Pearson, S.R., Akrasanee, N., 1976. Comparative advantage, government policies, and international trade in rice. *Food Res. Inst.* 15 (2), 1–27.
- Mousavi-Avval, S.H., Rafiee, S., Jafari, A., Mohammadi, A., 2011a. Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. *J. Clean. Prod.* 19, 1464–1470.
- Mousavi-Avval, S.H., Rafiee, S., Jafari, A., Mohammadi, A., 2011b. Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. *Appl. Energy* 88, 3765–3772.
- Nabavi-Pelesaraei, A., Abdi, R., Rafiee, S., Mobtaker, H.G., 2014. Optimization of energy required and greenhouse gas emissions analysis for orange producers using data envelopment analysis approach. *J. Clean. Prod.* 65, 311–317.
- Najarzadeh, R., Michael, R., Saghalian, S., Aghaei, M., Rezagholizadeh, M., 2010. A study of Iran's comparative advantage in saffron. *J. Int. Agric. Trade Econ. Dev.* 5, 1–10.
- Nezamoleslami, A., 2018. *The Comparative Advantage of Saffron Production in Khorasan Razavi Province with Regard to Greenhouse Gas Emissions*. Case Study: Torbat-Heydarieh Region (M.Sc thesis). Ferdowsi University of Mashhad, Iran (in Persian).
- Ozkan, B., Akcaoz, H., Karadeniz, F., 2004. Energy requirement and eco-nomic analysis of citrus production in Turkey. *Energy Convers. Manag.* 45, 1821–1830.
- Resistance Analysts, 2016. Lack of generating value added from the Iranian saffron exported to the world in spite of 94% of Iran share in the world's saffron production. Available from: <<http://ayaronline.ir/1395/07/211341.html>>.
- Ruffin, R., 2002. David Ricardo's discovery of comparative advantage. *Hist. Political Econ.* 34 (4), 727–748.

- Sadeghi, B., 2012. Effect of onion stem weight on saffron flowering. In: Fourth International Saffron Symposium: Advanced in Saffron Biology Technology and Trade. 22–25 October 2012, Kashmir.
- Salehi, N., Karimiyan, S., 2017. Efficiency of production and income of agricultural and horticultural products based on the water consumption index in the watershed area. In: Fourth International Conference on Environmental Planning and Management, 23–24 May 2017, University of Tehran, Tehran, Iran (in Persian).
- Sefeedpari, P., Shokoohi, Z., Behzadifar, Y., 2014. Energy use and carbon dioxide emission analysis in sugarcane farms: a survey on Haft-Tappeh Sugarcane Agro-Industrial Company in Iran. *J. Clean. Prod.* 83, 212–219.
- Shamsabadi, V., Mohammadiyanfar, A., Abdi, S., 2016. Investigating water use productivity in saffron crop (case study of Bakerz town). In: The First National Conference on Agricultural Management Using the Agricultural Model. 25 February 2016, University of Bo Ali Sina, Hamadan, Iran (in Persian).
- Sherman, H.D., Zhu, J., 2006. *Service Productivity Management: Improving Service Performance Using Data Envelopment Analysis (DEA)*. Springer Science and Business Media, New York.
- Tabatabaei, S., Shahidi, A., 2017. Investigating the increasing economic efficiency of water by changing the pattern of cropping in Mazrae-Avena village in Ardakan. *Yazd. J. Water Res. Agric.* 31, 119–128 (in Persian).
- Taki, M., Ajab-Shirchi, Y., Abdi, R., Akbarpour, M., 2011. Analysis of energy efficiency of greenhouse cucumber product by data envelopment analysis case study (Shahreza city-Isfahan province). *J. Agric. Machin. Eng.* 2, 28–37 (in Persian).
- UNIDO, 2016. Saffron industry value chain development. Available from: <<https://open.unido.org/projects/IR/projects/120595>>.
- Wyeth, P., Malik, N., 2008. A strategy for promoting Afghan saffron exports. RALF Manager, Report of ICARDA, Aleppo, Syria.
- Yaghoubi, F., Jami-Al-Ahmadi, M., Bakhsi, M., Sayarizohan, M., 2015. Comparison of technical and economic efficiency indicators of water use in wheat and saffron production in Ghaenat city. *Saffron Agron. Technol.* 3, 225–236 (in Persian).
- Ziyaei, S., Hosein-Panahi, F., Valizade, J., Barabadi, S., 2013. Comparison of the efficiency of wheat and barley production in terms of energy consumption and its productivity in Sistan and Balouchestan province. *Iran. J. Field Crop. Res.* 11, 327–336 (in Persian).
- Zwart, S.J., Bastiaanssen, W.G., 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Agric. Water Manag.* 69, 115–133.