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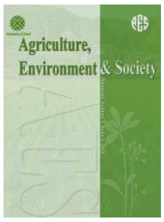

Analysis of reasonability for producing main crops using TOPSIS (case study: Azna, Lorestan province, Iran)

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ABSTRACT

Non-renewable energy consumption in agriculture increased greenhouse gases (GHGs) emissions and global warming. The present study aimed to look at energy use, GHGs emissions and economic indicators in Azna, a city in Iran's Lorestan Province in 2019. For this purpose, data were collected applying questionnaires via face-to-face interviews. The TOPSIS method was used to find the most energy efficient and environmentally friendly crop. Investigated crops were irrigated and rain-fed wheat and barley, rapeseed, bean, potato, and sugar beet. The results revealed that sugar beet cultivation is not efficient in terms of energy consumption and global warming potential (GWP). The highest share of the total energy input was recorded for diesel fuel, N and P fertilizer with at least 80% for all crops. The maximum GHGs emission and GWP was observed in sugar beet and bean at 0.019 and 0.02, however, the lowest was recorded in rain-fed barely at 0.005. The highest relative proximity to the ideal and the shortest distance from the ideal were observed in rain-fed barley and wheat. In general, wheat and barley, especially when cultivated under rain-fed condition, had the highest cultivation priorities in the region, which can reduce environmental problems.

Highlights

- The TOPSIS method, which is a technique for establishing order priority by similarity to ideal, was used for determination of suitable cultivation pattern.
- Production of sugar beet and potato in the Azna, Lorestan province, Iran is not reasonable because of the high energy input, greenhouse gases emission and global warming potential.
- The highest relative closeness to ideal and the shortest distance from the ideal were rain-fed barley and wheat; however, the farthest distance from ideal was recorded in sugar beet and potato.

1. Introduction

Energy plays a decisive role in the economic growth of countries, and its importance is increasing continuously. Scientific forecasts and energy consumption analysis will be of great importance for the planning of energy strategies and policies (Liang et al., 2007). Agriculture is one of the most important consumers of energy resources. The increase in energy inputs in agriculture has led to numerous environmental problems, such as high consumption of non-renewable energy resources, loss of biodiversity and pollution (Nemecek et al., 2011). Non-renewable energies include diesel fuel, machinery, chemicals, and chemical fertilizers, while renewable energies consist of human labor, seeds, and animal manure (Mohammadi et al., 2008). The additional use of non-renewable energy sources to boost agricultural production in developing countries with low levels of technological knowledge not only results in environmental deterioration but also causes the depletion of energy resources (Fadai., 2007). The analysis of energy in agricultural systems seems to be a hopeful advance when considering energy use efficiency and environmental problems (Giampietro et al., 1992). The increase in the consumption of renewable energy resources and energy use efficiency could be a valuable part of meeting the objectives of sustainable energy consumption (Streimikiene et al., 2007). The patterns of energy use and the amount of energy input depend on agricultural systems, growing seasons, and growing conditions (Hatirli et al., 2006). The efficient use of energy is one of the main requirements of sustainable agriculture, and its improvement will minimize

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environmental problems, the destruction of natural resources, and promote sustainable agriculture (Erdal et al., 2007). Energy input-output analysis is generally used to estimate the efficiency and environmental impacts of production systems. The energy consumption of agriculture can be classified into direct and indirect energy use; energy consumed directly as fuel and electricity, and indirectly outside the farm to produce chemical fertilizers, seed, machinery, and chemicals (Uhlin., 1998; Ozkan et al., 2004).

Global warming is one of the most important problems of recent times. Agricultural activities contribute a large percentage of GHGs emission (Guo et al., 2007). Over the past 100 years, the global mean temperature has increased (Pimentel et al., 1996). The use of fossil fuels for crop production emits carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), which have a greenhouse effect and cause global warming. Therefore, improving energy efficiency not only helps improve competitiveness by reducing costs, but also decreases GHGs emission (Alluvione et al., 2011). Proper coordination of issues in agriculture by the administration and the design of an appropriate crop pattern in the regions can be a solution for energy consumption and the reduction of GHGs emission. There are several studies, which focused on GHGs emission, energy and economic indicators for crops in a specific location (Mohammadi et al., 2014; Yousefi et al., 2016; Tzilivakis et al., 2005), but for the first time we evaluated the shortest distance of a crop from the ideal by using TOPSIS methodology. This study aimed to determine the energy efficiency, the GHGs emission, GWP and economic indicators of some important crops in Azna, Lorestan province, Iran, including rain-fed barley and wheat, irrigated barley and wheat, rapeseed, bean, sugar beet, and potato.

2. Materials and methods

2.1. Region and data collection

In this study, rain-fed agroecosystems of wheat and barley and irrigated agroecosystems of wheat, barley, rapeseed, bean, potato, and sugar beet were studied in Azna, Lorestan province, Iran. Azna is located at 33°27' N, 49°27' E and 1870 m above sea level in the west of Iran. The climate of the region is characterized by an annual average rainfall of 300 mm, distributed mainly in winter and spring; an annual average temperature of 12.3 °C, with a monthly maximum of 25 °C in July and a minimum of -0.8 °C in January. The economy of Azna depends on agriculture, and a large part of the city's population is engaged in the agricultural sector. The total farm of Azna is 62,000 ha, of which 29,000 ha is irrigated and another 33,000 ha is rain-fed. The quantity of crops obtained from irrigated and rain-fed farms is 275,000 and 25,000 metric tons, respectively (Marzban et al., 2021).

The study data were gathered using two methods: the first was obtained through interviews and face-to-face conversations with the farmers, and the second was obtained by completing questionnaires between September and August 2015 and 2016. The second set was composed of statistics acquired from the Agricultural Jihad Organization. The farms were randomly selected from the villages in the study area. The size of each sample was determined using the Neyman technique using relation. 1 (Yamane., 1967).

$$n = (\sum N_h S_h)^2 / (N^2 D^2 + \sum N_h S_h^2) \quad (1)$$

where n is the required sample size, N is the number of total holdings in the target population, N_h is the number of the population in the h stratification, S_h is the standard deviation in the h stratification, S_h^2 is the variance in the h stratification, D^2 is equal to d^2/z^2; d is the precision, where ($\bar{x}$-$\bar{X}$) (5%) is the permissible error and z is the reliability coefficient (1.96, which represents 95% reliability). The permissible error in the sample size was defined to be 5% for 95% confidence.

Wheat, barley, potato, sugar beet, and bean were the substantial products grown in the region (Table 1). The growing season for wheat and barley was from mid-September to the end of July, for sugar beet and potato was from the beginning of April to the middle of October and for bean from the beginning of June to the end of May.

Table 1. The area of cultivation for different crop in Azna

Crop	Area under cultivation (ha)	
	Irrigated	Rain-fed
Wheat	13000	15000
Potato	2000	-
Bean	8000	-
Sugar beet	450	-
Barley	1000	2000
Canola	400	-
Others	4150	-

2.2. Energy indicators

Human labor, machinery, diesel fuel, chemical fertilizer, pesticides, herbicides, fungicides, irrigation water, seed as a farm input and economic and biological yields of crops as farm output have been used to estimate the energy efficiency ratio. The energy equivalents for different inputs and outputs are presented in Table 2. The energy input and energy output were calculated by multiplying the input and output quantities by their respective energy equivalents. In this study, total energy input, total energy output, energy use efficiency, energy productivity, net energy and specific energy were calculated using Eqs. 2-5 (Zangeneh et al., 2010; Mandal et al., 2002).

$$\text{Energy use efficiency} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (2)$$

$$\text{Energy productivity} = \frac{\text{Plant performance (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})} \quad (3)$$

$$\text{Specific energy} = \frac{\text{Energy input (MJ ha}^{-1})}{\text{Plant performance (kg ha}^{-1})} \quad (4)$$

$$\text{Net Energy (MJ.ha}^{-1}) = \text{Energy out} - \text{Energy in} \quad (5)$$

2.3. GHGs emission and GWP

The amount of GHGs emission from inputs was estimated using CO_2, N_2O, and CH_4 emission coefficients of the inputs presented in Table 3. We did not estimate N_2O and CH_4 for the chemicals due to the unavailability of emission coefficients (Yousefi et al., 2016). Emissions are measured in terms of a reference gas, CO_2 At a time span of 100 years, the GWP of CO_2, CH_4, and N_2O are 1, 21, and 310, respectively (Demircan et al., 2006).

Table 2. Energy equivalent of inputs and output in agricultural production

Particulars	Unit	Energy equivalent (MJ Unit^{-1})	Sources
Inputs			
Human labor	h	1.96	(Mohammadi et al., 2008; Mohammadi et al., 2014; Yousefi et al., 2016)
Machinery	h	62.7	(Samavatean et al., 2011; Yousefi et al., 2016)
Diesel fuel	L	56.31	(Samavatean et al., 2011; Yousefi et al., 2016)
Chemical fertilizer			
Nitrogen (N)	kg	64.4	(Esengun et al., 2007; Mohammadi et al., 2008; Mohammadi et al., 2014)
Phosphate (P_2O_5)	kg	12.44	(Erdal et al., 2007; Yousefi et al., 2016)
Potassium (K_2O)	kg	11.15	(Erdal et al., 2007; Yousefi et al., 2016)
Micro-Fertilizers	kg	120	(Asgharipour et al., 2012; Banaeian et al., 2011)
Chemicals			
Herbicide	kg	238	(Rathke and Diepenbrock, 2006; Asgharipour et al., 2012)
Fungicide	kg	216	(Rathke and Diepenbrock, 2006; Asgharipour et al., 2012)
Pesticide	kg	101.2	(Rathke and Diepenbrock, 2006; Asgharipour et al., 2012)
Water for irrigation	M^3	1.02	(Mohammadi et al., 2008; Samavatean et al., 2011; Mohammadi et al., 2014; Yousefi et al., 2016)
Seeds			
Wheat	kg	20.1	(Ghorbani et al., 2011)
Barley	kg	14.7	(Mobtaker et al., 2010)
Bean	kg	25	(Mohammadi et al., 2014)
Sugar beet	kg	50	(Erdal et al., 2007; Asgharipour et al., 2012)
Potato	kg	3.6	(Mohammadi et al., 2008; Zangeneh et al., 2010)
Output (Seed)			
Wheat	kg	14.48	(Ghorbani et al., 2011)
Barley	kg	14.7	(Mobtaker et al., 2010)
Bean	kg	14.7	(Ozkan et al., 2004)
Sugar beet	kg	16.8	(Erdal et al., 2007; Asgharipour et al., 2012)
Potato	kg	3.6	(Ozkan et al., 2004; Mohammadi et al., 2008; Mohammadi et al., 2014)
Straw			
Wheat	kg	9.25	(Ghorbani et al., 2011)
Barley	kg	11.7	(Mobtaker et al., 2010)
Bean	kg	12.5	(Ozkan et al., 2004)

Table 3. Greenhouse gas (GHG) emission per unit of chemical sources and their global warming potential (GWP) in crops production (ha)

Inputs	Unit	CO_2	N_2O	CH_4	Sources
Diesel fuel	L	3560	0.70	5.20	(Kramer et al., 1999; Yousefi et al., 2016)
Chemicals					
Nitrogen (N)	kg	3100	0.03	3.70	(Mohammadi et al., 2014; Yousefi et al., 2016)
Phosphate (P_2O_5)	kg	1000	1.25	1.80	(Mohammadi et al., 2014; Yousefi et al., 2016)
Potassium (K_2O)	kg	700	0.01	1.00	(Mohammadi et al., 2014; Yousefi et al., 2016)
Herbicide	kg	6300	-	-	(Mohammadi et al., 2014; Yousefi et al., 2016)
Fungicide	kg	5100	-	-	(Mohammadi et al., 2014; Yousefi et al., 2016)
Insecticide	kg	3900	-	-	(Mohammadi et al., 2014; Yousefi et al., 2016)
GWP CO_2 equvalent factor		1	310	21	(Tzilivakis et al., 2005; Yousefi et al., 2016)

2.4. Economic indicators

The economic output of crops was calculated according to market prices. The basic unit for cost analysis was one hectare of experimental field. The investigated economic indicators are gross value of production, net return, and benefit to cost ratio. Economic indicators were calculated using Eqs. 6–8 (Simanaviciene et al., 2010).

$$\text{Gross prod. Value} = \text{Yield (kg.ha}^{-1}) \times \text{Price (\$.kg}^{-1}) \quad (6)$$

$$\text{Net return} = \text{Gross value of production (\$ ha}^{-1}) - \text{Total cost of production (\$ ha}^{-1}) \quad (7)$$

$$\text{Benefit to cost ratio} = \frac{\text{Gross value of production (\$ ha}^{-1})}{\text{Total cost of production (\$ ha}^{-1})} \quad (8)$$

2.5. TOPSIS evaluation method

Decision-making is the study of identifying and selecting alternatives based on the values and preferences of the decision maker. The reason for the problem is the high ability and capability for modeling real-world issues, as well as the simplicity and understandability for the majority of users. Some of these methods can be pointed to order preference by similarity to the ideal solution (Ansarifar et al., 2015). TOPSIS is a strong technique to prioritize options because of their similarities to the ideal solution. In this method, the selected option must have the shortest distance from the ideal response and the farthest distance from the most inefficient response (Dymova et al., 2013). One advantage of this method is that the scales and the indices applied for comparison are expressed in different assessment units and are therefore positive and negative in their nature. In other words, the positive and negative indices can be used in combination with this technique (Mohammadi et al., 2010);

Stage 1: Forming the raw data matrix according to Eq. (9).

$$X = \begin{bmatrix} X_{11} & X_{12} & X_{1n} \\ . & . & . \\ X_{m1} & X_{m2} & X_{mn} \end{bmatrix} \quad (9)$$

Stage 2: Forming a normalized matrix according to relation (10):

$$Vij = \frac{Xij}{[\sum_{i=1}^{m} Xij^2]^{1/2}} \quad (10)$$

i=(1, 2, …, n)

vij: normalized matrix

Stage 3: forming a weighted matrix: decision matrix is, in fact, parametric and it has to be parametrized. To do so, the decision maker specifies a weight for every index, according to relation (11):

$$V = N_D \times W_{n\times n} \quad (11)$$

A diagonal Matrix is obtained from the weights acquired for each of the indices. Based on the above relation, *W* is the balanced scaleless matrix and *V* is the balanced matrix. One of the important issues in decision-making is assigning a weight value to each of the scales that are carried out in various and different ways. The weight of each of the scales indicates how important each of the scales is and to what extent it influences the decision-making.

In the present study, Shanon's entropy technique can be used for weighting the indices. Basically, the method considers the idea that the more scattering in the amounts on every scale, the more important the scale.

Stage 4: calculating the positive ideal solution and negative ideal solution according to the below relations (12) and (13):

A^+ and A^- are indicative of the option with the highest priority (positive ideal response) and the option with the least priority (the worst response), respectively:

$$A^+ = \{(max, v_{ij} \mid j \in j_1), (Min, v_{ij} \mid j \in j_2)/i = 1,2, \dots n\} \quad (12)$$

$$A^+ = \{v_1^+, v_2^+, \dots, v_n^+\}$$

i=(1, 2, …, n)

$$A^- = \{(min, v_{ij} \mid j \in j_1), (max, v_{ij} \mid j \in j_2)/i = 1,2, \dots m\} \quad (13)$$

$$A^- = \{v_1^-, v_2^-, \dots, v_m^-\}$$

i=(1, 2, …, m)

Stage 5: Computing the distance size (d) to the next option n by the use of the Euclidean method. For every negative ideal solution and positive option, and similarly, for every positive ideal solution and negative option, corresponding to relations (14) and (15),

$$d_j^+ = \{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2\}^{1/2} \quad (14)$$

i=(1, 2, …, n)

Stage 6: calculating the relative closeness of *Ai* to the positive ideal solution based on relation (15):

$$Ci = \frac{d_i^-}{(d_i^- + d_i^+)} \qquad 0 < Ci < 1 \quad (15)$$

Ci = relative closeness to the ideal solution

It is evident that the shorter the option *Ai*'s distance to the ideal solution, the closer the relative closeness to unity.

Stage 7: Options Ranking:

Finally, the options are ranked in descending order. Every *Ai* option found closer to the ideal solution will have a *Ci* value closer to unity. Based on the descending order of the *Ci*, the existing options can be ranked based on their highest importance (Dymova et al., 2013). Finally, mathematical algorithms of the analysis of reasonability for producing main cropsusing, were used in the BT TopSis Solver software.

3. Results and discussion

3.1. Energy indicators

In the current cropping pattern of Azna, the total energy input in irrigated farms is 67% higher than on rainfed farms (Table 4). The lowest energy input was observed in rain-fed agroecosystems of barley and wheat. Energy input for potato and sugar beet agroecosystems was 5.8 and 4.5 times more than rain-fed barley (Table 4). The increase in the consumption of chemicals and machinery and the consequent increase in the use of non-renewable energies decrease the agro-ecosystem's sustainability. As a result, the lowest total energy input (direct and indirect energies, renewable and non-renewable energies) was observed in rain-fed barley and wheat (Table 4). In all agroecosystems, indirect energy was greater than direct energy. Researchers have indicated that the proportion of indirect energy is greater than that of direct energy in different agroecosystems (Rafiee et al., 2010; Kazemi et al., 2015). Interestingly, non-renewable energy in bean, barley, and wheat (rain-fed and irrigated) was more than renewable energy. however, an inverse trend was observed in sugar beet and potato (Table 4). The total energy output was 0.17, 0.039, 0.036, 0.026, 0.022, 0.018, 0.014, and 0.011 for sugar beet, irrigated wheat, potato, irrigated barley, bean, rapeseed, rain-fed barley, and rain-fed wheat, respectively (Table 4). Rain-fed practice can significantly reduce chemical fertilizers and energy output.

Table 4. Energy indicators and different form of energy in crops production using TOPSIS method

Crop	Energy input	Energy output	Direct energy	Indirect energy	Renewable energy	Non-renewable energy
Sugar beet	0.032	0.17	0.074	0.011	0.018	0.026
Potato	0.041	0.036	0.074	0.009	0.017	0.024
Bean	0.019	0.022	0.035	0.008	0.03	0.014
Irrigated barley	0.013	0.026	0.019	0.008	0.03	0.011
Irrigated wheat	0.021	0.039	0.024	0.012	0.054	0.015
Canola	0.012	0.018	0.006	0.008	0.002	0.01
Rain-fed barley	0.007	0.014	0.014	0.003	0.015	0.006
Rain-fed wheat	0.008	0.011	0.01	0.006	0.02	0.007

Table 4 continued.

Crop	Energy use efficiency	Energy productivity	Specific energy	Net energy
Sugar beet	0.051	0.073	0.004	0.261
Potato	0.009	0.057	0.006	0.023
Bean	0.011	0.009	0.034	0.018
Irrigated barley	0.019	0.017	0.018	0.031
Irrigated wheat	0.018	0.018	0.018	0.046
Canola	0.015	0.014	0.022	0.019
Rain-fed barley	0.019	0.019	0.017	0.016
Rain-fed wheat	0.013	0.016	0.02	0.011

The data provided in Table 4 demonstrated that the amount of input energy for sugar beet is higher than that of other crops in the region. Erdal et al (2006) reported that energy efficiency, energy productivity, and net energy in sugar beet were higher than the other products. Among other crops, sugar beet and potato had the highest and lowest energy use efficiency, respectively (Table 4). Energy use efficiency increases in two ways: one by an increase in crop yield and two by a reduction in the consumption of energy inputs (Pahlavan et al., 2012).

The efficient use of energy resources is essential to increasing the production, productivity, and competitiveness of agriculture and the sustainability (Hatirli et al., 2006) of rural production systems. Pahlavan et al. (2014) reported that sustainable agricultural production is closely related to the efficiency of energy use due to financial savings, the protection of fossil resources, and the reduction of air pollution. The highest energy productivity and net energy belonged to sugar beet at 0.073 and 0.261, respectively. However, the lowest amounts of energy productivity and net energy were recorded in bean and rain-fed wheat, respectively. For crops such as cereals whose economic yield is a proportion of biological yield, energy productivity is low, but this indicator seems to be higher in root crops and forage crops due to the greater denominator (Hulsbergen et al., 2001).

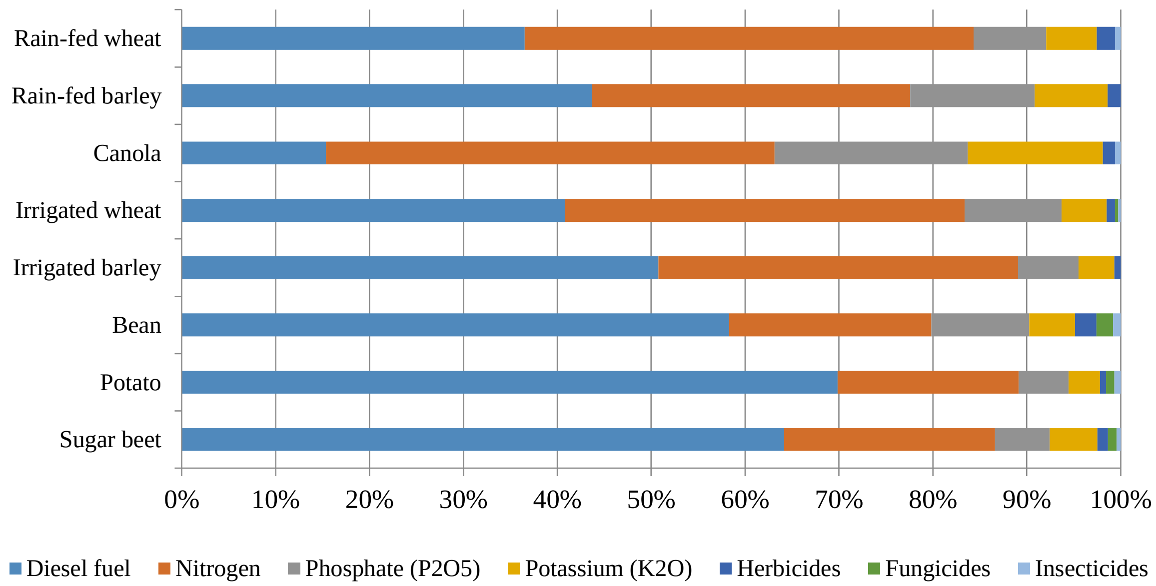

Figure 1. The share of different inputs of total energy in crops

In the case of specific energy, the highest and lowest values were recorded in bean (0.034) and sugar beet (0.004), respectively. Specific energy (energy intensity) is a measure of the environmental effects associated with crop production. From an ecological point of view, this parameter can be used to determine the best intensity of land and crop management from an ecological point of view (Alimagham et al., 2017).

Figure 1 shows the percentage distribution of energy associated with the inputs. The highest share of total input energy was recorded for diesel fuel, N and P fertilizers, with at least 80% for all crops. The maximum and minimum share of diesel fuel consumption was observed in potato and rapeseed with 70 and 16%, respectively. Recently, the mechanized agricultural system in Iran caused an increase in fuel consumption by 10% (Beheshti et al., 2010; Ozkan et al., 2004). In a study in Turkey, the cultivation of tomato, pepper, cucumber and eggplant made with fuel and fertilizers (mainly N) accounted for most of the total energy contribution (Börjesson et al., 2011). Börjesson and Tufvesson (Yuan et al., 2016) concluded that fertilizers and diesel fuel were the main energy inputs in the production of wheat, sugar beet, rapeseed, ley crops, maize, and willow. In all crops, the share of herbicides, fungicides, and pesticides was not more than 5% (Figure 1). In summary, the results of the classification based on the TOPSIS methodlogy in terms of energy indicators showed that the cultivation patterns of rapeseed, rain-fed barley, and wheat were ranked with higher priority compared to sugar beet and potato (Figure 2). Therefore, it seems that the current cultivation method used in Azna is not optimal. However, wheat, bean, and potato are cultivated in the largest farm area in the county. Given a higher growth rate and the production of high-value and low-energy crops versus low-value and high-energy crops, the economic performance of energy use increased while energy use efficiency decreased (Lal., 2004).

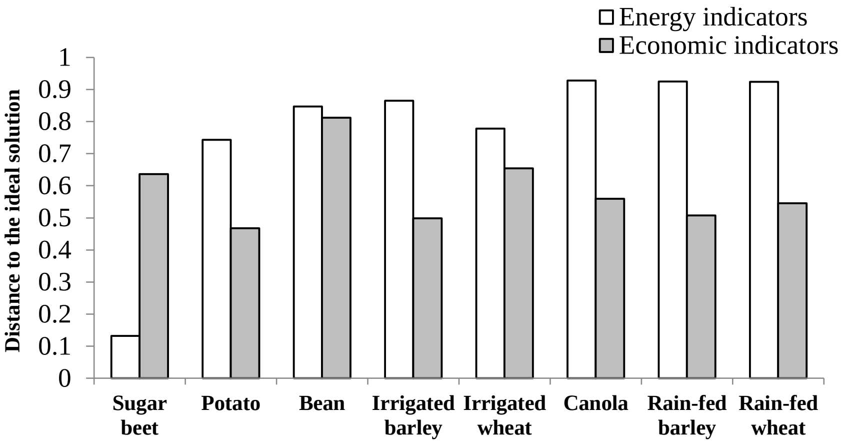

Figure 2. Ranking the options based on closeness to the ideal option in terms of energy and economic indicators

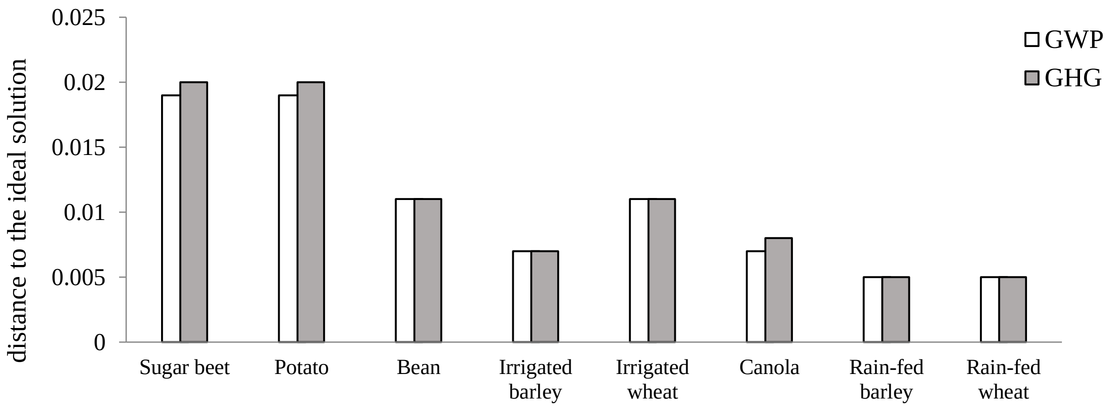

Figure 3. GWP (global warming potential) and greenhouse gas (GHG) emissions for crops using TOPSIS method

3.2. GWP and GHGs emission

According to Figure 3, the highest GWP was 0.019 for sugar beet and potato, while the lowest was 0.005 for rain-fed wheat and barley. Increased herbicide use for weed control has the potential to increase global warming (Khakbazan et al., 2009). According to Figure 3, GHGs emission for sugar beet, potato, bean, irrigated wheat, rapeseed, irrigated barley, rain-fed wheat, and barley were 0.02, 0.02, 0.011, 0.011, 0.008, 0.007, 0.005 and 0.005, respectively. Khan et al (2009) found that GHGs emission from wheat production are due to the fertilization rate, location, and planting system. The extreme application of the energy contribution of chemical fertilizers in agriculture can have drastic environmental effects (Lin et al., 2017). Fertilizer and diesel fuel consumption were the main sources of GHGs emission (Lu et al., 2017), with N fertilizer being the most important factor in terms of energy use and GHGs emission (Ghorbani et al., 2011). In addition, it should be mentioned that energy consumption in agriculture causes an increase in GHGs emission worldwide. So, determining a sustainable cultivation pattern is one of the most effective strategies to reduce climate change. The results indicated that the GHGs emission in the irrigated system is three times greater than that in the rain-fed system. Therefore, the use of the rain-fed system can play an effective role in reducing GHGs emission, which was also observed in the TOPSIS methodology. As a result, a larger area of land should be allocated to the cultivation of rain-fed barley and wheat, irrigated barley and rapeseed (Figure 3).

3.3. Economic indicators

The cost of production is a key factor in the cropping pattern. In the current study, the production costs of potato, sugar beet, bean, irrigated wheat, rapeseed, irrigated barley, rainfed wheat, and barley agroecosystems were 2293, 997, 562, 397, 392, 371, 239, and 235 \$ ha^{-1} (data not shown), respectively. According to the TOPSIS methodlogy, the highest and lowest total production costs were for potato and rainfed barley, at 0.283 and 0.028, respectively (Figure 4). The total cost of production in rainfed farms was lower than in irrigated systems, and the difference is due to the lower consumption of chemicals, chemical fertilizers, and machinery in rainfed farms.

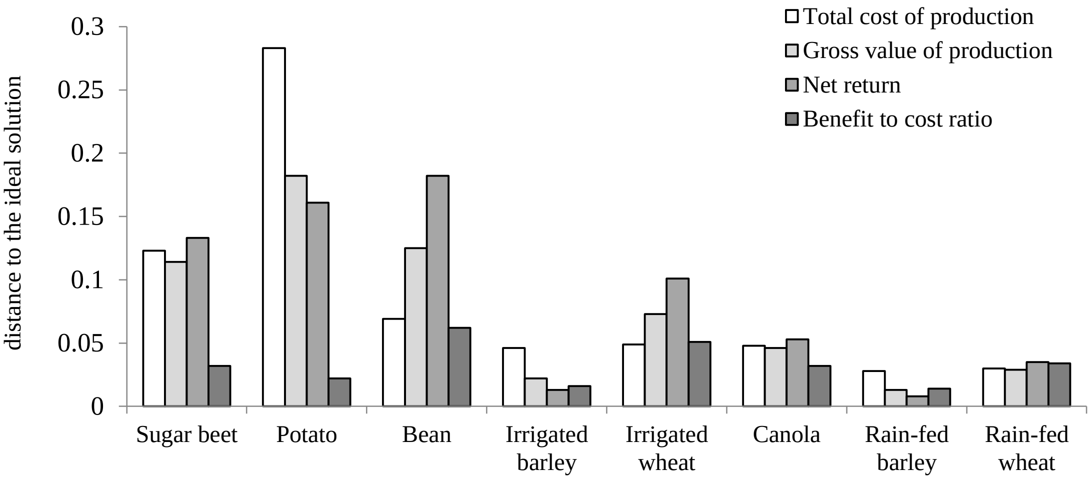

Figure 4. Economic parameters for crops production using TOPSIS method

In addition, the production of the highest gross value and the net return were obtained in potato and bean by 0.182, respectively (Figure 4). Furthermore, had the highest benefit to cost ratio (0.062), followed by irrigated wheat (0.051), and rainfed barley had the lowest (0.014) (Figure 4). Ghorbani et al (2016) reported that the benefit-to-cost ratio for rain-fed wheat was higher than irrigated wheat. The TOPSIS model classified the crops according to economic indices as bean, irrigated wheat, sugar beet, rapeseed, rainfed wheat, barley, irrigated barley, and potato (Figure 1). Our results showed that the current cropping pattern exerted in Azna is not acceptable in terms of economic indicators. The objectives of the producers play an important role in the selection of the crop and the cultivated area (Dalgaard et al., 2001).

Table 5. The effect and the weight of the energy indicators, economic factors, GHG emission and GWP on the cultivation pattern determination

	Energy input	Energy output	Direct energy	Indirect energy	Renewable energy	Non-renewable energy	Energy efficiency	Energy productivity
Scales weights (entropy)	0.042	0.122	0.077	0.016	0.051	0.03	0.043	0.067
Each scale's effect	-	+	-	-	-	-	+	-

Table 5 continued.

	Specific energy	Net energy	Total cost of production	Production gross value	Net return	Benefit to cost ratio	GHG	GWP
Scales weights (entropy)	0.037	0.18	0.088	0.071	0.081	0.028	0.035	0.033
Each scale's effect	-	+	+	+	+	+	-	

GWP: Global warming potential; GHG: Greenhouse gas emission

3.4. Evaluation of the sectors in crop production by TOPSIS

In the current study, the TOPSIS methodology was used for group decision-making to address multi-criteria decision problems. This methodology allows us to find the best alternatives for crop production in Azna. The effects of each of these scales (energy and economic indicators, GHGs, and GWP) were indicated according to their weight in the TOPSIS model. As the results are presented in Table 5, the highest effect was on net energy, followed by energy output. In other words, the mental priorities of the farmers were net energy and output energy, and after these costs of production and net return. New researches in agriculture are looking for solutions that minimize input energy in favor of producing and maximizing output energy (Payraudeau et al., 2007). In addition, the development of agricultural systems with lower input energies can help GHGs emission and GWP reduction (Samavatean et al., 2011).

The relative proximity to the ideal for each crop is shown in Table 6 by the TOPSIS model. The relative proximity to the ideal for rain-fed barley and wheat, rapeseed, irrigated barley and wheat, bean, potato and sugar beet were 0.931, 0.924, 0.906, 0.872, 0.759, 0.752, 0.623, and 0.21, respectively. In other words, the highest relative proximity to the ideal and the lowest distance to the positive ideal were observed in rain-fed barley at 0.931 and 0.017, respectively. In contrast, the lowest relative proximity to the ideal and the highest distance to the positive ideal were for sugar beet at 0.21 and 0.218, respectively. It can be concluded that rain-fed barley is the first/highest priority. Rain-fed wheat and rapeseed came as the second and third highest priority.

Table 6. Fuzzy TOPSIS results.

Crop	Relative closenes to ideal	Distance to positive ideal	Ranking of crops
Sugar beet	0.21	0.218	8
Potato	0.623	0.114	7
Bean	0.752	0.069	6
Irrigated barley	0.872	0.031	4
Irrigated wheat	0.759	0.061	5
Canola	0.906	0.023	3
Rain-fed barley	0.931	0.017	1
Rain-fed wheat	0.924	0.019	2

4. Conclusion

The objective of this study was to analyze the energy and economic indicators, GHGs emission and GWP of some crops in Azna, Lorestan Province, Iran. Energy management is the main part in terms of efficient and sustainable use of energy. Minimizing of energy inputs is essential, but it is not adequate to obtain an economic benefit, as well as the sustainability of these production systems and reduce GHGs emission. Although the net return in rain-fed was lower than that of the irrigated farms, the relative proximity to the ideal in rain-fed was much greater than in the irrigated systems. It can be inferred from the results that the cultivation of sugar beet and potato in the studied region is not reasonable. However, rain-fed barley and wheat, and rapeseed are suitable crops for this region. Although the new system offered by the TOPSIS model decreases farmer's incomes, it could sustain the environment and agriculture. Low energy input is not acceptable for farmers of the Azna who prefer economic benefits instead of sustainable agriculture. We believe that government support can provide incentives for farmers to grow the crops offered, which increases the stability of farmers' incomes. Rain-fed systems can be used to reduce the rate of non-renewable energy inputs, chemical synthetic fertilizers and, consequently, GHGs emission and GWP. Therefore, the cultivation of rain-fed barley and wheat, and rapeseed propose to reduce fossil fuel consumption and improve the environmental profile of agricultural systems in the region.

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