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# Evaluation of Environmental, Energy, and Economic Indices in Irrigated and Dryland Coriander Production Systems Using a Life Cycle Assessment

**Mansoor Ahmadi[1], Farzad Mondani[*1], Ashkan Nabavi-Pelesaraei[2]**

[1]*Department of Plant Production and Genetics, Razi University, Kermanshah, Iran*
[2]*Department of Mechanical Engineering of Biosystem, Razi University, Kermanshah, Iran*

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**ABSTRACT**

The development of medicinal plant cultivation is of particular importance. However, this development has been accompanied by an increase in the consumption of chemical and energy inputs, a trend that is also observed in coriander cultivation. Therefore, this study was conducted from 2021 to 2023 to compare irrigated and dryland coriander production systems in terms of environmental, economic, and energy indices across Kermanshah Province. The study employed a life cycle assessment approach and utilized the ReCiPe 2016 methodology. The results indicated that the irrigated coriander production system has significantly higher input and output energy than dryland production system. For irrigated production system, the input energy was 20999 Mj ha$^{-1}$ and the output energy was 44400 Mj ha$^{-1}$, which were 166% and 328% higher than those for dryland production system, respectively. Additionally, energy indices showed that irrigated production system outperformed dryland production system by 61% in energy ratio, 55% in energy efficiency, 56% in energy intensity, and 843% in net energy gain. However, irrigated production system produces 65% of the environmental pollutants due to higher consumption of diesel fuel and chemical fertilizers (8446 and 4129 Mj ha$^{-1}$, respectively). Moreover, irrigated coriander production system is more profitable than dryland production system, with a net income of $841.88 ha$^{-1}$. Optimizing the use of chemical inputs and increasing energy efficiency can improve production sustainability and environmental protection.

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## 1. Introduction

Agricultural sciences and crop management seek to achieve increased production while improving energy efficiency and economic productivity. In this regard, optimal management of inputs used in different stages of production is of particular importance, and by implementing appropriate strategies, resource waste can be prevented (Jalilian *et al.*, 2023c). Optimization of energy resource consumption and increased energy efficiency are effective approaches for reducing environmental damages caused by energy input consumption in agricultural production. This optimization not only contributes to financial savings but also leads to the conservation of fossil resources and the reduction of air pollution (Jalilian *et al.*, 2023b). Optimal use of energy and increasing utilization of renewable energy sources to improve air quality and reduce greenhouse gases is presented as a vital necessity. These measures not only help reduce adverse environmental impacts but can also lead to reduced operational costs in agricultural production (Nabavi-Pelesarae *et al.*, 2022a). In this context, improper and excessive use of agricultural inputs such as chemical fertilizers, pesticides, and fossil fuels like diesel can result in severely destructive environmental consequences. These consequences include increased global warming, reduced biodiversity, and degradation of soil and air quality. Therefore, proper management of these inputs is essential to prevent environmental degradation and preserve natural resources (Mostashari-Rad *et al.*, 2020). Pollutants emitted from the consumption of various energy sources account for

[*] Corresponding author.
E-mail address: f.mondani@razi.ac.ir

two-thirds of total greenhouse gas emissions (Nabavi-Pelesaraei *et al*., 2022b). The emission of these gases has been due to human activities, such as deforestation and fossil fuel combustion (Nabavi-Pelesaraei *et al*., 2019). The agricultural sector's share in these emissions constitutes 10 to 12% of total emitted gases (Taherzadeh-Shalmaei *et al*., 2021). Studies show that in irrigated wheat production system, nitrogen and phosphorus fertilizers contribute significantly to increasing environmental pollutant indices (Taghinezhad and Vahedi, 2021). Another study showed that the environmental pollutants of dryland wheat production system were 1.85 times higher than its irrigated production system (Pourmehdi and Kheiralipour, 2023). Mondani et al. (2017) showed that the total energy consumption in irrigated and dryland wheat agroecosystems was 53082.9 and 15603.3 MJ $ha^{-1}$, respectively, and energy use efficiency was 22.1% higher in dryland wheat agroecosystem than irrigated wheat agroecosystems. They also stated that total greenhouse gas emissions for irrigated wheat agroecosystems were 3184.4 kg $CO_{2\text{-eq}}$ $ha^{-1}$ and 680.36 kg $CO_{2\text{-eq}}$ $t^{-1}$ while it was 553.1 kg $CO_{2\text{-eq}}$ $ha^{-1}$ and 381.3 kg $CO_{2\text{-eq}}$ $t^{-1}$ in dryland wheat agroecosystems. Zahedi et al. (2014) indicated that the energy use efficiency, specific energy and energy productivity of cotton production system were 0.7, 19.2 $MJ^{-1}$ kg and 0.10 kg $MJ^{-1}$, respectively.

Today, medicinal plants are among the important economic crops that are used in both raw and processed forms in traditional and modern medicine. In recent decades, the use of medicinal plants has increased in both developing and developed countries due to their wide range of biochemical activities, effectiveness, relative safety, and cost-effective preparation. Approximately one-quarter of manufactured drugs contain plant extracts or compounds derived from plant materials (Asigbaase *et al*., 2023). Coriander (*Coriandrum sativum* L.), belonging to the Apiaceae family, is an annual plant reaching 60 to 100 cm in height, with a growth period of 100 to 120 days. It is thermophilic and grows in various soil types. The essential oil from coriander fruits is used in pharmaceutical, cosmetic, and hygiene industries, while its grain oil is utilized in food and pharmaceutical industries. This plant is also used as a digestive aid, anti-flatulent, appetite stimulant, muscle pain reliever, and relaxant (Aminifard *et al*., 2020; Bahmaniyan *et al*., 2019). Beyond its medicinal aspects, coriander holds special economic and social significance as it is primarily cultivated by small-scale farmers and rural communities (Guimarães *et al*., 2024). Kermanshah province accounts for 7.2% of Iran's total crop harvesting area (854592 ha). This province contributes 4% of the country's total crop production (3.234 million tons), placing it seventh nationally. The cultivation area of medicinal plants in Kermanshah province is about 5500 ha, with an annual harvest of 11700 tons. Coriander production system in Kermanshah province covers about 3500 ha with a reported yield of 9900 tons (Agricultural Statistics, 2023). Coriander production in Kermanshah province is conducted under both drylands and irrigated production systems, using both traditional and modern cultivation methods.

Given increasing consumer awareness of environmental issues and their shifting preference toward food products with lower environmental impact and higher quality, the importance of studying and evaluating life cycle assessment and related indices in agricultural production processes has increased. In this context, it is essential to carefully examine the greenhouse gas emissions resulting from the consumption of various inputs, including fossil fuels, fertilizers, pesticides, and irrigation. Optimizing energy efficiency in production systems can significantly contribute to reducing operational costs, plant production expenses, and overall agricultural costs. Therefore, considering coriander's medicinal nature and its significant role in the food industry, the objectives of this study were i) to determine the amount of input and output energies, ii) to measure the amount of greenhouse gas emissions, and iii) to investigate the life cycle and related issues in irrigated and dryland coriander production systems.

## 2. Materials and methods

### *2.1. Study area*

This research was conducted during 2021-2023 in Kermanshah Province. Kermanshah Province, covering an area of 24640 $km^2$. The province, which comprises 1.5% of the country's total area, is among the western provinces sharing a border with Iraq. It is bounded by Kurdistan Province to the north, Lorestan and Ilam Provinces to the south, Hamadan Province to the east, and Iraq's Diyala and Halabja Provinces to the west.

### *2.2. Data collection*

The average cultivation area of coriander in Kermanshah province during the study period was about 4328 ha, and the required information was collected in different counties, taking into account irrigated and dryland production systems. The following introduces the characteristics of irrigated and dryland coriander production systems in Kermanshah Province.

### *2.3. Irrigated production system*

In the irrigated production system, pre-sowing soil preparation is performed using a moldboard plow followed by disk harrowing. Additionally, ridges are created using a furrower to form plots 2-3 m wide for irrigation. In this method, sowing is done using a grain row planter. Seeds are planted in January, and harvesting is conducted using a mower in late June to early July. The sowing depth is about 5 cm and the distance between rows is 10 to 15 cm. Since the coriander's water requirement is low, it is watered once or twice during the growing season. Irrigation is usually done by flood or traditional methods. After collection and drying, coriander is threshed using a combine harvester.

### *2.4. Dryland production system*

In the dryland production system, pre-sowing soil preparation is similar to irrigated production system. In some cases, a chisel plow replaces the moldboard plow, though the latter is more commonly used. In this production system, sowing is done using a grain row planter, which reduces seed consumption. The sowing depth is about 5 cm and the distance between rows is 10 to 15 cm. Harvesting is performed either traditionally using a sickle or mechanically using a mower, and after collection and drying, a combine harvester is used for threshing. The average of cultivation areas during 2021-2023 is shown in Table 1.

**Table 1. The average cultivated area of coriander for each production system and in each county during the study period**

| County | Dryland (ha) | Irrigated (ha) | Total (ha) |
|---|---|---|---|
| Kangavar | 200 | 700 | 900 |
| Sahneh | 80 | 1450 | 1530 |
| Kermanshah | 200 | 656 | 856 |
| Sonqor | 45 | 60 | 105 |
| Harsin | 205 | 732 | 937 |
| Total | 730 | 3598 | 4328 |

According to information from Kermanshah Province's Agricultural Organization, there are 3500 coriander farmers, of whom 2500 practice irrigated production system and 1000 practice dryland production system. Among these, approximately 200 producers have been identified who each dedicate at least 5 hectares to this crop. The Cochran formula was used to determine the sample size, and data were collected from 131 farmers. This data was obtained to examine the various stages of coriander cultivation, including planting, growing, and harvesting. The selected farmers for this assessment all allocated at least 5 hectares to coriander cultivation and had experience in growing this crop.

### *2.5. Energy indices measurement*

The collected data for evaluating energy indices included all inputs used in the planting, growing, and harvesting stages, as listed in Table 2. For energy index evaluation, these data are multiplied by energy equivalents to calculate input and output energy in production systems. The energy equivalents of various inputs, including seeds, chemical fertilizers, pesticides, human labor, diesel fuel, etc., are shown in Table 2.

**Table 2. Energy coefficients and inputs used in different coriander production systems**

| Inputs | Unit | Energy equivalent (MJ) | References |
|---|---|---|---|
| Human labor | h | 1.96 | Kaab et al. (2019) |
| Machinery | h | 62.70 | Ghasemi-Mobtaker et al. (2020) |
| Diesel fuel | L | 56.31 | Nabavi-Pelesaraei et al. (2018) |
| Nitrogen | kg | 66.14 | Nabavi-Pelesaraei et al. (2018) |
| Phosphate ($P_2O_5$) | kg | 12.44 | Nabavi-Pelesaraei et al. (2018) |
| Potassium ($K_2O$) | kg | 11.15 | Nabavi-Pelesaraei et al. (2018) |
| Micronutrients | kg | 120 | Hesampour et al. (2022) |
| Manure | kg | 0.30 | Tuti et al. (2012) |
| Seed | kg | 14.48 | Dekamin et al. (2022) |
| Grain yield | kg | 14.80 | Dekamin et al. (2022) |

Various indices are used to examine energy consumption and production in agricultural production processes. These indices enable a comprehensive evaluation of energy status in agriculture. The indices considered include energy ratio, energy productivity, energy intensity, and net energy gain (Table 3). All indices were examined based on a functional unit of one hectare to enable comparison between production systems, as analysis based on one ton could differ from hectare-based analysis due to varying yield weights in each system (Jalilian *et al*., 2023b).

**Table 3. Energy indicators in different coriander production systems**

| Index | Unit | Formula |
|---|---|---|
| Energy Ratio | Ratio | Output energy (MJ $ha^{-1}$) / Input energy (MJ $ha^{-1}$) |
| Energy Productivity | kg $MJ^{-1}$ | Yield (kg $ha^{-1}$) / Input energy (MJ $ha^{-1}$) |
| Specific Energy | MJ $kg^{-1}$ | Input energy (MJ $ha^{-1}$) / Yield (kg $ha^{-1}$) |
| Net Energy Gain | MJ $ha^{-1}$ | Output energy (MJ $ha^{-1}$) – Input energy (MJ $ha^{-1}$) |

*2.6. Economic index measurements*

For economic index evaluation, the share of each production factor in total cost was calculated. The calculated production cost includes variable costs and costs related to used inputs. Fixed costs were rent, insurance, and machinery depreciation. Variable costs, on the other hand, change with production volume, such as input purchase costs, labor wages, and similar items. Consumption costs are calculated in dollars based on the current exchange rate (1 US dollar equivalent to 60,000 tomans) to ensure consistent price estimation across different times (Mostashari-Rad *et al*., 2021). After estimating and calculating the required information, the economic indices of coriander production were calculated using Equations 1-4 (Jalilian *et al*., 2023a).

$$\text{Gross production value (\$ ha}^{-1}\text{)} = \text{Coriander yield (kg ha}^{-1}\text{)} \times \text{Selling price (\$)} \quad (1)$$

$$\text{Net income (\$ ha}^{-1}\text{)} = \text{Gross production value (\$ ha}^{-1}\text{)} - \text{Total production cost (\$ ha}^{-1}\text{)} \quad (2)$$

$$\text{Economic productivity} = \frac{\text{Coriander yield (kg)}}{\$} \quad (3)$$

$$\text{Benefit to cost ratio} = \frac{\text{Gross production value (\$ ha}^{-1}\text{)}}{\text{Total production cost (\$ ha}^{-1}\text{)}} \quad (4)$$

*2.7. Environmental indices measurement*

The ReCiPe 2016 method was selected to evaluate environmental pollutant emissions (Mostashari-Rad *et al*., 2021). This method is an update of ReCiPe2008, featuring three endpoints and 17 midpoints, based on global rather than European scale, though it can be applied to any country or continent (Huijbregts *et al*., 2017). Using this method, three endpoints will be examined: human health, resources, and ecosystems. Human health is measured in DALYs (Disability-Adjusted Life Years), where one damage equal to either the loss of one year of life for one person or one person living four years with 25% disability. Ecosystem impact is measured in (species. yr), indicating the disappearance of all species from one square meter over one year. Resources are measured in USD 2013, indicating the economic value of resources in dollars. The life cycle assessment project includes four fundamental stages: 1. Goal and scope definition; 2. Inventory analysis; 3. Life cycle impact assessment; and 4. Results interpretation. An essential action in the goal and scope definition stage is determining the system boundary. In this research, the system boundary is defined from planting to harvesting of coriander. SimaPro V. 9.5.0 software was used for life cycle assessment calculations, while Office software was used for writing and figure creation.

## 3. Results and discussion

*3.1. Energy indices*

Analysis of energy input in irrigated coriander production systems showed that the highest values were 8446, 6000, and 4129 MJ $ha^{-1}$ for diesel fuel, manure, and chemical fertilizers, respectively, while human labor had the lowest share of total input energy at 78 MJ $ha^{-1}$ (Table 4). In dryland production system, the highest energy inputs were 4504 and 1803 MJ $ha^{-1}$ for diesel fuel and chemical fertilizers, respectively, with human labor showing the lowest input (Table 4). In both production systems, nitrogen had a higher share compared to other chemical fertilizers (Table 4). Total energy input for irrigated and dryland production systems was 20999 MJ $ha^{-1}$ and 7883 MJ $ha^{-1}$, respectively, with irrigated systems requiring 166% more input energy (Table 4). The total output energy for irrigated and dryland production systems was 44400 and 10360 MJ $ha^{-1}$, respectively, with irrigated production system showing 328% higher output energy than dryland production system (Table 4). Analysis of input shares in irrigated production system showed that chemical fertilizers, manure, and diesel fuel accounted for 36.21%, 27.09%, and 25.42% of total energy input, respectively, totaling approximately 88% (Fig. 1). In the dryland production system, diesel fuel and chemical fertilizers had the highest shares of total energy input at 57.14% and 22.87%, respectively (Fig. 1). Human labor contributed the lowest share in both production systems (Fig. 1).

Analysis of energy indices showed that irrigated production system outperformed dryland production system in terms of energy ratio, energy productivity, energy intensity, and net energy gain, with advantages of 61% in energy ratio, 55% in energy productivity, 56% in energy intensity, and 843% in net energy gain (Table 4). Although irrigated coriander production system had higher energy input due to greater use of chemical inputs and diesel fuel compared to dryland production system, it generated higher energy output and energy gain due to higher yields. However, optimization of energy use should focus on improving the identified high-energy input priorities. In a study examining energy consumption in peanut production in Gilan province, results showed that total energy input and energy output were about 19248 and 87210 MJ ha$^{-1}$, respectively, with chemical fertilizers accounting for the highest share (45%) of energy input (Nabavi-Pelesaraei *et al*., 2022a). Evaluation of energy indices in dry melon production in Ilam County showed total energy input and energy output were 39021 and 39190 MJ ha$^{-1}$, respectively. Diesel fuel accounted for 51% of total energy consumption, followed by agricultural machinery (24%) and nitrogen fertilizer (14%) (Kaab *et al*., 2021). Another study reported that in a meta-analysis based on principal component analysis of 628 observations, irrigation water significantly increased grain yield by 142%, energy input by 120%, energy production by 133%, and net energy profit by 152% compared to dryland conditions (Nasseri, 2024).

**Table 4. The amount of energy indicators, average of energy input and energy output for coriander production systems (ha$^{-1}$)**

| Inputs | Dryland | | Irrigated | |
|---|---|---|---|---|
| | Amount | Energy (MJ ha$^{-1}$) | Amount | Energy (MJ ha$^{-1}$) |
| Human labor | 16.0 | 31.4 | 40.0 | 78.4 |
| Machinery | 20.0 | 1254.0 | 30.0 | 1881 |
| Diesel fuel | 80.0 | 4504.8 | 150.0 | 8446.5 |
| Nitrogen | 23.0 | 1521.2 | 46.0 | 3042.4 |
| Phosphate ($P_2O_5$) | 11.5 | 143.1 | 34.5 | 429.2 |
| Potassium ($K_2O$) | 12.5 | 139.4 | 37.5 | 418.1 |
| Micronutrients | 0.0 | 0.0 | 2.0 | 240.0 |
| Manure | 0.0 | 0.0 | 20000.0 | 6000.0 |
| Seed | 20.0 | 289.6 | 32.0 | 463.4 |
| Total energy inputs | | 7883.41 | | 20999.1 |
| Total energy output (grian yield) | 700.0 | 10360.0 | 3000.0 | 44400.0 |
| Energy Ratio (Ratio) | | 1.31 | | 2.11 |
| Energy Productivity (kg MJ$^{-1}$) | | 0.09 | | 0.14 |
| Specific Energy (MJ kg$^{-1}$) | | 11.3 | | 7.0 |
| Net Energy Gain (MJ ha$^{-1}$) | | 2476.6 | | 23401.0 |

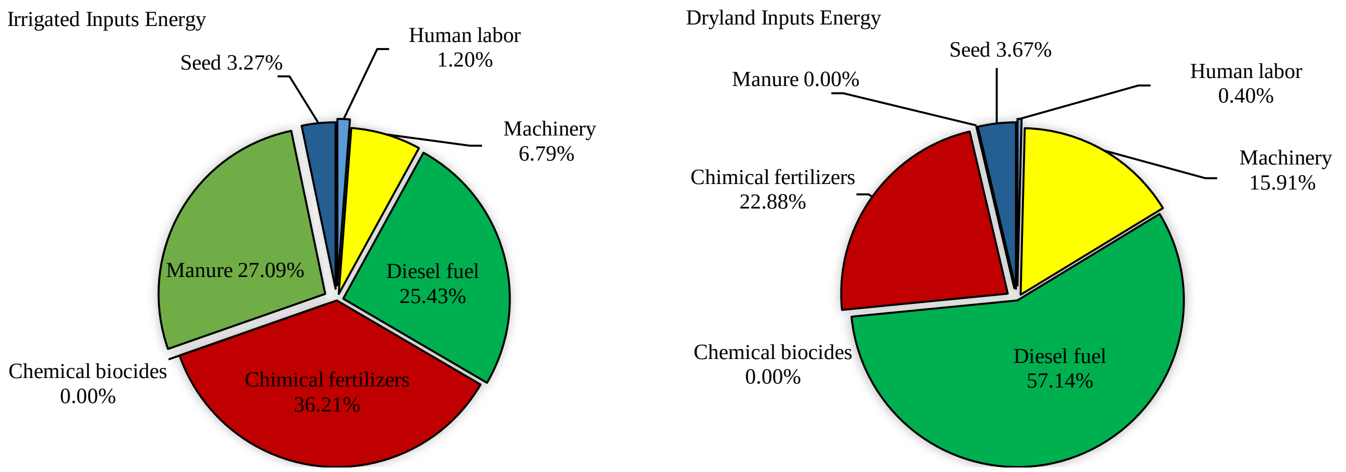


**Figure 1. The contribution of inputs to the total energy input in coriander production for irrigated and dryland systems**

### *3.2. Economic indices*

Analysis of gross production value for coriander production systems showed the highest value of 2850 USD ha$^{-1}$ under irrigated conditions, demonstrating a 328% advantage over dryland cultivation (Table 5). This superiority was achieved due to higher yield per hectare. Examination of net income showed that irrigated production system generated 841.88 USD $ha^{-1}$ compared to 8.24 USD $ha^{-1}$ in the dryland production system, providing significantly higher profits to farmers due to higher yields (Table 5).

**Table 5. Economic indices and production costs in different coriander production systems**

| Item | $ Unit$^{-1}$ | Dryland ($ $ha^{-1}$) | Irrigated ($ $ha^{-1}$) |
|---|---|---|---|
| Human labor (h) | 1.25 | 20.00 | 50.00 |
| Machinery (h) | 13.33 | 266.67 | 400.00 |
| Diesel fuel (L) | 0.01 | 0.80 | 1.50 |
| Nitrogen (kg) | 0.14 | 3.25 | 6.50 |
| Phosphate ($P_2O_5$) (kg) | 0.51 | 5.96 | 17.88 |
| Potassium ($K_2O$) (kg) | 0.54 | 6.75 | 20.25 |
| Micronutrients (kg) | 6.66 | 0.00 | 13.33 |
| Manure (kg) | 0.006 | 0.00 | 133.33 |
| Seed (kg) | 1 | 20.00 | 32.00 |
| Land rent ($) | - | 333.33 | 1333.33 |
| Total production cost | $ $ha^{-1}$ | 656.76 | 2008.13 |
| Economic and competitive indicators | | Dryland | Irrigated |
| Gross production value | | 665.00 | 2850.00 |
| Net income | | 8.24 | 841.88 |
| Economic efficiency | | 1.07 | 1.49 |
| Benefit to cost ratio | | 1.01 | 1.42 |

Economic efficiency, which indicates the yield per dollar invested, showed that irrigated production system achieved 1.49 kg $USD^{-1}$ $ha^{-1}$, representing a 39.25% advantage over dryland production system, attributed to higher yields and net profit (Table 5). The benefit-to-cost ratio analysis showed that irrigated production system at 1.42 significantly outperformed dryland production system at 1.01 in this important production profitability indicator (Table 5). Another study reported that in irrigated and dryland wheat production systems in Lorestan province, the highest cost was related to the consumption of chemical inputs and the use of machinery. Also, the economic income of irrigated production system was higher than that of dryland production system due to higher grain yield (Fatolahi *et al*., 2017). Positive cost-benefit ratio and high economic returns have also been reported in coriander production system in India (Meena *et al*., 2020). The researchers also stated that there is a need to optimize the use of chemical fertilizers to reduce production costs. In the modern rice production system, economic value was higher compared to the traditional rice production system in Myanmar (Htwe *et al*., 2021).

### *3.3. Environmental indices*

Analysis of ReCiPe 2016 midpoint environmental indicators in the irrigated coriander production system showed that direct emissions and nitrogen consumption (indirect emissions) had higher contributions compared to other inputs in most indicators (Fig. 2). In the dryland coriander production system, direct emissions had the greatest impact on indicators including climate change human health, human toxicity, photochemical oxidant formation, particulate matter formation, climate change ecosystems, terrestrial acidification, freshwater eutrophication, and terrestrial ecotoxicity, followed by nitrogen fertilizer. For other indicators, nitrogen fertilizer showed the highest impact (Fig. 2). Amount of environmental pollutants was 65 and 35% in the irrigated and dryland production systems, respectively. This indicated that optimization priority for input consumption, such as diesel fuel and chemical fertilizers, should first focus on irrigated production system (Fig. 2). This optimization should not compromise production sustainability. It is also necessary to emphasize increasing yield while reducing the consumption of chemical inputs in the dryland production system.

Analysis of final environmental damage indicators in three categories (human health, ecosystem, and resources) in the irrigated production system showed that direct emissions from coriander production per hectare had the greatest impact on human health and ecosystem indicators. Nitrogen fertilizer and machinery (indirect emissions) ranked next in impact. For the resources indicator, diesel fuels ranked first, followed by nitrogen fertilizer and machinery (Fig. 3).

In the dryland production system, direct emissions from coriander production per hectare, nitrogen fertilizer, and agricultural machinery had the highest impact on human health and ecosystem indicators. For the resources indicator, diesel fuels had the greatest impact, followed by machinery and nitrogen fertilizer (Fig. 3). A comparison of irrigated and dryland production systems showed that about 65% of pollutants in all three indicators were attributed to irrigated production system, primarily due to higher consumption of chemical inputs and diesel fuels (Fig. 3). With the mechanization of both dryland and irrigated coriander production system, diesel fuel consumption has increased, consequently increasing its contribution to indicator damage. The significant contribution of nitrogen fertilizer, similar to other sectors, necessitates sustainable agricultural approaches and movement toward increasing soil organic matter through available methods to reduce chemical fertilizer use. Other studies indicated that inputs such as nitrogen and phosphorus were the primary causes of acidification and eutrophication in rice production, and optimizing chemical fertilizer use could reduce these pollutants (Escobar *et al*., 2022; Xu *et al*., 2020). Research by Khanali et al. (2018) showed that nitrogen fertilizer and animal manure were major factors in increasing the global warming index. Nevertheless, nitrogen fertilizer remains essential in modern agriculture and plays a crucial role in meeting the food needs of the growing population. However, its use can lead to environmental damage, making optimization of its consumption necessary to reduce these impacts (Tyagi *et al*., 2022). Another study showed that irrigated crop production systems cause more environmental damage compared to dryland production systems due to higher chemical input consumption, and nitrogen fertilizer contributes significantly to environmental pollutants (Pourmehdi and Kheiralipour, 2023; Taghinezhad and Vahedi, 2021).

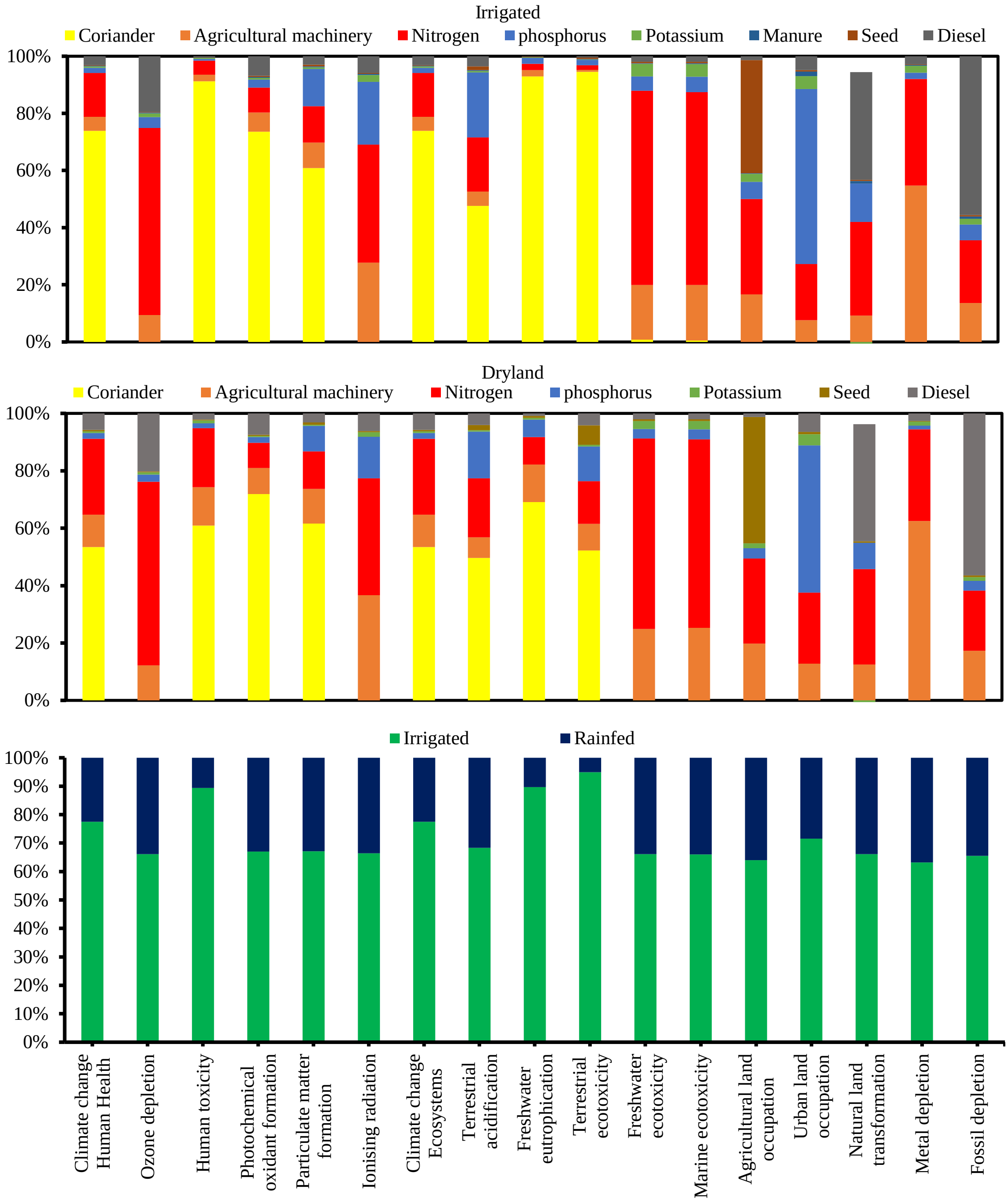


**Figure 2. Intermediate indicators for the cultivation of coriander in dryland and irrigated systems**

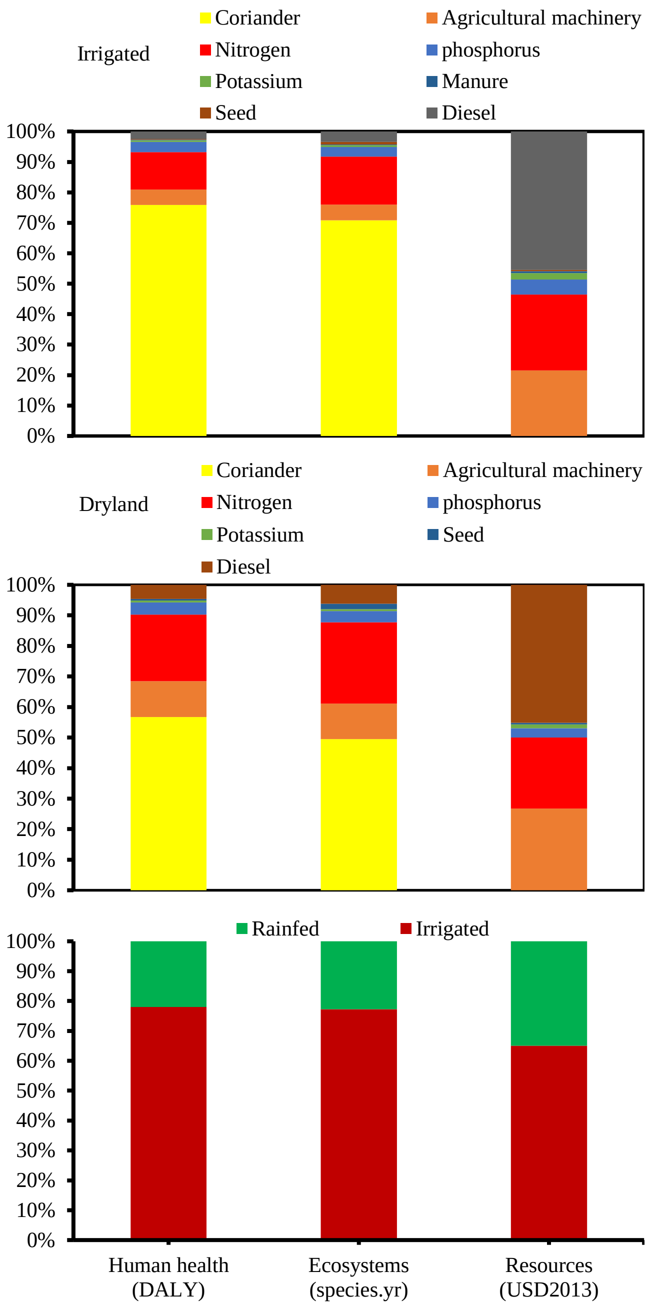


**Figure 3. Final indicators for the cultivation of coriander in dryland and irrigated systems**

## 4. Conclusion

This study demonstrated that the irrigated coriander production system performs better than the dryland production system in terms of energy efficiency and economic production. In the irrigated production system, higher energy input and output were recorded due to the increased use of diesel fuels and chemical fertilizers, contributing to increased production and farmer profitability. Additionally, in the irrigated production system, higher energy productivity and net energy gain were higher compared to dryland systems. However, these advantages come with significant environmental impacts, with irrigated production system accounting for 65% of environmental pollutants. These pollutants result from the high consumption of fossil fuels and chemical fertilizers, potentially leading to environmental issues such as climate change and water pollution; therefore, optimizing input consumption, reducing chemical fertilizer use, and moving toward sustainable agricultural methods can help reduce environmental impacts while maintaining productivity in irrigated production system. Furthermore, improving dryland cultivation methods to increase production and reduce input consumption can be considered as a complementary approach.

### Conflict of interests

All authors declare no conflict of interest.

### Ethics approval and consent to participate

No humans or animals were used in the present research. The authors have adhered to ethical standards, including avoiding plagiarism, data fabrication, and double publication.

### Consent for publications

All authors read and approved the final manuscript for publication.

### Availability of data and material

All the data are embedded in the manuscript.

### Authors' contributions

All authors had an equal role in study design, work, statistical analysis and manuscript writing.

### Informed consent

The authors declare not to use any patients in this research.

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