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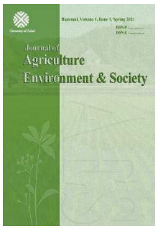

Evaluation of the sustainability of wheat production systems in the Sistan using emergy analysis

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ABSTRACT

This study was conducted using the emergy analysis approach in wheat production systems in order to plan and manage the major challenges facing the Sistan region's wheat production. All inputs for wheat production, the most important crop in the region, were assessed in this study. These inputs include renewable inputs, such as sunlight, wind, and rain; nonrenewable inputs, such as soil erosion; and purchased inputs and services, such as machinery, fossil fuels, electricity, labor, nitrogen, potassium, phosphorus, and chemical fertilizers. According to the results of the study, the total emergy production of wheat was 1.061016 sej ha^{-1}. The irrigation water consumed the most energy at 28.96%, followed by nitrogen and phosphorus fertilizers at 20.75 and 16.5%, respectively. The emergy yield ratio index was 1.41, the emergy investment ratio index was 2.4, the environmental loading ratio was 2.41, and the emergy sustainability index was 0.585, which indicates the average sustainability and environmental load of this system relative to other researchers' reports. By increasing input efficiency by optimizing the consumption of irrigation water, nitrogen fertilizer, and phosphorus fertilizer, this production system can be made more sustainable and less taxing on the environment.

Highlights

- This study used emergy analysis to manage Sistan's wheat production challenges.
- Irrigation water consumed 28.96% of the emergy, followed by nitrogen and phosphorus fertilizers.
- The EYR was 1.41, the EIR was 2.4, the ELR was 2.41, and the ESI was 0.585, indicating the system's average sustainability and environmental load.
- By optimizing irrigation water, nitrogen fertilizer, and phosphorus fertilizer use, this production system can be made more environmentally friendly.

1. Introduction

Today, the agricultural industry relies heavily on energy consumption in order to meet the rising food demands of the world's expanding population. Due to limited natural resources and the negative effects of improper use of various energy sources on human health and the environment, it is necessary to study agricultural energy consumption patterns (Wang et al., 2014).

Emergy analysis is one of the new methods of evaluating sustainability based on energy and precise estimations of energy quantity and quality (Odum, 2007). Emergy is the direct or indirect use of available solar energy to provide a service or product. Emergy, also known as embodied energy or "energy memory," is measured in solar emJoule (sej) (Odum, 2000). Every available energy in agriculture has a specific unit of emergy, such as sej, coal emJoule, and electric emJoule. As solar energy is the direct and indirect source of all biosphere energy, solar energy (emJoule) is the unit of measurement (Fallahinejad and Armin, 2022; Shahhoseini and Kazemi, 2022). Consequently, the radiation emergy per unit of energy can be calculated using the appropriate conversion factor. The

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greater the conversion ratio, the greater the requirement for solar energy to generate and conserve resources, goods, or services (Brown, 2004).

Over the past several decades, emergy has proven to be an efficient and potent tool that can be utilized to support the flow of natural ecosystem resources and macroeconomic systems. After about 30 years of development and application, this analysis has become a common and valid method for assessing the transformation of ecological-economic systems and processes, with a particular focus on the agricultural sector (Brown, 2004). By converting all currents, natural resources, and economic resources into solar energy units, the emergy methodology enables a comprehensive review of system stability. Emergy experts believe that using the emergy approach to guide policymaking can result in a more remarkable coexistence between humans and the natural world (Wang et al., 2014). The natural input valuation system serves as the foundation for emergy methods. It is based on the flow of available energy, which has the potential to do more work individually or in the form of conversion forms (Asgharipour et al., 2020; Amiri et al., 2021).

Energy flow alone is insufficient for valuing ecological goods and services because it disregards the work performed by the environment and economy in the past to produce a good or service. EmJoule calculates the energy used directly and indirectly in the past to produce a good or service, as opposed to the joule, which measures the amount of available energy used in the present. The modified solar coefficients represent the amount of solar energy utilized in the past to produce one joule of current energy. Consequently, the use of emergency indicators to evaluate the system's sustainability provides valuable insight into the sustainability of present and future policies (Brown, 2004).

Numerous studies have demonstrated that conventional agriculture is less productive and more energy inefficient than agriculture based on natural inputs. Using the emergy yield ratio, environmental loading ratio, and emergy sustainability index, a number of researchers compared the organic and conventional red-orange production in Sicily, Italy. Their research confirmed that organic orange production utilized less nonrenewable energy sources than conventional agriculture (La Rosa et al., 2008). Using emergy based indices, Brazilian researchers evaluated soybean cultivation in Brazil. They demonstrated that soybean production is not profitable due to the commodity's market price and the high cost of production inputs (Cavalett and Ortega, 2009). Four common types of agriculture in the Vichy region of China were evaluated based on emergy indices. The results demonstrated that corn cultivation is more sustainable than that of other crops (Zhang et al., 2012). A study of three types of ecosystems in the United States, including corn cultivation systems, blackberry cultivation, and the traditional production of several intermittent crops, revealed that corn cultivation systems are the most environmentally friendly and have the least impact on the environment compared to conventional agriculture. Additionally, corn cultivation was related to the lowest stability and highest ecological load (Martin, 2006). A group of researchers demonstrated that integrated cultures are significantly more justifiable than single cultures (Wang et al., 2014). Using emergy, energy, and economic indicators, the study evaluated the rice cultivation and vegetable cultivation systems. The results demonstrated that although the short-term profitability of continuous rice and vegetable cultivation is greater, the stability of intermittent rice and vegetable cultivation is greater (Lu, 2010).

Small-scale (smallholder) farming systems traditionally practiced in northern China were compared to large-scale farming systems using emergy indicators. The results indicated that the emergy efficiency of corn production on large-scale farms was 88% greater than on small-scale farms. In addition, the emergy efficiency of wheat production in large farms was 41% greater than that of conventional farms. They hypothesized that this model could boost resource productivity for grain production in northern China (Wang et al., 2014).

Undoubtedly, resource efficiency is one of the primary objectives of sustainable agriculture. Therefore, emergy efficiency in agriculture is one of the prerequisites for sustainable agriculture (Ghaley and Porter, 2013). This highlights the need to revise agroecosystem management and consumption practices. In this regard, it appears necessary to examine energy consumption patterns in order to identify energy-intensive areas in agricultural systems and evaluate energy consumption efficiency, environmental issues, and their connection to agricultural sustainability. Therefore, agroecosystems must be analyzed in terms of inputs and outputs in order to implement new solutions (Martin et al., 2006). Thus, studying the emergy budget of various crops will assist in identifying the available potential in Iran. In addition, comparing the energy productivity of different crops is one of the methods that will assist in prioritizing the cultivation of different crops in each region (Beheshti Tabar et al., 2010).

The Sistan wheat production system contributes the most to the regional cropping pattern. Consequently, this region has become the province's principal wheat-producing region. This study's objective was to evaluate the Sistan wheat production system using emergy indicators to precisely plot energy flow, calculate environmental load, and determine the system's sustainability.

2. Materials and Methods

2.1. Study area

In Sistan, more than 120,000 ha are devoted to crop cultivation. Wheat, barley, summer crops, alfalfa, fodder corn, Yaghuti grapes, and greenhouse crops are the primary crops in this region. the wheat production system in Sistan was examined and analyzed in this study using data from a one-hectare farm at the Zahak Agricultural Research Station (which is the average representative of agricultural lands in the Sistan region). Zahak Agricultural Research Station is located 20 km south of Zabol city and north of Zahak city with a latitude of 30° 154′, a longitude of 41° 61′, and an altitude of 483 m above sea level. This region has an arid agricultural climate with long, sweltering summers. This field has loamy soil with a conductivity of 3.3 dS/m and an acidity of 8, and irrigation water with a conductivity of 2-3 dS/m and an acidity of 8.

Wheat is cultivated in the study area in November and harvested in June. Most of the agricultural operations for wheat cultivation on this farm, including land preparation, planting, irrigation, weed control, fertilization, and harvesting, were performed using agricultural machinery. Chemical fertilizers were used to stimulate crop growth, and herbicides were used to control weeds.

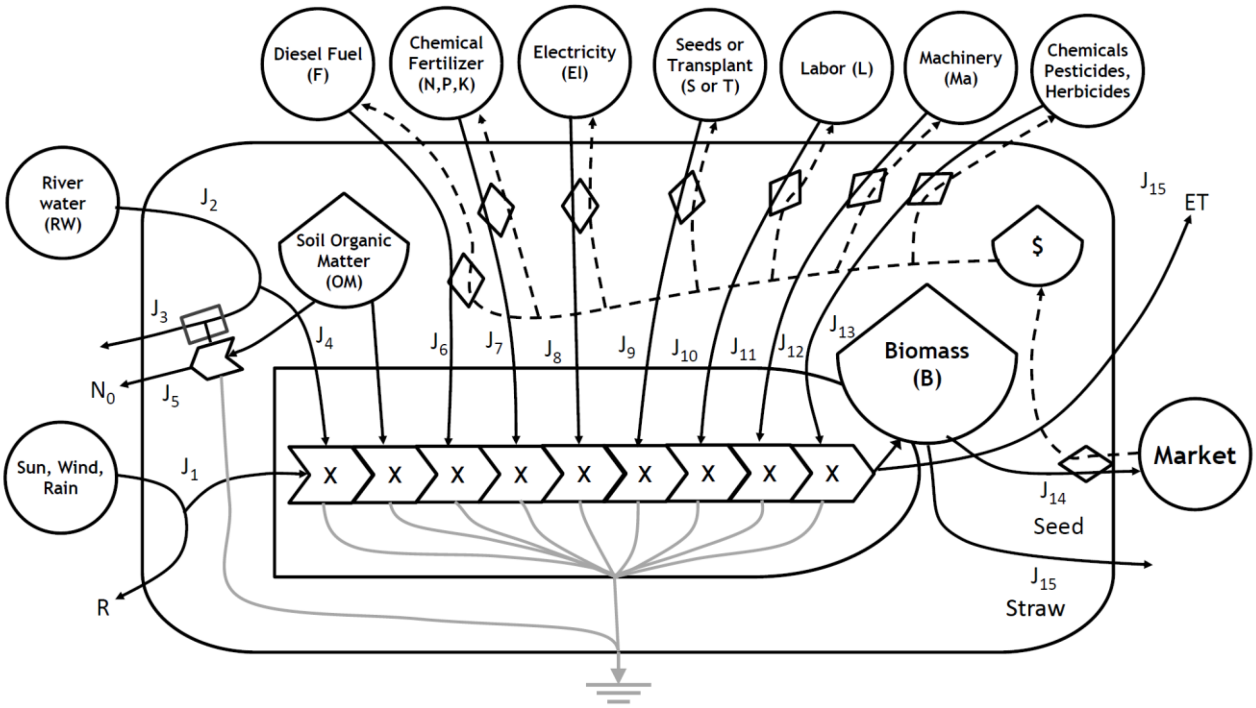

Figure 1. Emergy diagram of wheat cultivation system

2.2. Emergy analysis method

The first step in emergy analysis is to determine the spatial and temporal boundaries of the systems under study and draw an emergy flow chart. It is essential to classify the system's inputs under investigation into renewable or non-renewable, local, or imported sources. In addition, the emergy flow chart is used to show the inputs and outputs of the culture system clearly. This work is essential for managing the relationships between key components and processes of a profitable strategy. It also demonstrates the environmental foundations of ecologists and their relationship to the larger economy (Odum, 2007). The emergy diagram of the Sistan wheat production system is shown in Figure 1.

2.3. Data collection

The first step in emergy analysis is drawing energy flow diagram of the system. The second step in emergy analysis is to draw emergy evaluation tables. To obtain the emergy value of each input, the raw data of each input was multiplied by their conversion coefficients in joules, grams, or Dollars. Total emergy is the sum of emergy from all independent inputs (Odum et al., 2000).

In the wheat production system in the Sistan, free renewable resources, including sunlight, rain, and wind, were considered. Also, renewable sources purchased included seeds, irrigation water, and labor. Surface soil erosion was considered a non-renewable source of environment, and machinery, fossil fuels, chemical fertilizers, herbicides, and electricity were considered as purchased non-renewable sources. Services were considered as input, and the product of grain, and stubble produced was considered as output.

2.4. Method of calculating and measuring emergy inputs

The formula for converting energy to emergy is calculated according to Eq. 1:

$$\text{Emergy (sej)} = \text{available energy (J)} \times \text{conversion factor (sej/J)} \quad (1)$$

Where the emergy unit is the sej and the unit of transfer conversion of emergy is the sej factor per joules (sej/J) (Brown and Ulgiati, 2004).

Specific emergy is defined as emergy per unit of output mass and is usually expressed as solar emergy per gram (sej/g).

Emergy per currency is considered emergy supporting an economical product unit (currency) production. This unit converts paid money into emergy units (Odum, 2007).

Solar radiation energy was calculated based on Eq. 2:

$$\text{Solar rad. energy (joules)} = A\ (m^2) \times I\ (W\ m^{-2}) \times F_{ab} \quad (2)$$

Where A is the land area, I is the average solar radiation in the Zabol region during the growing season of different crops, and Fab is the percentage of radiation absorption. The radiation absorption percentage of albedo coefficient for the wheat production system was considered to be 20%.

The solar to emergy conversion factor is defined as 1 sej per joule (Odum, 2007). The chemical energy potential of rainwater and irrigation water was calculated based on Eq. 3:

Chemical energy Water potential (joules)= A (m^2) × p (mm yr^{-1}) × d (g m^{-3}) × G (J gr^{-1}) (3)

Where A is the area of land, p is the amount of annual rainfall + water entering through irrigation (mm / year), d is the density of water (1×10^6 g/m^3), and the Gibbs free energy for water is 4.94 joules in gram (Odum and Odum, 1983).

The solar conversion coefficient of chemical energy of rainwater potential to emergy was considered as 18199sej/j.

Wind kinetic energy was calculated based on Eq. 4.

Wind kinetic energy (joules)= A (m^2) × r (kg m^{-3}) × c × $(vg)^3$ (4)

Where A is the area of the earth, r is the density of air (1.23 kg/m^3), and c is the drag constant (a dimensionless quantity to calculate the drag force on a moving object), vg is a geostrophic wind. A geostrophic wind is a theoretical wind due to the equilibrium between the Coriolis effect and the pressure gradient force; the value of this wind is defined as 1.67 times the average wind speed.

The solar conversion factor of wind energy to emergy is considered to be 1496 sej per joule.

The amount of wasted soil energy was calculated using Eq. 5.

Waste soil energy =A (m^2) × ErodSoil (g m^{-2} yr^{-1}) × OM (%) × EOM (kcal gr^{-1}) × 4186 J $kcal^{-1}$ (5)

Where A is land area, ErodSoil is the amount of soil eroded per square meter per year, OM is the percentage of soil organic matter, and EOM is the energy content of soil organic matter, which is 5.4 kcal/g (Odum, 2007). Soil erosion was measured by a sediment sampling device installed in the field.

The solar conversion coefficient of net surface soil losses is 1.24×10^5 sej/J (Odum, 2007). Emergy human resources are considered based on the solar conversion factor of 4.5×10^6 sej/J (La Rosa et al., 2008). A coefficient of 15.7×10^6 sej/kg was used to calculate the seed content. The solar conversion factor was used to calculate the seed emergy of 1.11×10^5 sej/J (Ghaley and Porter, 2013). To calculate the energy content of diesel, a coefficient of 56.31×10^6 J/l was used. Also, to estimate the emergy of diesel, the solar conversion coefficient of 1.11×10^5 sej/J was used (Odum, 2007). Emergy Machines were considered based on a solar conversion factor of 3×10^{12} sej/kg (La Rosa et al., 2008).

To calculate the energy content of electricity, a coefficient of 3.6×10^6 J/kWh of electricity was used. The solar conversion factor was calculated to estimate the emergy of the electricity equal to 2.69×10^5 sej/J (Odum, 2007). The energy content of herbicide is 9.6×10^6 sej/kg (Asgharipour et al., 2012). To calculate the emergy of pesticides, the solar conversion factor was considered to be 2.49×10^{10} sej/J (Brown and Ulgiati, 2004). To calculate nitrogen emergy, the solar conversion factor was considered equal to 4×10^{10} sej/g of nitrogen (Brandt-Williams, 2002). To calculate phosphorus emergy, the solar conversion factor was considered equal to 3.69×10^{10} sej/g of phosphorus (Brandt-Williams, 2002). To calculate potassium emergy, the solar conversion factor equivalent to K_2O is 3×10^9 sej/g of potassium was considered (Odum, 2007). To calculate the irrigation of irrigation water, the average solar conversion coefficient is 4.34×10^{12} sej/m^3 of water (Buenfil, 2001). The energy content of the wheat grain is 14.7×10^6 J/kg, and straw is 9.25×10^6 J/kg (Ghaley and Porter, 2013).

2.5. Emergy indicators

The indicators used in the wheat production system in Sistan are as follows (La Rosa et al., 2008).

2.5.1. Emergy Yield Ratio

This index is derived from Eq. 6 by dividing emergy output by purchased emergy inputs.

$$(\mathrm{EYR}) = \frac{\mathrm{Y}}{\mathrm{NP+RP}} \tag{6}$$

Where EYR represents the yield ratio of emergy, Y represents the output of emergy, NP represents non-renewable purchased inputs, and RP represents renewable purchased inputs. A greater value for this index indicates a greater return per unit of invested emergy.

2.5.2. Emergy Investment Ratio

This index is derived from Eq. 7 by dividing economic inputs (purchased) by accessible environmental inputs.

$$(\mathrm{EIR}) = \frac{\mathrm{NP+RP}}{\mathrm{RR+NR}} \tag{7}$$

Where EIR represents the investment ratio, NP represents the emergence of non-renewable purchased inputs, RP represents renewable purchased inputs, NR represents non-renewable natural inputs, and RR represents renewable natural inputs. The lower the value, the lower the economic cost, and consequently, such systems tend to compete in the market. The greater the transaction, the greater the economic development.

Index of the environmental loading ratio This index is the ratio of total non-renewable environmental inputs and non-renewable purchased inputs to total renewable environmental inputs and purchased inputs, as determined by Eq. 8.

$$(\mathrm{ELR}) = \frac{\mathrm{NP+NR}}{\mathrm{RR+RP}} \tag{8}$$

This index determines the pressure ratio on the environment and the system pressure on the environment. A lower percentage of this index indicates less environmental stress. NP represents non-renewable purchased inputs, NR represents non-renewable natural inputs, RP represents renewable purchased inputs, and RR represents natural renewable inputs.

2.5.3. Emergy self-supporting ratio

This ratio is calculated by dividing the emergy of all environmental inputs by the emergy of product performance derived from Eq. 9.

$$(\mathrm{ESR}) = \frac{\mathrm{RR+NR}}{\mathrm{Y}} \qquad (9)$$

Where ESR is the self-sustaining ratio, NR is the emergy of non-renewable natural inputs, RR is the natural renewable input, and Y is the emergy of product performance. The greater this index's value, the greater the system's dependence on free environmental resources. This system has greater potential to increase economic productivity and economic investment.

2.5.4. Environmental Sustainability Index

The index of environmental sustainability is obtained from Eq. 10.

$$(\mathrm{ESI}) = \frac{\mathrm{EYR}}{\mathrm{ELR}} \qquad (10)$$

Where ESI represents the environmental sustainability index, EYR represents the energy yield ratio, and ELR represents the environmental loading ratio. This metric indicates whether it is possible to find a process that, while performing well, has a smaller environmental impact. In calculation of ESI the degree of compatibility between the economy and the environment is considered. A high value for this index indicates a stable crop system (Brown and Ulgiati, 2004). Reducing feedback and increasing the proportion of renewable inputs relative to feedback results in an increase in this index's rate, leading to an increase in this ratio.

The average annual long-term weather data for solar radiation, precipitation, and wind speed were collected from Zahak Agricultural Meteorological Research Station. In this investigation, to determine the price of inputs and wheat crops, we consulted with the Jihad Agricultural Office, farmers, and region traders.

3. Results and discussion

Table 1 contains information on the inputs and outputs of wheat production in Sistan, as well as their equivalent emergy values.

According to Table 1, irrigation water has the highest emergy in the Sistan wheat production system at 3.07×10^{15} sej ha^{-1}. The highest amount of emergy consumption is associated with nitrogen fertilizer at 2.15×10^{15} sej ha^{-1}, followed by phosphate fertilizer at 1.77×10^{15} sej ha^{-1}.

A study to evaluate the emergy of a wheat field in Denmark found that the highest emergy application was for nitrogen fertilizer at 7.7×10^{15} sej ha^{-1} (Ghaley and Porter, 2013). In the emergy analysis of the corn and wheat production system in China, it was found that the emergy of irrigation water consumption for corn and electricity for wheat is 9.005×10^{14} and 5.95×10^{15} sej ha^{-1}, respectively (Wang et a., 2014).

Table 1. The Assessment of the Emergy of wheat production system in Sistan

Note	Item	Unit	Data	Transformity (sej/unit)	Emergy (sej ha^{-1} yr^{-1})	%
Renewable natural resources						
1	sunlight	J	3.41×10^{13}	1	3.41×10^{13}	0.321
2	wind	J	5.5×10^{6}	1496	8.2×10^{9}	0.0004
3	rain	J	2.47×10^{8}	18199	4.49×10^{12}	0.04
4	water	J	5650	5.43×10^{11}	3.07×10^{15}	28.96
	total	J			3.11×10^{15}	29.33
Nonrenewable natural resources						
5	Topsoil	J	4.65×10^{7}	1.24×10^{5}	5.76×10^{12}	0.054
Renewable purchased resources						
6	Labor	J	3.66×10^{8}	4.5×10^{6}	1.65×10^{15}	15.56
7	Seed	J	2.83×10^{9}	1.11×10^{5}	3.14×10^{14}	2.96
	Total				1.96×10^{15}	18.49
Nonrenewable purchased resources						
8	Fuel	J	3.3×10^{9}	1.11×10^{5}	3.66×10^{14}	3.45
9	Machinery	kg	3.59	3.00×10^{12}	1.08×10^{13}	0.1
10	Electricity	J	1.84×10^{9}	2.69×10^{5}	4.95×10^{14}	4.67
11	Nitrogen	g	5.50×10^{4}	4.00×10^{10}	2.2×10^{15}	20.75
12	Phosphate	g	4.8×10^{4}	3.69×10^{10}	1.77×10^{15}	16.7
13	Potash	g	6.00×10^{4}	3.00×10^{9}	1.84×10^{14}	1.73
14	Herbicide	g	1640	2.49×10^{10}	4.08×10^{13}	0.38
15	Services	$	150	3.12×10^{12}	4.68×10^{14}	4.41
	total	J			5.53×10^{15}	52.17
	Emergy yield				1.06×10^{16}	100
Output						
16	Grain yield	kg	3850			
17	energy	J	5.56×10^{10}	$1. 87\times10^{5}$	1.04×10^{16}	
18	Specific emergy	sej g^{-1}	2.75×10^{9}			
19	Straw yield	kg	4200			
20	Straw energy	J	$3. 88\times10^{10}$	$2. 73\times10^{5}$	1.06×10^{16}	

Irrigation of irrigation water, nitrogen fertilizers, and phosphorus fertilizers are due to the high consumption of these inputs in traditional cultivation systems. The general classification results of different emergy sources involved in the Sistan wheat production system are shown in Table 2. Based on the above results, the share of natural resources (R + N) of total emergy consumption was 29.38%, and the percentage of purchased resources (P) was 70.62%. Total renewable resources (R + RP) accounted for 47.8% and total non-renewable resources for 52.2% of the total emergy. The total emergy yield of Sistan wheat production was 1.06×10^{16} sej ha^{-1}, and the grain conversion coefficient of wheat, straw, and stubble was 1.87×10^{5} and 2.73×10^{5} sej/J, respectively.

Table 2. The General Categorization of Different Emergy Resources of wheat production system in the Sistan

Note	Item	Emergy (sej ha^{-1} yr^{-1})	%
	Natural resources		
1	Renewable natural resources	3.11×10^{15}	29.33
2	Nonrenewable natural resources	5.76×10^{12}	0.05
3	Sub-total	3.115×10^{15}	29.38
	Purchased resources		
4	Renewable purchased resources	1.96×10^{15}	18.47
5	Nonrenewable purchased resources	5.53×10^{15}	52.15
6	Sub-total	7.49×10^{15}	70.62
7	Total	1.06×10^{16}	100
8	Wheat transformity	1.87×10^{5}	
9	Straw transformity	2.73×10^{15}	

3.1. Emergy indicators in the Sistan wheat production system

Indicators related to wheat production are shown in Table 3. Based on the results, the renewability percentage index (R%) equals to 47.83. This index shows the share of renewable resources in total production resources, and its low means low renewable canvas cultivation and poor sustainability (Amiri et al., 2021).

Emergy Yield Ratio (EYR): This index in Sistan wheat was 1.41. A higher value of this index is more desirable because it shows the ratio of emergy performance for invested emergy. In the estimate of potato emergy in Florida, the emergy yield ratio was 1.24 (Brandt-Williams, 2002). Italian researchers in the study of orange emergy in Italy reported the value of this index as 1.5 (La Rosa et al., 2008). In another survey of grapes in southwest China, the grape emergy yield ratio was 1.07 (Feng et al., 2013).

Table 3. Emergy Indices for wheat production system in the Sistan

Indices	Data
Renewability (R %)	47.83
Emergy yield ratio (EYR)	1.41
Emergy investment ratio (EIR)	2.4
Environmental loading ratio (ELR)	2.41
Emergy self-sufficiency ratio (ESR)	0.294
Emergy sustainability index (ESI)	0.585

Emergy Investment Ratio (EIR): This index indicates the economic capital consumed in the system, so its higher value indicates the greater share of purchased resources. The lower the value of this index, the more desirable it is. The value of this index in Sistan wheat production was equal to 2.4, which suggests that the system relies more on purchased resources than free environmental resources. In the evaluation of soybean emergy in Brazil, the emergy investment ratio was 1.25 (Cavalett and Ortega, 2009). In a study on grapes in southwest China, several researchers reported a grape emergy investment ratio of 14.08 (Feng et al., 2013).

Environmental Loading Ratio (ELR): This indicator shows the amount of pressure a cultivation system imposes on the environment. Its value in this study was equal to 2.41, which indicates the average pressure of this system on the environment. Researchers reported an environmental loading for grapes in southwest China of 2.78 (Feng et al., 2013). In the emergy study of the rice cultivation system in China, the above index was 0.62 (Lu et al., 2010). In the assessment of barley emergy in Washington state, this index was declared 2.94 (Haden, 2002).

Emergy Self-Sufficiency Index (ESR): This indicator indicates the degree to which the system relies on its internal resources, and the higher the value, the better. The value of the above index in this study was 0.294. In an emergy study performed on protected grapes in China, the emergy self-sufficiency index was 0.66 for southwest China and 0.11 for north China (Feng et al., 2013).

Emergy Stability Index (ESI): This indicator shows the sustainability of a cultivation system. The higher the share of renewable resources than non-renewable resources, the higher the value of this index and the more desirable it is. The value of this index in the present study was 0.585. An American researcher evaluating the emergy of different cropping systems in the state of Florida reported a sustainability index of 0.68 for oats and 0.16 for potatoes (Brandt-Williams, 2002). Other researchers in evaluating the emergy of the rice cultivation system in China obtained that the value of this index is 1.83 (Lu et al., 2010).

4. Conclusion

In this study, different sources of energy supply and essential indicators of sustainability and environmental burden of the Sistan wheat production system were analyzed using the emergy evaluation method. The results showed that among all inputs involved in wheat production, three variables of irrigation water, nitrogen fertilizer, and phosphate fertilizer, 28.96%, 20.75%, and 16.7% had the highest share in emergy consumption, respectively. If energy efficiency is to be considered, the main priority must be to optimize these three sources. Also, the analysis of emergy indices showed that R% is equal to 47.83, EYR is 1.41, EIR is 2.4, ELR is 2.41, ESR is 0.294, and ESI is 0.555. The results obtained compared with many similar studies show that the emergy indices of Sistan wheat are moderate. The environmental load is essential, and the lower the value, the less pressure on the environment.

The value obtained for this index is the average of similar studies, which indicates the relative pressure of this cultivation system on the environment. Although the environmental sustainability index in this study is higher than the average of similar studies, its value is not desirable and shows the relative sustainability of this system.

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