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Greenhouse gas (GHG) emissions in fruit production-I: berries, nuts and citrus

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Abstract

The greenhouse gas emission values obtained from agricultural activities such as tillage, pruning, spraying, fertilizing, harvesting and transporting etc. are not at a negligible level when compared to other sectors. Each practice has an energy input amount. There have been studies on many agricultural products all over the World. Therefore, the carbon dioxide equivalent ($CO_{2\text{-}eq}$) emissions associated with agricultural processes were compared in this study with selected berry, nut and citrus fruits.

As a result; when the greenhouse gas emission equivalent values are examined on a fruit basis, strawberry fruit has 34517.75 kg $CO_{2\text{-}eq}$ per ha amount has the highest input. Wolfberry fruit also follows strawberry fruit with a value of 20718.66 kg$CO_{2\text{-}eq}$ per ha. The minimum greenhouse gas emission equivalent is in tangerine fruit with 399.89 kg $CO_{2\text{-}eq}$ per ha.

Keywords: GHG, Berry, Nuts, Citrus, Fruit

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INTRODUCTION

Energy is an important factor for both nature and social life. Energy production, transformation and consumption are considered important inputs for the environment and sustainable development. Energy production causes significant environmental problems that harm the ecosystem. Energy systems emit various emissions into the environment at different stages from energy production to consumption and disposal. The most important of these is greenhouse gas (GHG) emissions. GHG is a gas in an atmosphere that absorbs and spreads radiation within the thermal infrared range. Keeping these emissions to a minimum is necessary for sustainable development. Energy use, GHG emissions and their potential effects on global climate change are among the current discussions. In this context, increased energy consumption leads to significant environmental issues such as GHG emissions that harm human health.

The natural environment is affected by all human activities. Fossil fuel consumption, which has continued to increase since the beginning of the industrial revolution and has reached very high levels, is the main reason for the emergence of energy environmental problems. Environmental effects caused by energy production can be listed as acid pollutants, global warming, human health and safety problems, particles, heavy metals, disaster probability, waste problems, bad images, noise, light pollution, radiation pollution and land use.

The total greenhouse gas emissions was 219.5 million tonnes $CO_{2\text{-}eq}$ in 1990 and increased to 564.4 million tonnes $CO_{2\text{-}eq}$ in 2021. The share of agriculture is equal to 21.00% in 1990 and 12.77% in 2021 (TUIK, 2024).

In this study, published papers till 2024 on energy analysis in berry, nuts and citrus production were evaluated in terms of GHG emissions. The total energy input and total $CO_{2\text{-}eq}$ values were given and the percentage of input parameters on $CO_{2\text{-}eq}$ were also given as graphs.

MATERIALS AND METHODS

Greenhouse gas emissions are calculated by using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines. The greenhouse gas emissions statistics press release includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F-gases) which are direct GHGs originating from energy, industrial processes and product use, agriculture and waste sectors. İndirect GHG emissions from nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and sulphur dioxide (SO_2) are not included. Emissions and removals from land use, land use change and forestry are not included in the press release (TUIK, 2024).

Agricultural production necessitates the use of a variety of input materials such as fertilizers, biocides, seeds, and energy carriers such as natural gas and diesel fuel. The production, formulation, storage, and distribution of agricultural inputs result in the use of energy sources that trigger the combustion of fossil fuels and the release of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere (Lal, 2004).

This study compares GHG emission values in different norms using prior research and statistical data in berry, nut and citrus production. These fruits are berries as grape, pomegranate, strawberry, wolfberry, nuts as almond, pistachio, walnut, citrus as orange, lemon, mandarin and grapefruit.

The following equation is used to define the GHG emissions;

$$GHG_{ha} = \sum_{i=1}^{n} R(i) \times EF(i)$$

GHG_{ha}: GHG emission $\left(kg\ CO_{2-eq}/ha\right)$,
$R(i)$: Amount of i input $\left(unit_{input}/ha\right)$,
$EF(i)$: GHG emission equivalent of i input $\left(kg\ CO_{2-eq}\ per\ input\right)$.

In this study, only published papers were evaluated according to the each fruit. So, the place and country were given in the graphs and text. In some fruits there are limited information in the literatures.

Table 1. Greenhouse gas (GHG) emissions coefficients in agriculture production

Input Parameters	Unit	GHG Coefficient (kg CO_{2-eq}per unit)	References
Human	h	0.700	Eren et al., 2019a
Animal	h	0.043	Gokdogan et al., 2022
Diesel	L	2.760	Eren et al., 2019b
Gasoline	L	2.350	Annoymous, 2024
Propane	L	1.525	Annoymous, 2024
Farm Machinery	MJ	0.071	Agizan et al., 2024
Pesticides	kg	5.210	Alizadeh and Taromi, 2014
Herbicides	kg	6.300	Khoshnevisan et al., 2014
Insecticides	kg	5.100	Moe et al., 2024
Fungucides	kg	3.900	Taki et al., 2013
Organic Chemicals	kg	5.100	Agizan et al., 2024
Acaroids	kg	5.100	Ozalp et al., 2018
Farmyard Manure	ton	0.005	Baran et al., 2023
Chemical Fertilizer	kg	4.550	Ekinci et al., 2020
Nitrogen	kg	1.300	Pishgar-Komleh et al., 2012
Phosphate	kg	0.200	Seydosoglu et al., 2023
Potassium	kg	0.200	Kazami and Zardari, 2018
Sulphur	kg	0.370	Sari and Gokdogan, 2024
Lime	kg	0.390	Ekinci et al., 2020
Ferrum	kg	4.550	Ekinci et al., 2020
Microelements	kg	4.550	Ekinci et al., 2020
Organic Fertilizer	kg	0.129	Agizan et al., 2024
Electricity	kWh	0.608	Candemir et al., 2024
Water	m^3	0.170	Kulekci and Sari, 2020
Transportation	ton km	0.150	Gokdogan et al., 2024
Plastic	kg	3.120	Annoymous, 2024

RESULTS AND DISCUSSION

BERRIES

Grape

Figure 1 shows the total energy input and CO_{2-eq} values in grape production in the World. The highest GHG amount was 6257.4 kg CO_{2-eq} per ha in the West Azerbaijan (Iran) (Mardani and Taghavifer, 2016). When the total energy input values were evaluated, it reached to 82193.2 MJ/ha in East Azerbaijan (Iran) (Sattari-Yuzbashkandi et al., 2014). It was minimum in Thrace Region (Turkey) (Akdemir, 2022) with 12144.6 MJ/ha.

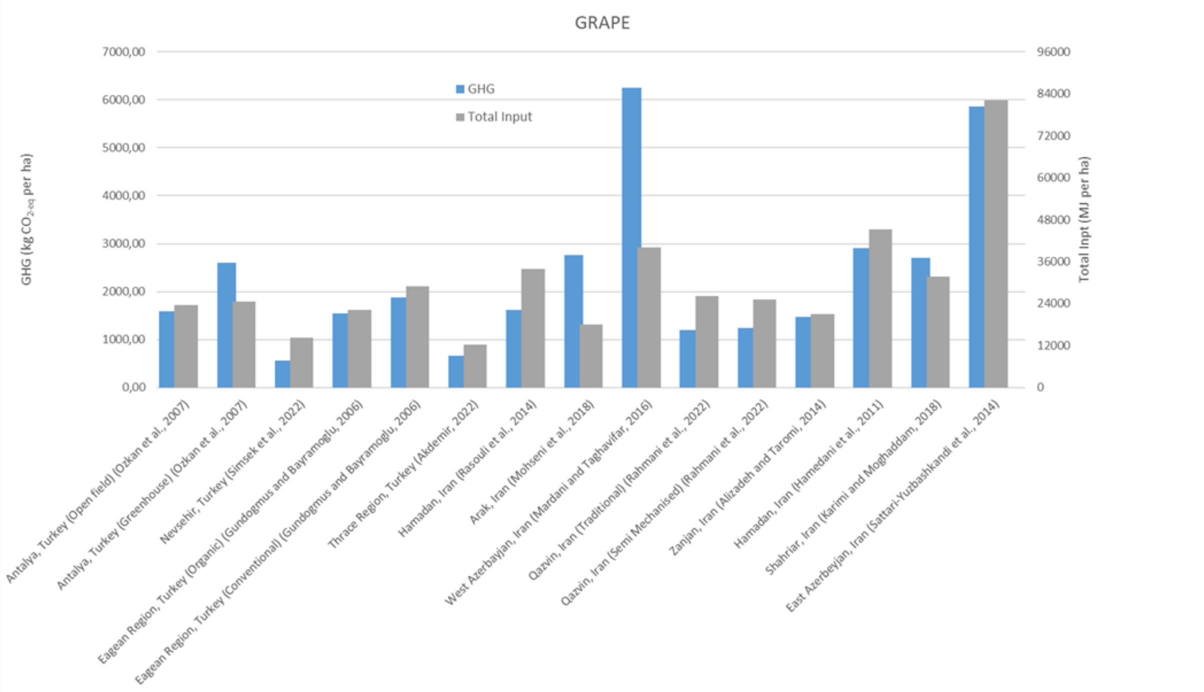

Figure 1. CO_{2-eq} and total energy input values in grape production in the Iran and Turkey.

Figure 2 shows input rates in grape production in the World and Turkey. In grape production, the input rate in human labor was used the most in Antalya (Turkey) (Ozkan et al., 2007) with 57.45%. In Nevsehir (Turkey) (Simsek et al., 2022), the input rates in farm machinery and diesel were used the most with 26.92% and 37.73%, respectively, as seen in Figure2. The highest pesticide use is in Zanjan (Iran) (Alizadeh and Taromi, 2014) with a rate of 29.48%. Although the use of herbicides and insecticides is low, the rate of fungicide is 12.64% in the Eagean Region (Turkey) (Gundogmus and Bayramoglu, 2006). Nitrogen was used the most in Qazvin (Iran) (Rahmani et al., 2022) with a rate of 20.40% among chemical fertilizers. In the Thrace Region (Turkey) (Akdemir, 2022), the input in sulphur is the highest with a rate of 13.88%, as seen in Figure 2. The electricity input parameter is in Hamadan (Iran) (Rasouli et al., 2014) with a rate of 25.62%. Among the parameters used in grape production, the highest input rate is in the West Azerbaijan (Iran) (Mardani and Taghavifer, 2016) region with 63.90%.

Pomegranate

In pomegranate production, the maximum GHG emission value is 4307.4 kg CO_{2-eq} per ha in Mazandaran (Iran) (Nouri-Khjebelagh et al., 2023) as seen in Figure 3. Its' minimum value was 832.3 kg CO_{2-eq} per ha in Mazandaran (Iran) (Troujeni et al., 2018) in another study. The total energy input was ranged between 11195.1 in Mazandaran (Iran) (Troujeni et al., 2018) and 54934.6 MJ/ha in Antalya (Turkey) (2.1-4.0 ha) (Ozalp et al., 2018).

Figure 4. shows the input rates in pomegranate production in the World. Berry fruits are mostly collected by hand. Therefore, the human factor is among the important parameters. In pomegranate production, the input rate of human labor is 41.22% in Antalya (Turkey) (Akcaoz et al., 2009) as seen in Figure 4. The input in diesel was used the most in Mazandaran (Iran) (Troujeni et al., 2018) with a rate of 30.20%. Figure 4 shows that, the input rate of farm machinery is used the most in Antalya (Turkey) (Ozalp et al., 2018) with 13.91%. There is no pesticide use in pomegranate production in Turkey. However, the highest pesticide use is in Fars (Iran) (34.39%) (Housyar et al., 2017). The use of herbicides, insecticides and fungicides in pomegranate fruit is low. The input rates of these chemicals in Antalya (Turkey) are 3.43%, 5.81% and 9.92%, respectively. The use of farmyard manure in pomegranate production is low with a rate of 0.2% in Antalya (Turkey) (Ozalp et al., 2018). The chemical fertilizers used in pomegranate production are nitrogen, phosphate and potassium. Among these fertilizers, nitrogen was used the most in Antalya (Turkey) (Ozalp et al., 2018) with a rate of 21.34%. Electricity use in

Antalya (Turkey) (Ozalp et al., 2018) is 29.08%. It is seen in Figure that, water is used the most in Mazandaran (Iran) (Nouri-Khjebelagh et al., 2023) with a rate of 63.15%.

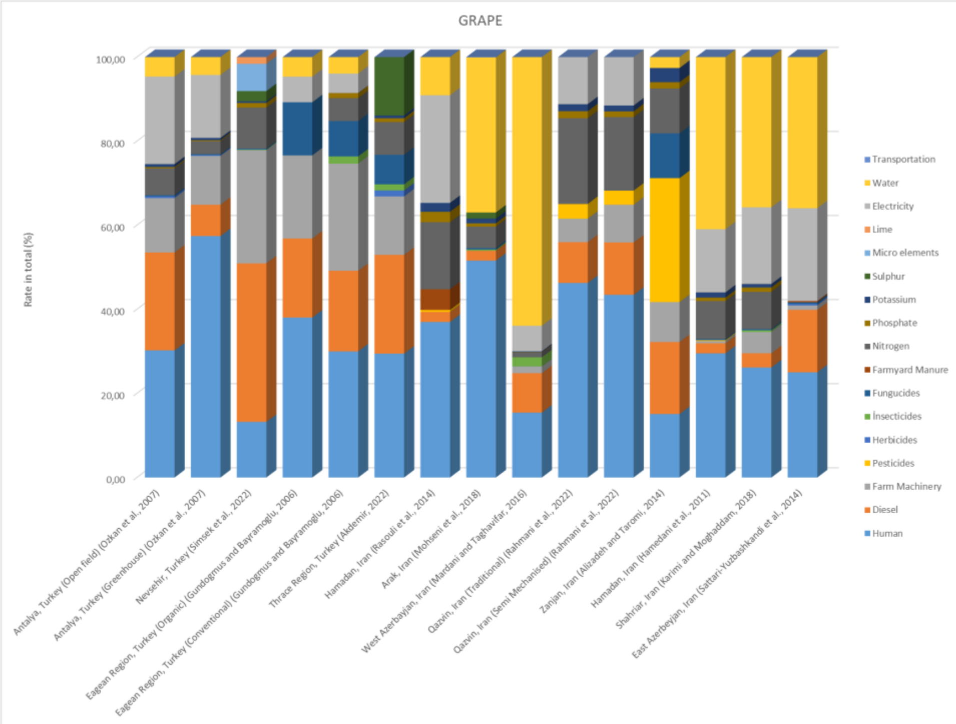

Figure 2. Percentage of input parameters in grape production in the Iran and Turkey

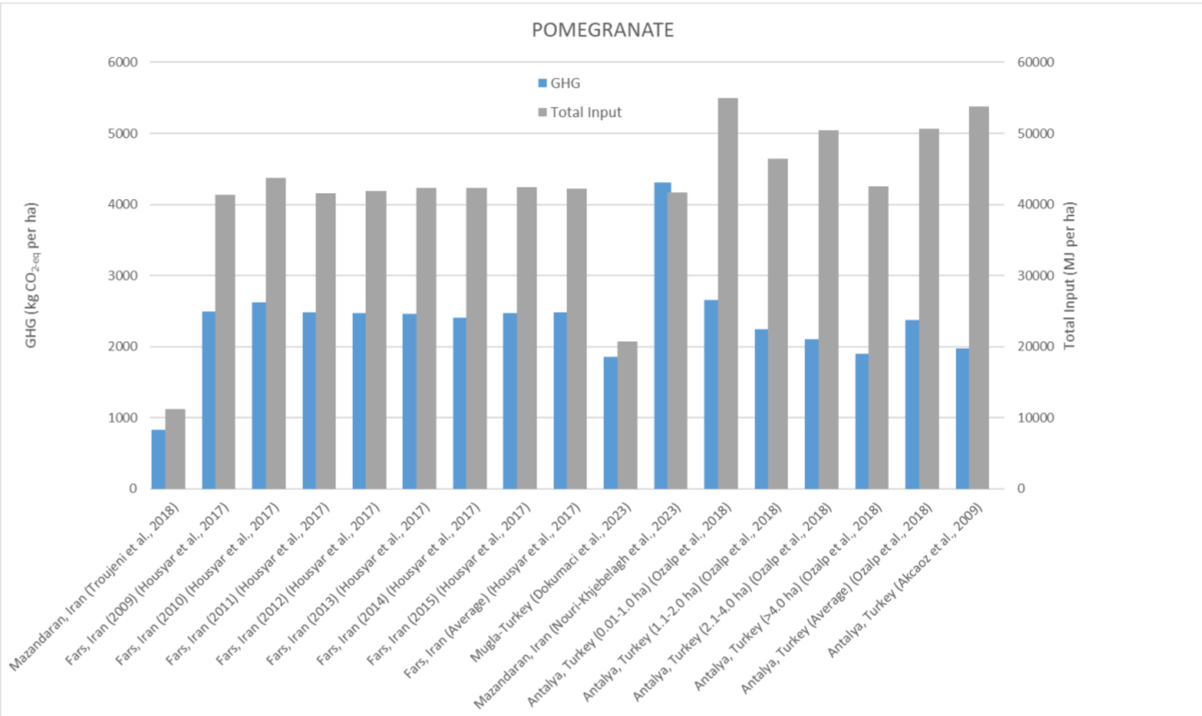

Figure 3. $CO_{2\text{-eq}}$ and total energy input values in pomegranate production in the Iran and Turkey

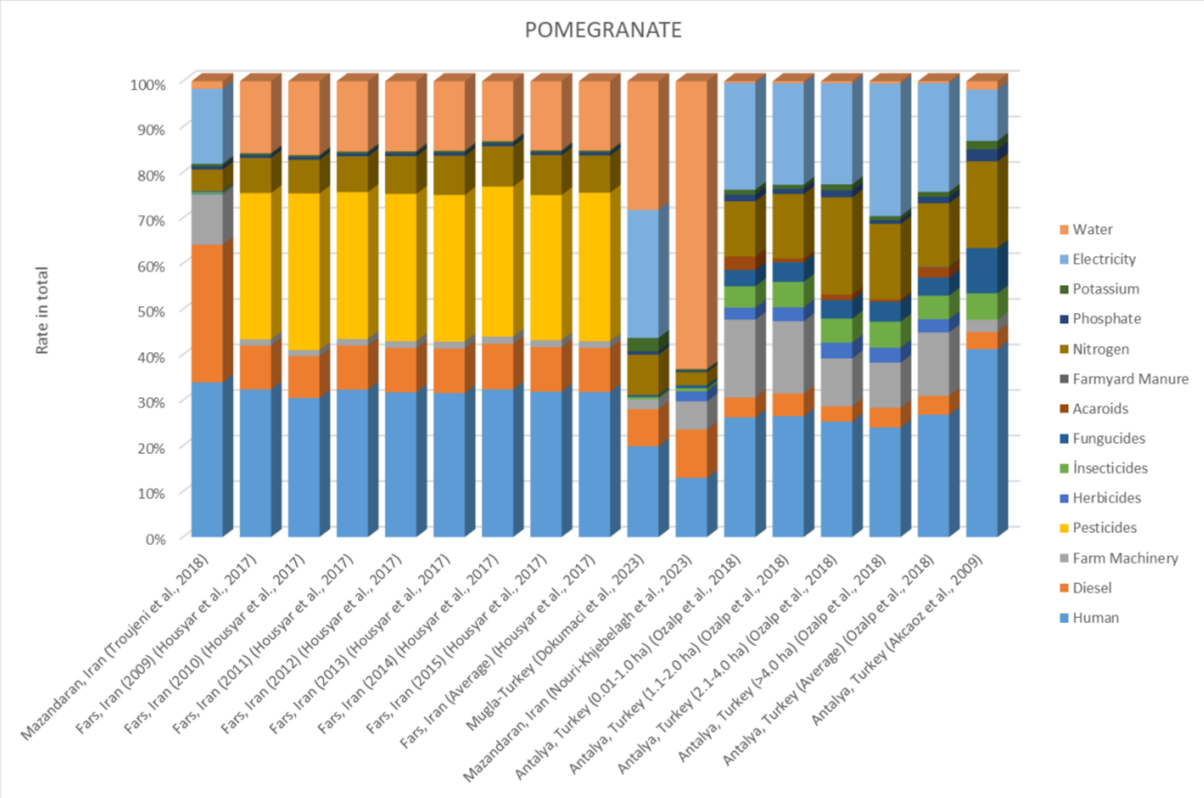

Figure 4. Percentage of input parameters in pomegranate production in the Iran and Turkey

Strawberry

Figure 5 shows the $CO_{2\text{-eq}}$ values in strawberry production in the World. The max GHG emission value was calculated as 34517.76 kg $CO_{2\text{-eq}}$ per ha in Guilan (Iran) (Greenhouse) (Khoshnevisan et al., 2013). This value was 9145.5 kg .$CO_{2\text{-eq}}$ per ha in Nevsehir (Turkey) (Organic) (Baran et al., 2017). The total energy input value ranged between 35092.4 (open field) and 1356932.8 (greenhouse) MJ/ha in Guilan (Iran) (Khoshnevisan et al., 2013).

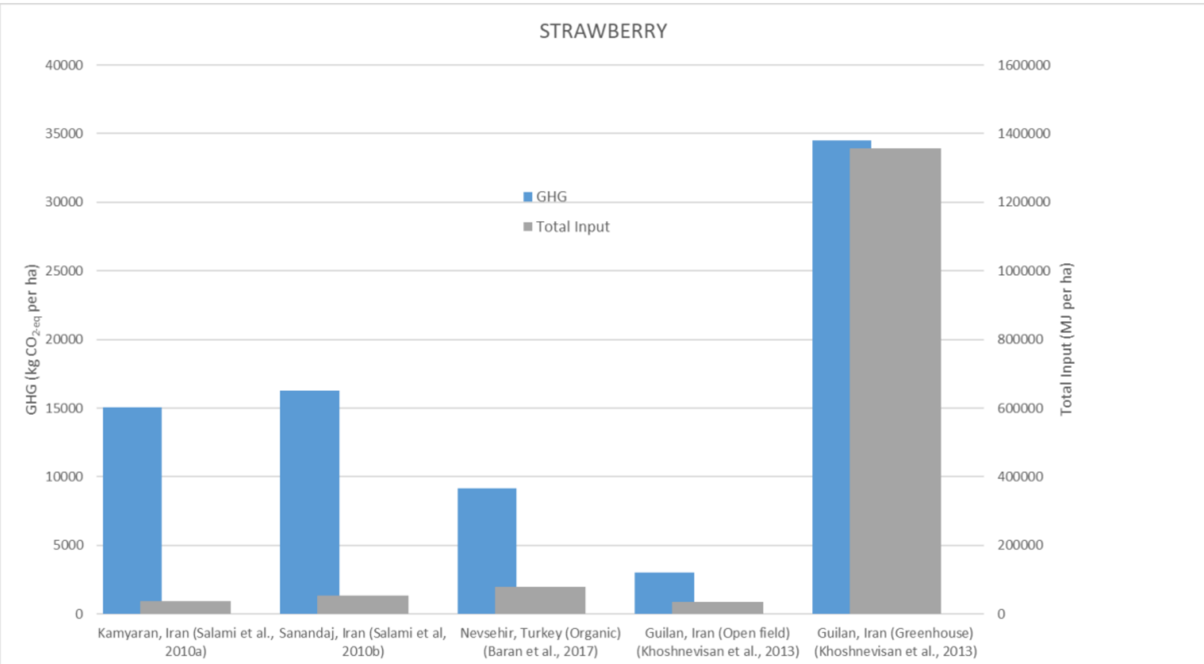

Figure 5. $CO_{2\text{-eq}}$ and total energy input values in strawberry production in the Iran and Turkey

Figure 6. shows the percentage of input parameters in strawberry production in the World. The human factor is of great importance in strawberry production. Therefore, when looking at Figure 6, it is seen that the input rate of human labor is 68.39% in the Guilan (Iran) (Open field) (Khoshnevisan et al., 2013). The use of farm machinery in strawberry production is at low levels. The rate of diesel in total GHG is also low in Guilan (Iran) (Khoshnevisan et al., 2013) with 2.60%. Pesticide use has high rates in Kamyaran and Samandaj (Iran) (Salami et al., 2010a,b). It is used the most in Samandaj (Iran) (Salami et al., 2010b) with a rate of 63.11%. Organic chemicals and fertilizers are used only in Nevsehir (Turkey) (Baran et al., 2017). The rates are 1.25% and 2.82%, respectively. The highest use of chemical fertilizers is in Guilan (Iran) (Khoshnevisan et al., 2013). Among these fertilizers, nitrogen is used the most with a rate of 9.37%, as seen in Figure 6. The GHG rate in the electricity is 54.93% in Guilan (Iran) (Khoshnevisan et al., 2013), where strawberry is grown in greenhouses. The water input rate in strawberry produced in Kamyaran (Iran) (Salami et al., 2010a) is 35.51%. Plastic use in strawberry production is only in Nevsehir (Turkey) (Baran et al., 2017) with a rate of 13.65%.

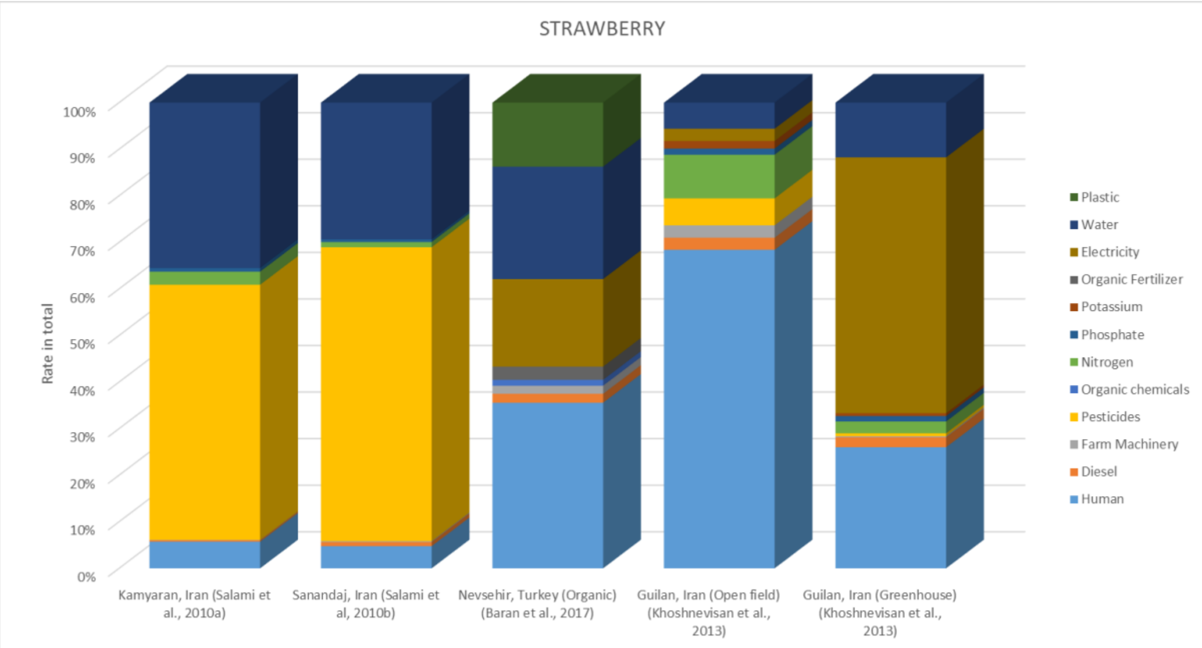

Figure 6. Percentage of input parameters in strawberry production in the Iran and Turkey

Wolfberry

Figure 7 shows the CO_{2-eq} values in wolfberry production in the World. This value changed between 1343.5 (Aksaray, Turkey) (Oguz et al., 2019) and 20718.7 kg CO_{2-eq} per ha (Gansu, China) (Wang et al., 2019). The total energy input is 7753.8 MJ/ha in Aksaray (Turkey) (Oguz et al., 2019) and about 40 times higher in Gansu (China) (Wang et al., 2019).

Figure 8 shows the input rates in wolfberry production in the World. Wolfberry production is carried out in Gansu (China) (Wang et al., 2019) and Aksaray (Turkey) (Oguz et al., 2019). It is seen in Figure 8 that, the GHG input in human labor is in Aksaray (Turkey) (Oguz et al., 2019) with a rate of 80.92%. and 28.8% in Gansu (China) (Wang et al., 2019). Diesel and farm machinery parameters in wolfberry production are used more in Aksaray (Turkey) (Oguz et al., 2019) with 6.18% and 6.05%, respectively. The use of organic chemicals is only available in Aksaray (Turkey) (Oguz et al., 2019) with a rate of 1.42%. Chemical fertilizers, pesticides and herbicides were not used in wolfberry production in Aksaray (Turkey) (Oguz et al., 2019). The input rate of herbicides is 0.27% in Gansu (China) (Wang et al., 2019) as seen in Figure 8. Pesticide use was also obtained in Gansu (China) (Wang et al., 2019) as 1.58%. Nitrogen, phosphate and potassium fertilizers were used in Gansu (China) (Wang et al., 2019) and the highest rate was 3.43% in nitrogen fertilizer. Organic fertilizer was used only in Aksaray (Turkey) (Oguz et al., 2019) with a rate of 0.90%. The GHG input in electricity was used only in Gansu (China) (Wang et al., 2019) with a rate of 51.77%. The highest input in water is 10.34% in Gansu (China) (Wang et al., 2019) as seen in Figure 8. The high CO_{2-eq} value is due to the excessive use of electricity and water inputs in wolfberry production in Gansu (China) (Wang et al., 2019).

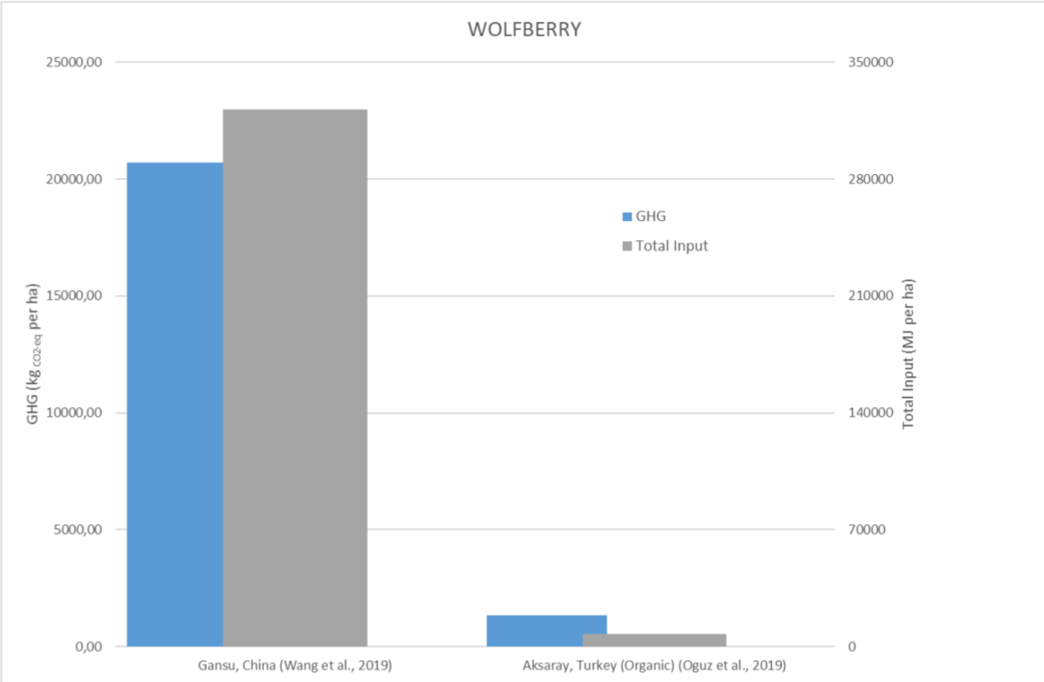

Figure 7. $CO_{2\text{-eq}}$ and total energy input values in wolfberry production in the China and Turkey

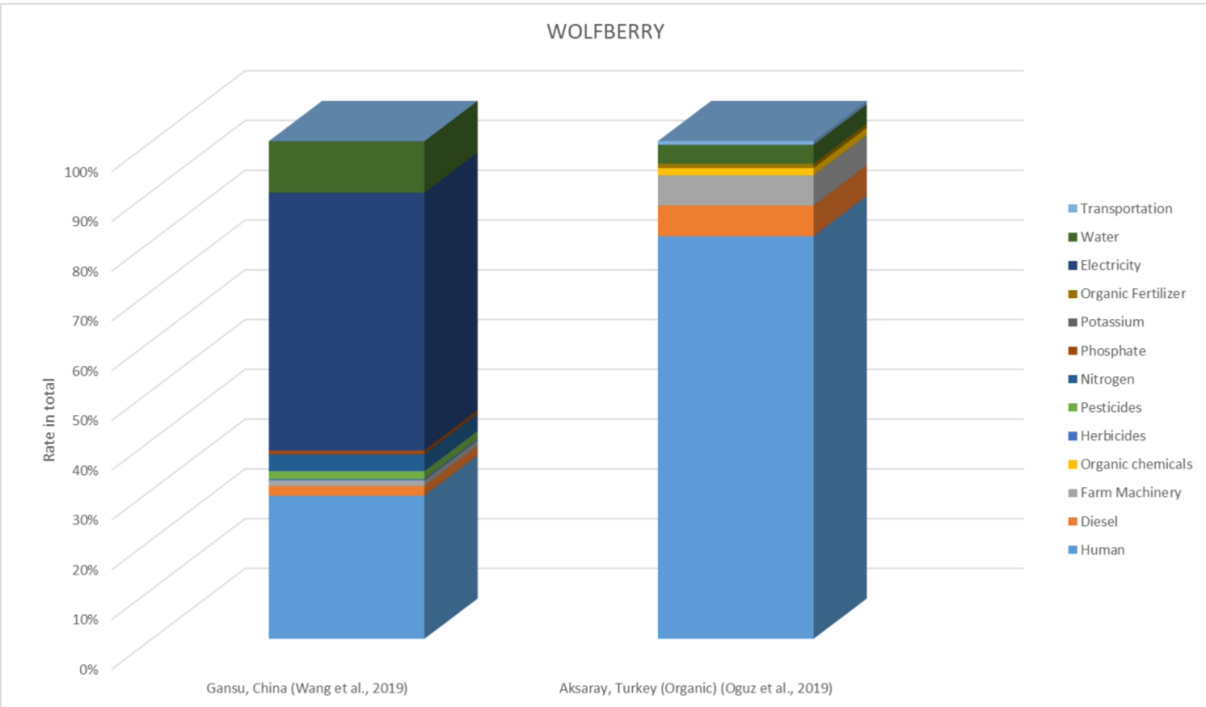

Figure 8. Percentage of input parameters in wolfberry production in the China and Turkey.

NUTS

Almond

Figure 9 shows the $CO_{2\text{-eq}}$ and total energy input values in almond production in the World. The highest GHG emission value was calculated between 2231.7 in Shahrekord (Iran) (Beni et al., 2023) and 6778.0 kg $CO_{2\text{-eq}}$ per ha in the Central Valleys of California (USA) (Pimentel, 1980). It is seen in Figure 9 that, the total energy input value is the highest in the Central Valleys of California (USA) (Pimentel, 1980) with 88491.6 MJ/ha, while it is 19670.4 MJ/ha in Adiyaman (Turkey) (Yilmaz and Beyan, 2023).

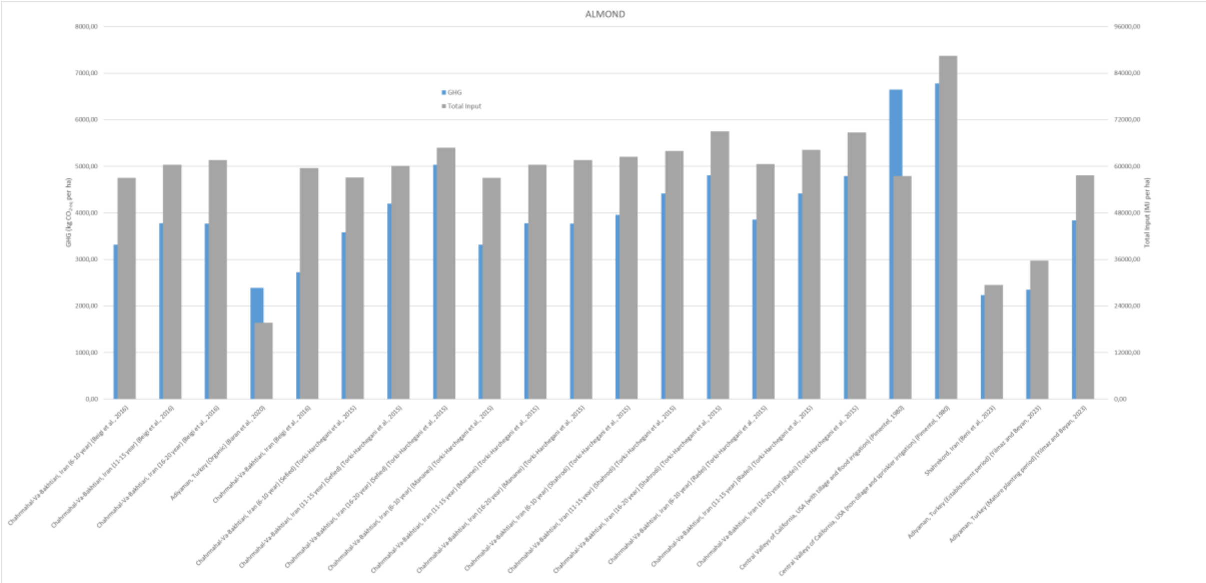

Figure 9. $CO_{2\text{-eq}}$ and total energy input values in almond production in the Iran, USA and Turkey

Figure 10 shows the rates of different input parameters in almond production in the World. It is seen in Figure that, the highest input rate in human labor is in Adiyaman (Turkey) (Yilmaz and Beyan, 2023) with 57.07%. In almond fruit production, fuel energy input parameter was entered in two separate forms as diesel and gasoline. Diesel fuel was used the most in Adiyaman (Turkey) (Yilmaz and Beyan, 2023) with a 15.01% rate. Gasoline was used the most in Central Valleys of California (USA) (Pimentel, 1980) with a 5.38% rate. In almond production, 19.84% was used the most in farm machinery in Shahrekord (Iran) (Beni et al., 2023). Pesticides have the highest usage rate in Shahrekord (Iran) (Beni et al., 2023) and the percentage value is 3.59%. The use of herbicides, insecticides and fungicides in almond production is low. It is seen in Figure 10 that, the rate values of herbicides with 0.43% and fungicides with 0.66% were carried out in Central Valleys of California (USA) (Pimentel, 1980) and insecticides with 5.98% in Chahrmahal-va-Bakhtiari (Iran) (Torki-Harchegani et al., 2015). Lime was used only in Adiyaman (Turkey) (0.07%) (Yilmaz and Beyan, 2023). No farmyard manure was used in almond production. The use of chemical fertilizers in almond production is low. The highest input was nitrogen (8.27%) used in Shahrekord (Iran) (Beni et al., 2023). Sulphur was used only in Shahrekord (Iran) (Beni et al., 2023) with a rate of 0.07%. Propane was calculated only in Central Valleys of California (USA) (Pimentel, 1980) with a rate of 0.83%. Organic chemicals were used only in Adiyaman (Turkey) (Yilmaz and Beyan, 2023) where organic almond is produced with a rate of 0.35%. The highest input of electricity was used in Chahrmahal-va-Bakhtiari (Iran) (Torki-Harchegani et al., 2015) with a rate of 62.31%. The highest rate among the energy parameters in almonds (76.96%) was calculated in the Central Valleys of California (USA) (Pimentel, 1980) for water. Transportation was used the most in the Central Valleys of California (USA) (Pimentel, 1980) with a rate of 7.83%.

Pistachio

Figure 11 shows the $CO_{2\text{-eq}}$ and total energy input values in pistachio production in the World. The GHG emission value is minimum in Southeastern Anatolia (Turkey) (Saglam et al., 2012) with 571.0 and maximum with 3955.75 kg $CO_{2\text{-eq}}$ per ha in Markazi (Iran) (Afshar et al., 2013). Total energy input value is also low in Southeastern Anatolia Region (Turkey) (Saglam et al., 2012) and high in Markazi (Iran) (Afshar et al., 2013) as 12044.0 and 54305.40 MJ/ha, respectively.

Figure 12 shows the energy input rates in pistachio fruit production in the World. The human factor is used intensively in the production of pistachio. Figure 12 shows that, pistachios are used human labor the most in Gaziantep (Turkey) (Kulekci and Aksoy, 2011) with 49.62%. The production carried out using animal power only in Adiyaman (Turkey) (0.36%) (Gokdogan et al., 2022). The percentage value in diesel was used the most in the Southeastern Anatolia (Turkey) (Saglam et al., 2012) with a rate of 33.25%. The rate of farm machinery was realized in Adiyaman (Turkey) (Gokdogan et al., 2022) with a rate of 20.11%. Pesticide is used in pistachio in Adiyaman and Southeastern Anatolia (Turkey) region and the highest input rate is in Southeastern Anatolia (Turkey) (Saglam et al., 2012) with 2.28%. Herbicide, insecticide and fungicide are not used in Adiyaman and Southeastern Anatolia (Turkey). The highest input value is used in Gaziantep (Turkey) (0.1-10 ha) (Kulekci and Aksoy, 2011) with 13.80%. As for herbicide and insecticide, it is seen in Markazi (Iran) (Afshar et al., 2013) with 0.84% and Gaziantep (Turkey) (0.1-10 ha) (Kulekci and Aksoy, 2011) with 0.62%, respectively. Farmyard manure was not used in pistachio production. In pistachio production, nitrogen and phosphate fertilizers are used the most in the Southeastern Anatolia (Turkey) (Saglam et al., 2012) with 25.50% and 3.50%, respectively. Potassium fertilizer was used the most in Gaziantep (Turkey) (0.1-10 ha) (Kulekci and Aksoy, 2011) with 0.57%. Sulphur and microelements are used only in Adiyaman (Turkey) (Gokdogan et al., 2022) with a very low level (1.24% and 0.28%). Electricity and water input values are used the most in Markazi (Iran) (Afshar et al., 2013) with a rate of 27.73% and 35.94%, respectively.

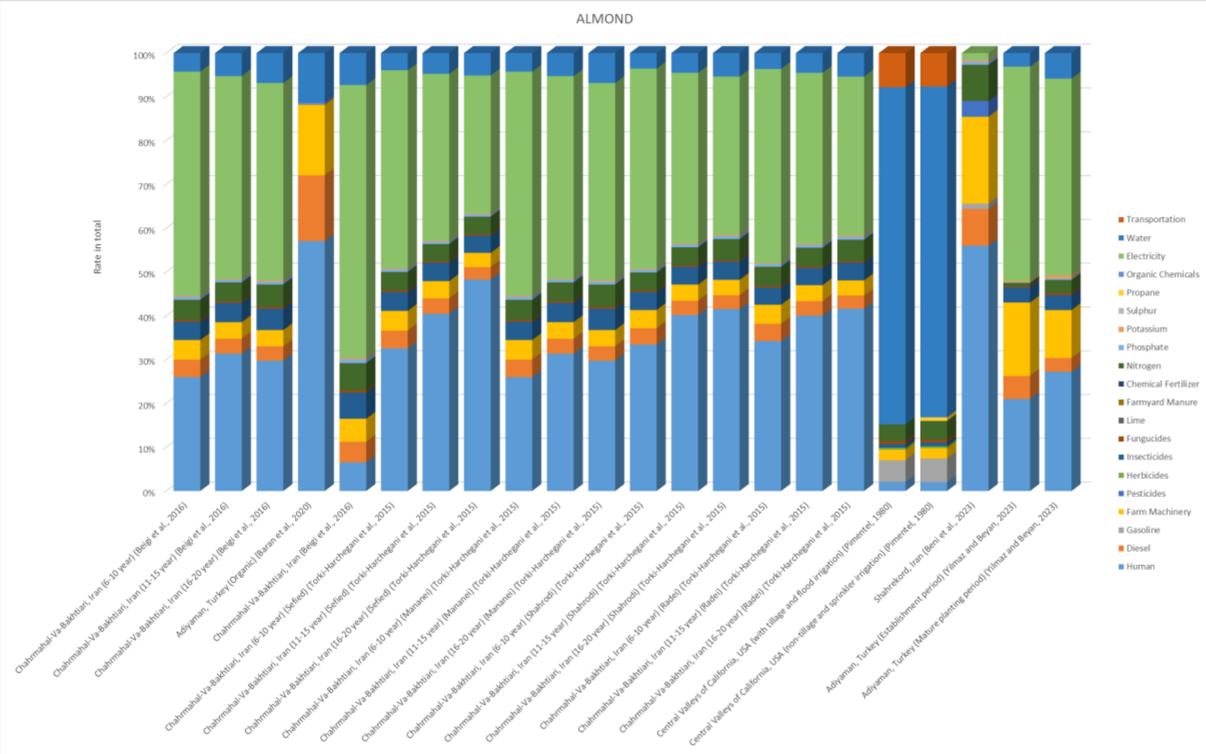

Figure 10. Percentage of input parameters in almond production in the Iran, USA and Turkey

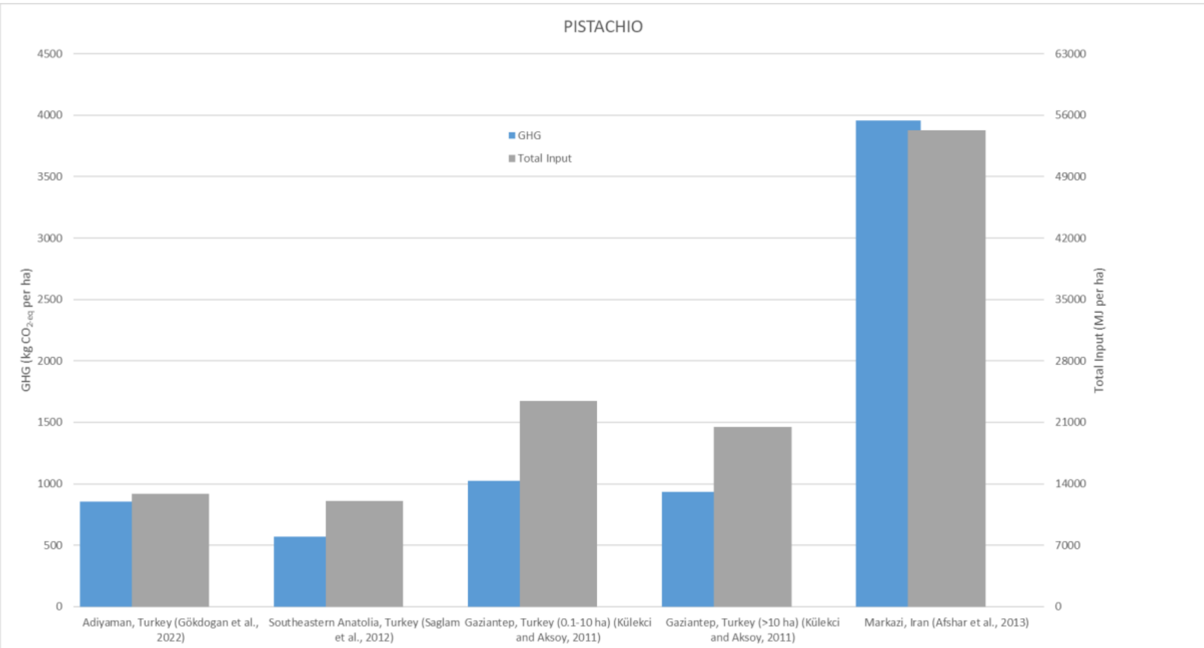

Figure 11. $CO_{2\text{-eq}}$ and total energy input values in pistachio production in the Iran and Turkey

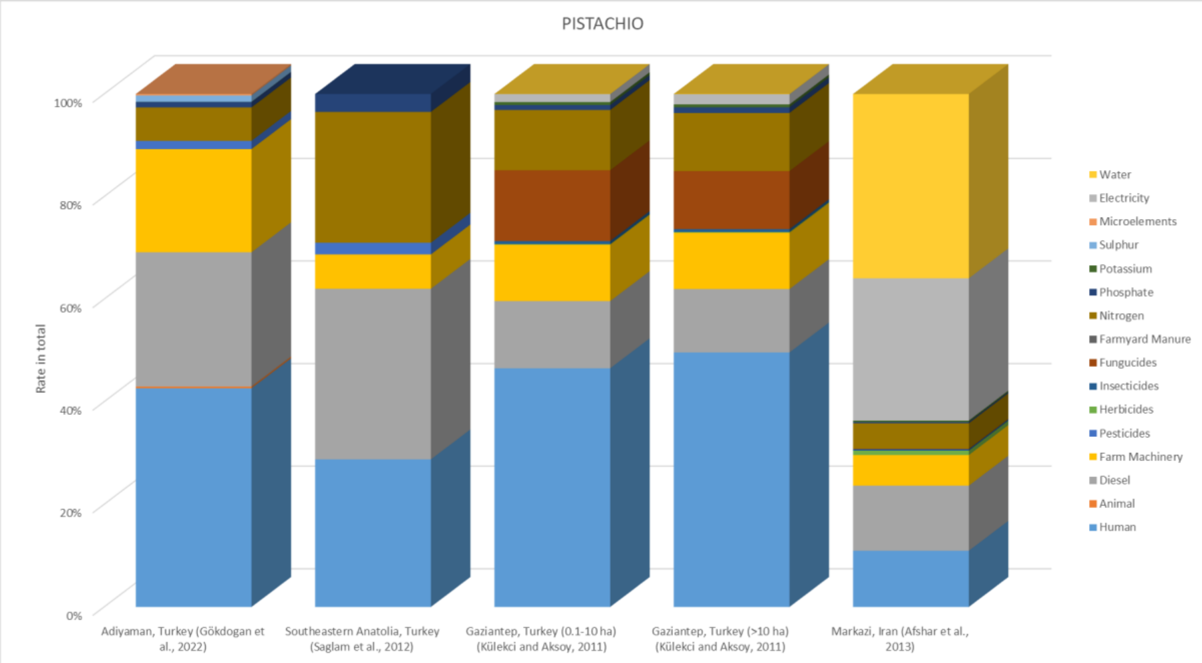

Figure 12. Percentage of input parameters in pistachio production in the Iran and Turkey

Walnut

Greenhouse gas emission in walnut production is seen to be the highest in California (USA) (Pimentel, 1980) with 7099.5 kg $CO_{2\text{-}eq}$ per ha in Figure 13. It is low in Istanbul (Turkey) (Unakitan and Inan, 2020) with a value of 522.1 kg $CO_{2\text{-}eq}$ per ha. The total energy input in walnut production was calculated as 103201.00 MJ/ha. The high rates of input parameters in GHG ensured that, the total energy input value was also high at the same rate. It is minimum with 10096.4 MJ/ha in California (USA) (Pimentel, 1980).

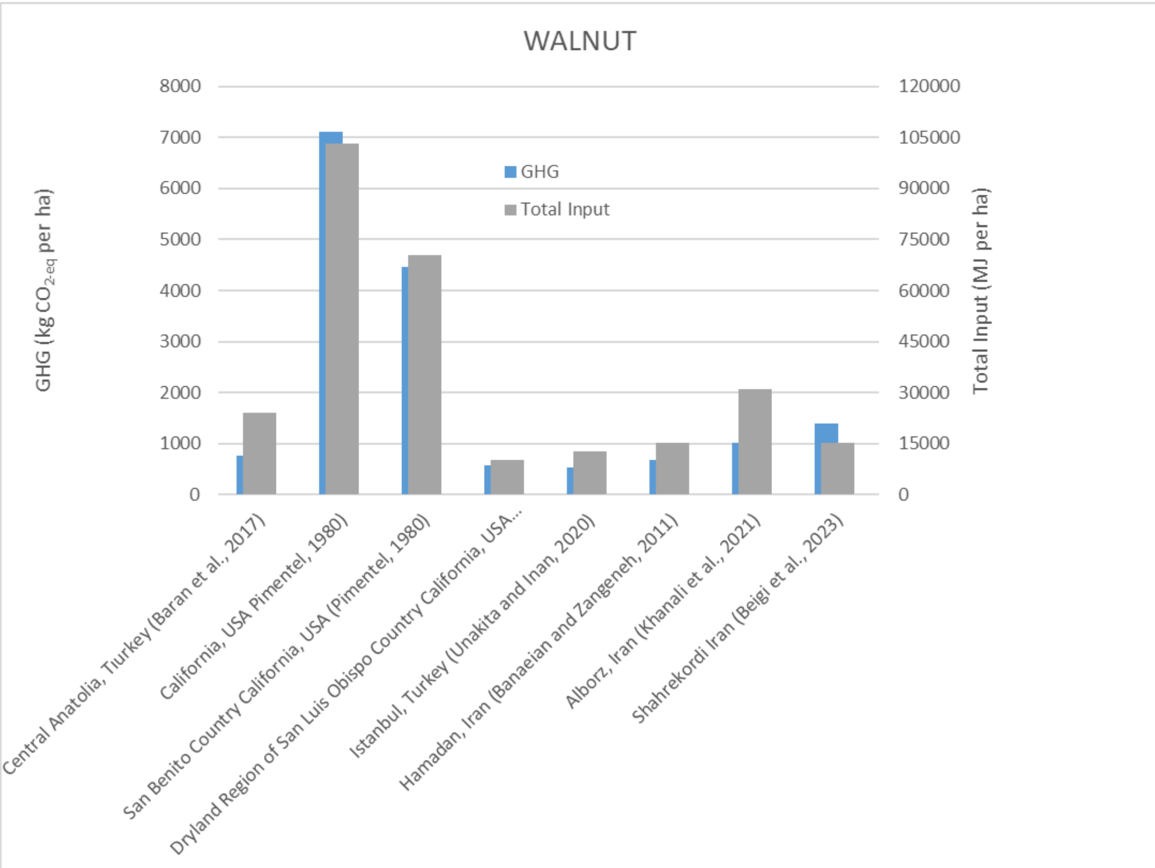

Figure 13. $CO_{2\text{-}eq}$ and total energy input values in walnut production in the Iran, USA and Turkey

Human labor use in walnut production is high and is at the highest level in Shahrekordi (Iran) (Beigi et al., 2023) with a rate of 56.53% as seen in Figure 14. Rate of input parameters in fuel and farm machinery are at their highest rates in the Dryland Region of San Luis Obispo Country California (USA) (Pimentel, 1980). The percentage values in these input parameters are 72.11% and 17.65%, respectively. The pesticide was used in the Central Anatolia Region (Turkey) (Baran et al., 2017), Alborz (Iran) (Khanali et al., 2021), and Shahrekordi (Iran) (Beigi et al., 2023), as seen in Figure 14. The highest input rate was 4.74% in Shahrekordi (Iran) (Beigi et al., 2023). Figure shows that, herbicides, insecticides and fungicides are used in walnut production and the highest rate is 5.79% in Hamadan (Iran) (Banaeian and Zangeneh, 2011). Farmyard manure is used in walnut production to a very small extent in the Central Anatolia Region (Turkey) (Baran et al., 2017) and Hamadan (Iran) (Banaeian and Zangeneh, 2011). Farmyard manure contributed 0.10% in the Central Anatolia Region (Turkey) (Baran et al., 2017) and 0.01% in Hamadan (Iran) (Banaeian and Zangeneh, 2011).

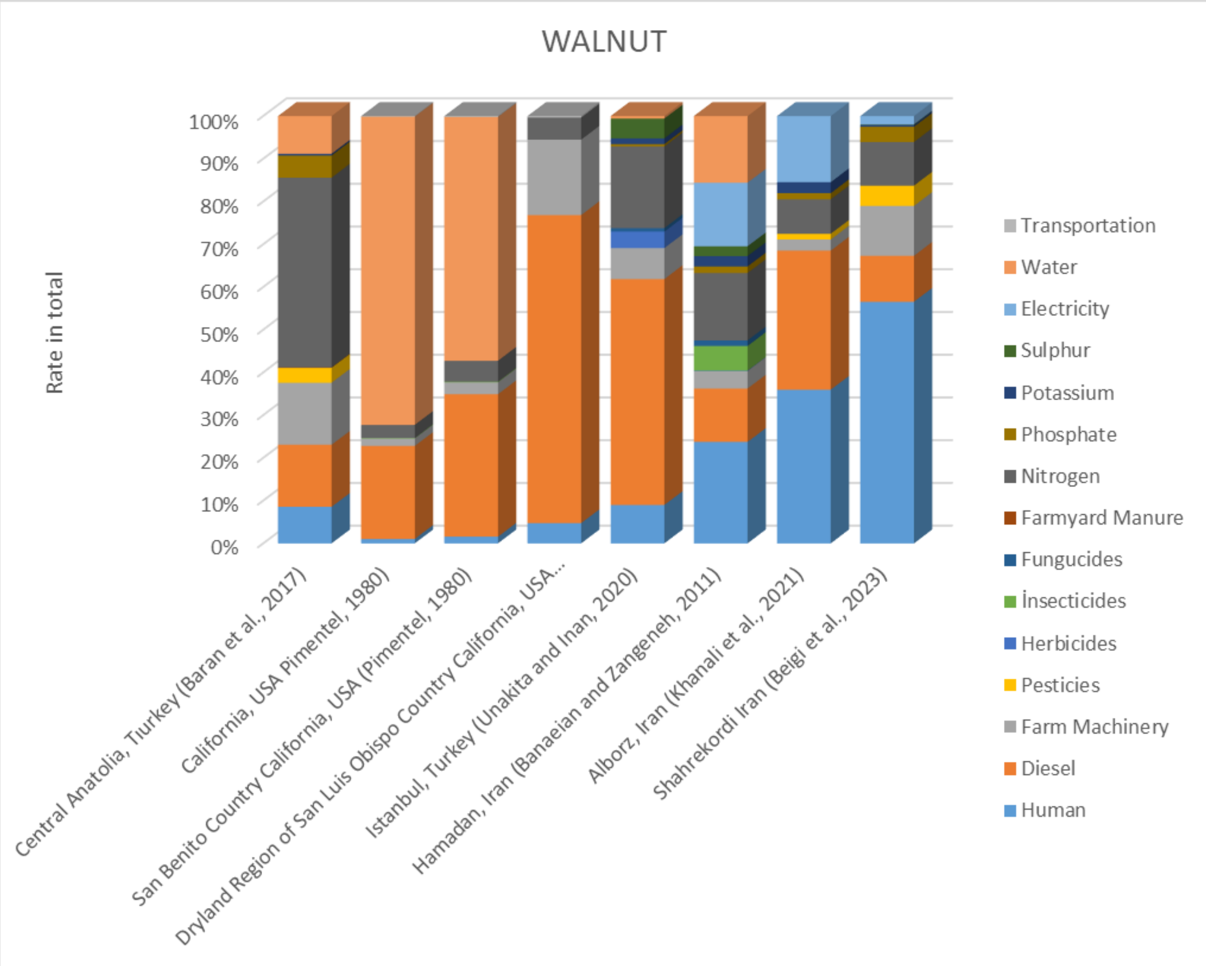

Figure 14. Percentage of input parameters in walnut production in the Iran, USA and Turkey

Nitrogen and phosphate fertilizers are used at the highest values in the Central Anatolia Region (Turkey) (Baran et al., 2017). The percentage values of these fertilizers are calculated as 44.43% and 5.16%, respectively. Potassium fertilizer is used in Alborz (Iran) (Khanali et al., 2021) with a rate of 2.57%, as seen in Figure 14. There is sulphur use in walnut production and it is the highest in İstanbul (Turkey) (Unakitan and Inan, 2020) with a rate of 4.63%. It is seen in Figure 14 that, the input rate in electricity is the highest in Hamadan (Iran) (Banaeian and Zangeneh, 2011) with a rate of 14.88%. The water use in walnut production is 72.15% in California (USA) (Pimentel, 1980). The input rate of transportation is the highest in the Dryland Region of San Luis Obispo Country California (USA) (Pimentel, 1980) with a rate of 0.35%.

CITRUS

Orange

GHG emission values in orange production in the World are shown in Figure 15. GHG emissions are highest in Kayseri (Turkey), where conventional and organic orange production is carried out. As a result of the high use of chemical fertilizers in this region, GHG emissions are high as 14183.87 in conventional and 10403.35 kg $CO_{2\text{-eq}}$ per ha in organic production. The lowest value is obtained in Mazandaran (Iran) with 1058.3 $CO_{2\text{-eq}}$ per ha.

The total energy input ranged between 23723.8 (North Iran) (<2 ha) and 110361.3 MJ/ha (Mazandaran, Iran) (7th year).

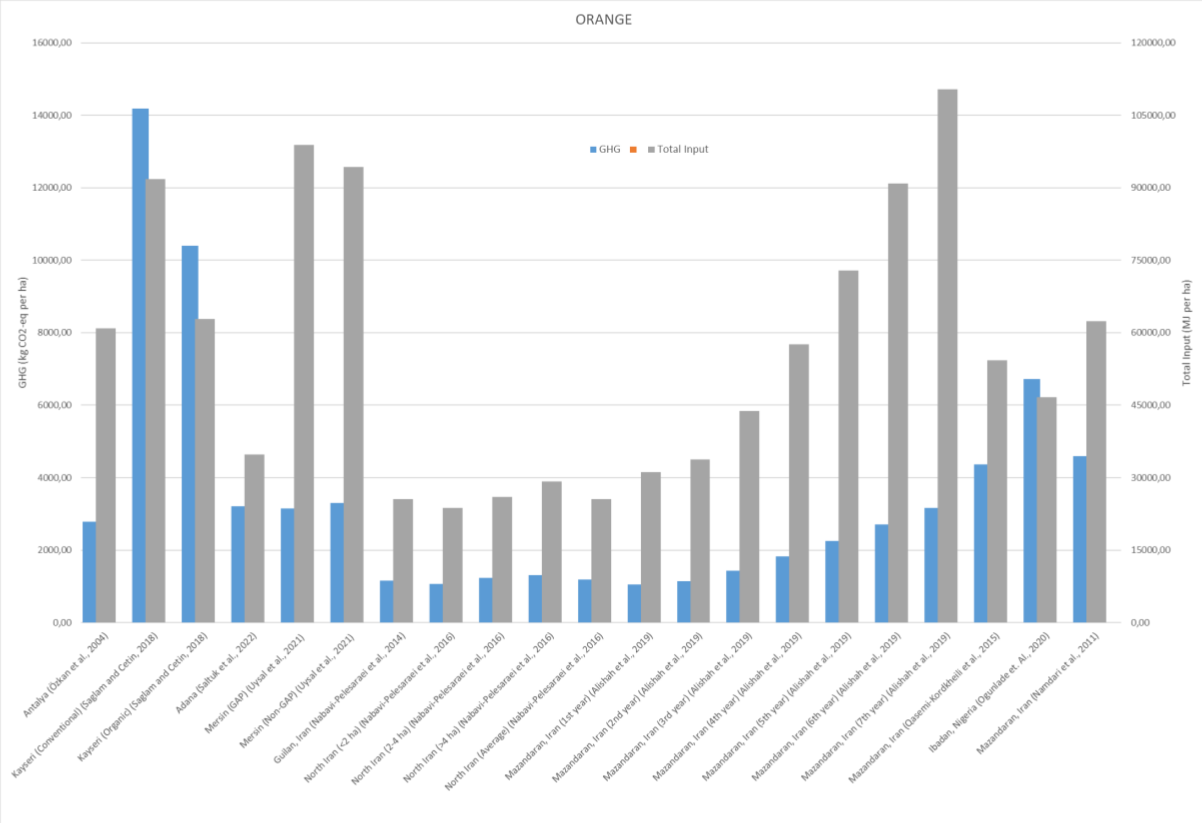

Figure 15. CO_{2-eq} and total energy input values in orange production in the Iran and Turkey

Figure 16 shows the input percentage values for orange in the World. Figure 16 shows that Kayseri, which is a traditionally orange producing city in Turkey, has the highest share of chemical fertilizers (67.37%). The value of chemical fertilizers is 48.11%. The electricity value is very high in Adana (Turkey) with 62.60%. Human labor is mostly used in the harvesting process of orange production. Among these values, it is seen that, the human labor share is the highest in Ibadan (Nigeria) with a rate of 79.19%. The lowest rate of human labor is in Kayseri (Turkey) (Traditional) with 3.85%. It is seen in Figure that, the diesel input rate is highest in Mazandaran (Iran) (42.45%). The highest farm machinery input is in Guilan (Iran) with a rate of 13.15%.

The highest input rate in pesticide parameter is 29.95% in Kayseri (Turkey) (Organic). Insecticide use in orange production only in Turkey. The input rate is 1.73% and is highest in Mersin (Turkey) (Non-GAP). The rate of herbicide use in Mazandaran (Iran-1st year) is 9.11%. The energy input rate in fungicide use is 3.17% in Mazandaran (Iran-7th year). It is seen in Figure 16 that, the highest use of farmyard manure is in North Iran (<2 ha) (0.85%). It is seen in Figure 16 that, the input rate in nitrogen is 17.90% in North Iran (>4 ha). It is seen in Figure that, the input rate of electricity parameter has the highest rate with a value of 62.60% in Adana (Turkey). It is in the water parameter with a 46.60% input rate and it reached the highest value in Mazandaran (Iran).

Lemon

It can be seen in Figure 17 that the CO_{2-eq} emission value is at the lowest in Antalya, Turkey (2655.32 kg CO_{2-eq} per ha). The highest value is 3577.3 kg CO_{2-eq} per ha occurred in Mersin (Turkey). Total energy input changed between 28952.2 in Mugla (Turkey) and 66741.2 MJ/ha in Mersin (Non GAP) (Turkey).

The input parameter rates for lemon production are given in Figure 18. Energy input analysis in lemon fruit was obtained by utilizing the data from the all published papers.

As seen in Figure 18, water, which is one of the input parameters, was used intensively in other cities except Antalya. It is seen in Figure 18 that, the input in human labor has the highest ratio in Adana (Turkey) with a value of 24.57%. The input rate in the diesel parameter is the highest share in Antalya (Turkey) (35.79%). It is seen in Figure 18 that, the input of farm machinery is concentrated in Mersin (Turkey) with a rate of 5.33%. The nitrogen fertilizer was used the most in Antalya (Turkey) (23.16%). The input parameter in electricity, with a rate of 51.92%, was used the most in Mugla (Turkey).

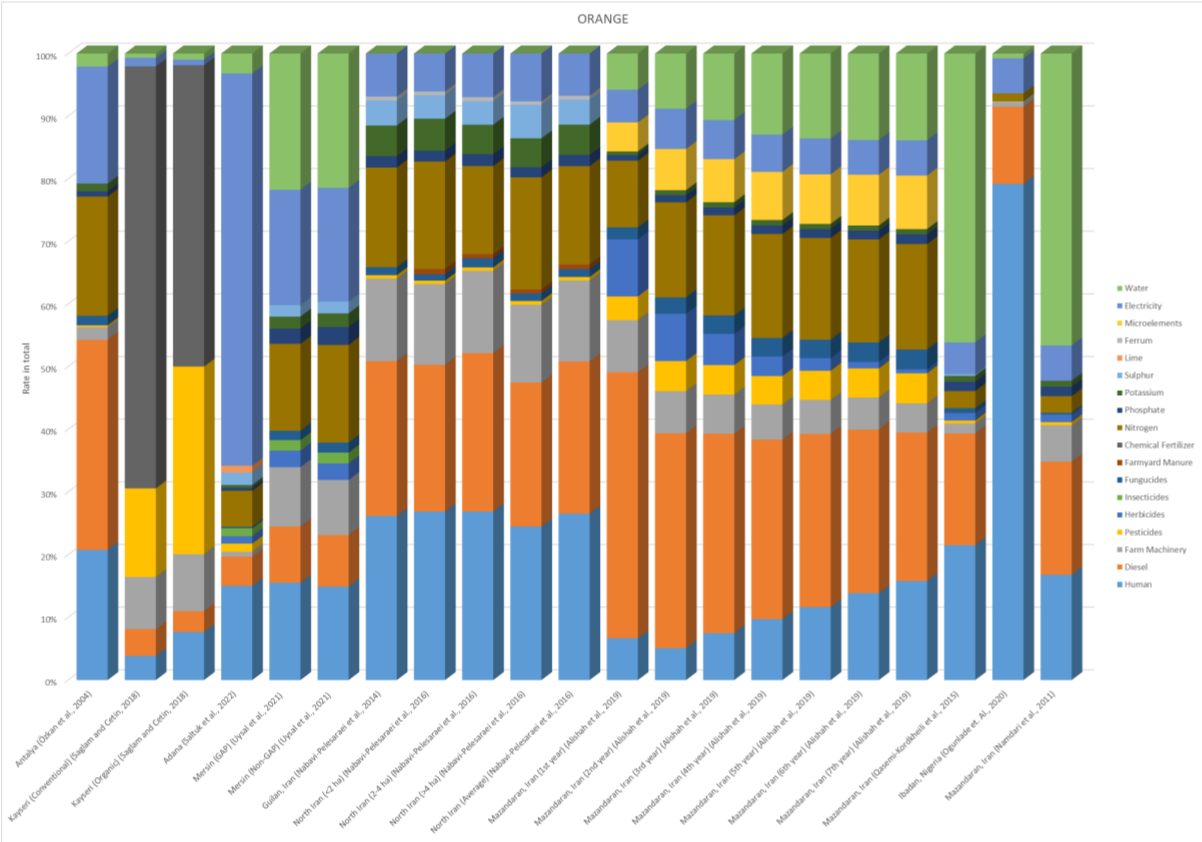

Figure 16. Percentage of input parameters in orange production in the Iran and Turkey

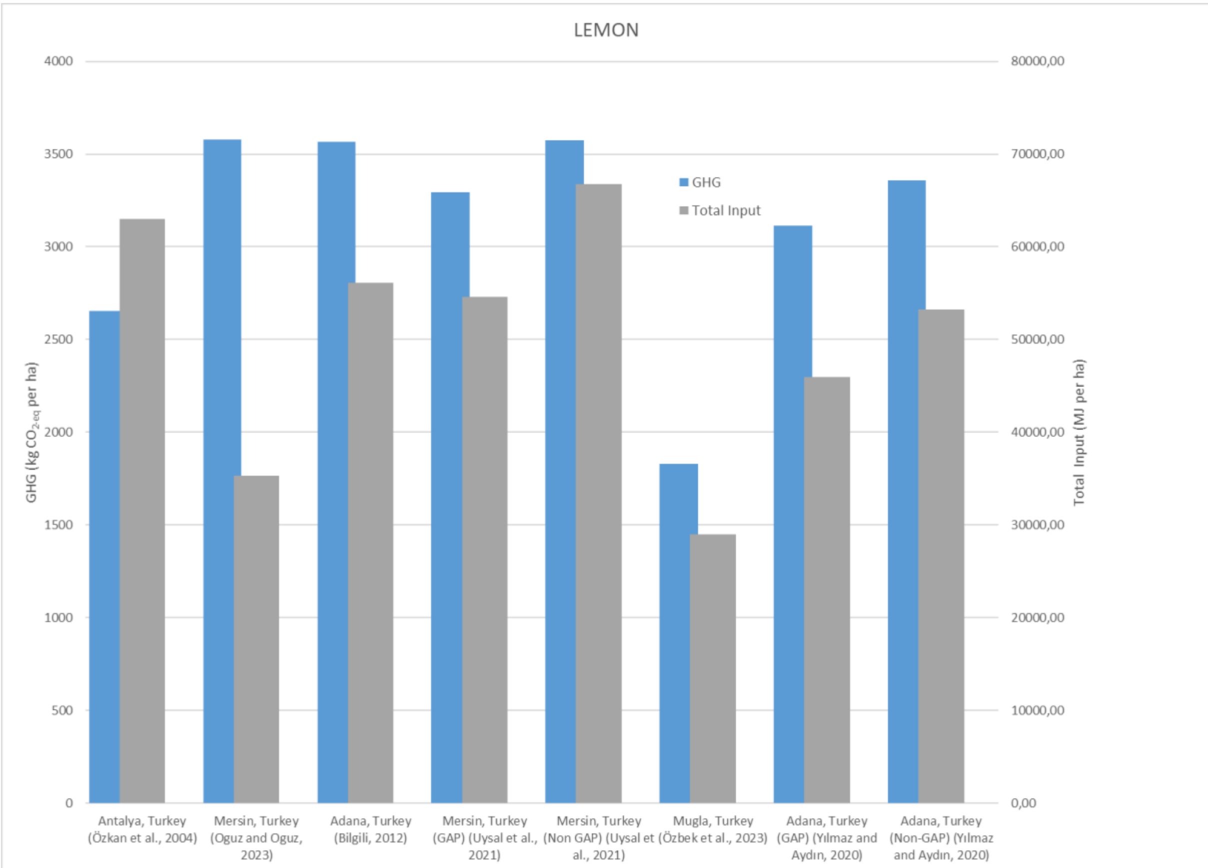

Figure 17. $CO_{2\text{-eq}}$ and total energy input values in lemon production in the Turkey

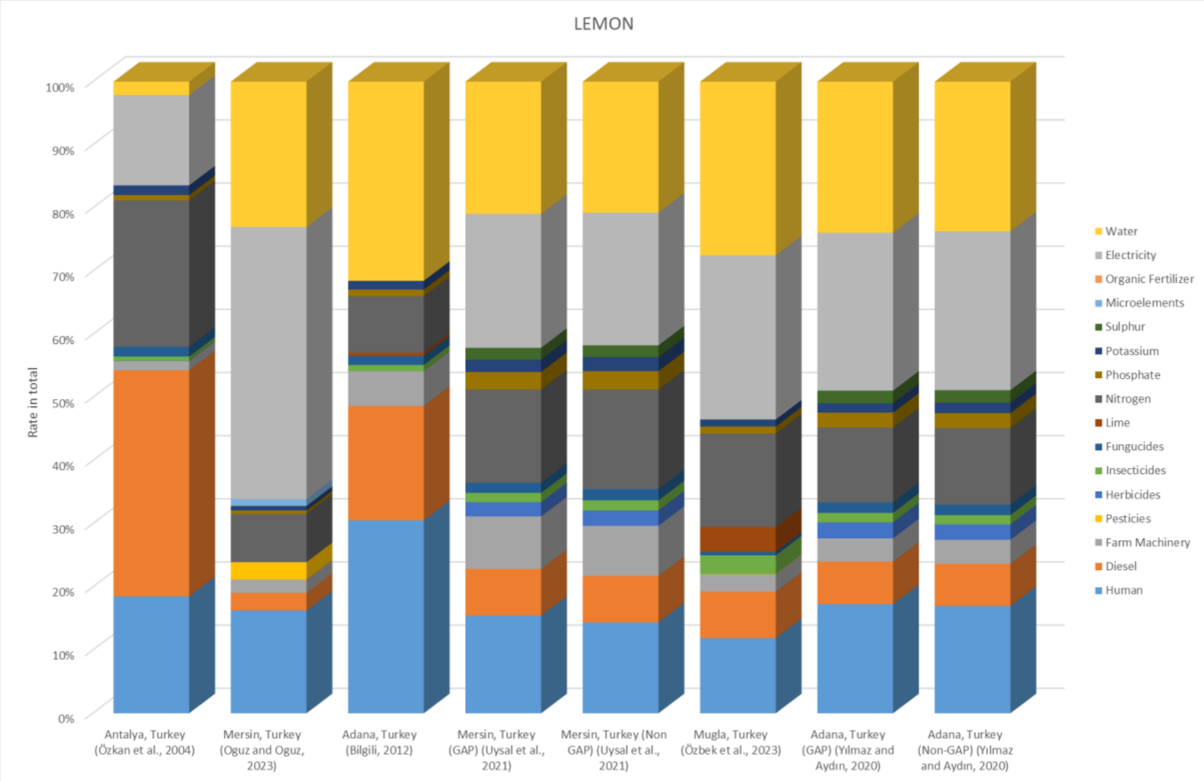

Figure 18. Percentage of input parameters in lemon production in the Turkey

Mandarin

Figure 19 shows $CO_{2\text{-eq}}$ per ha in mandarin production in the World. It is seen in Figure 19 that the highest $CO_{2\text{-eq}}$ value is in Mazandaran (Iran) with 5910.3 kg $CO_{2\text{-eq}}$ per ha. The lowest value is in Adana (Turkey) with 399.9 kg $CO_{2\text{-eq}}$ per ha. The total energy input is ranged between 4686.5 in Adana (Turkey) and 77501.2 MJ/ha in Mazandaran (Iran).

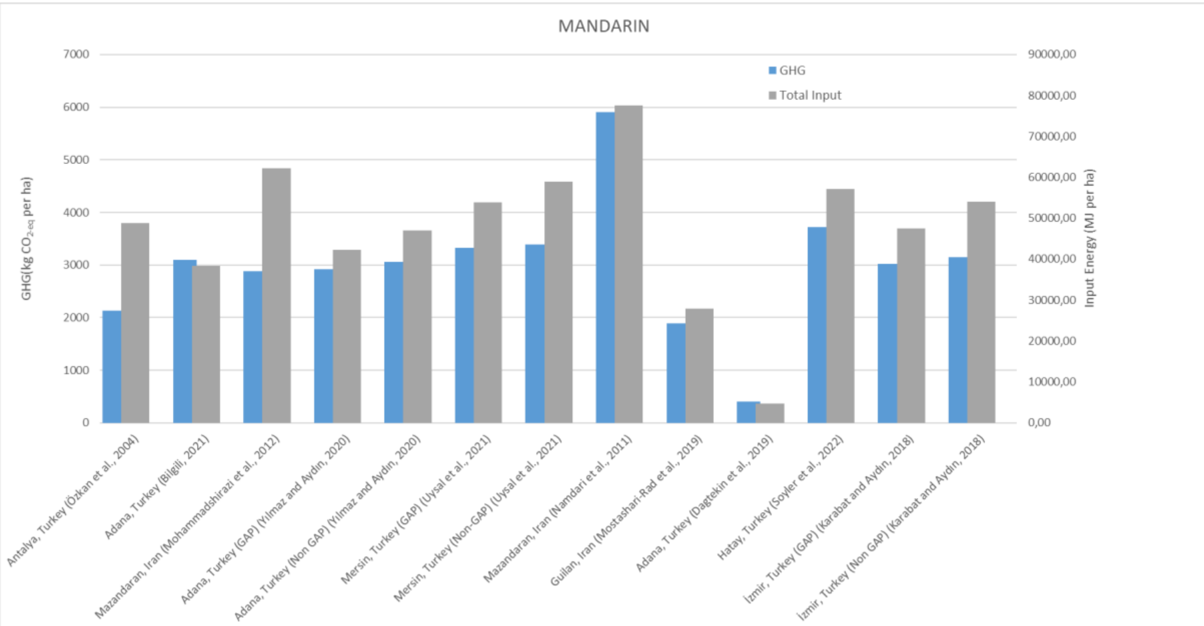

Figure 19. $CO_{2\text{-eq}}$ and total energy input values in mandarin production in the Iran and Turkey

Energy input rates in mandarin fruit produced in the world and in Turkey are given in Figure 20. A total of 15 input parameters and the necessary data were calculated.

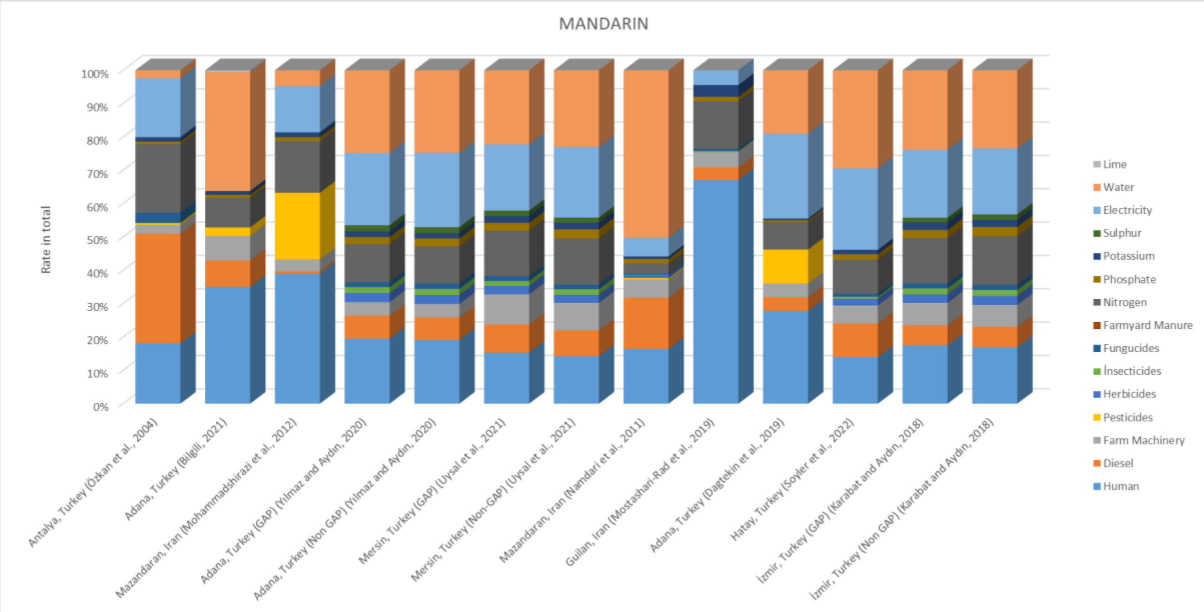

Figure 20. Percentage of input parameters in mandarin production in the Iran and Turkey

The human factor is of great importance in the harvesting of such fruits. In the harvesting process, which is the last stage of mandarin production in the World, more human labor is used. Therefore, the share of human labor is 67.09% in Guilan (Iran) as seen in Figure 20. Since the harvesting process of mandarin is based on human labor, input rates in farm machinery remain low. Looking at Figure 20, the highest input is in Mersin (Turkey) with a rate of 8.98%. It is seen in Figure 20 that, the input rate in diesel is 32.88% in Antalya (Turkey). Pesticide use was highest in Mazandaran (Iran) with a rate of 19.96%. As the rates of herbicide, insecticide and fungicide are given in Figure 20, the highest use is in Antalya (Turkey) with 3.06% fungicide, in Izmir (Turkey) with 2.69% herbicide (Non GAP) and in Adana (Turkey) with 1.86% insecticide (Non GAP). The use of farmyard manure in mandarin production is very low in the studies examined. Nitrogen fertilizer is used the most among the input rates in nitrogen, phosphate, potassium and sulphur fertilizers, with a rate of 20.59%, in Antalya (Turkey). The input rate of electricity is in Hatay (Turkey) with a rate of 24.43%. In the studies conducted in Mazandaran (Iran) in 2011 and 2014, it is seen in Figure 20 that, the input rate in water in mandarin production is 50.24%. Lime was used only in Adana (Turkey) (0.56%).

Grapefruit

Figure 21 shows the $CO_{2\text{-eq}}$ input values in grapefruit production in the World. $CO_{2\text{-eq}}$ values are seen in Figure 21 as 3945 kg $CO_{2\text{-eq}}$ per ha in Hatay (Turkey), 3130.0 kg in the USA and 1868.7 kg $CO_{2\text{-eq}}$ per ha in the USA. Total energy input is 60944.9, 53083.6 and 31612.5 MJ/ha, respectively, in the same locations.

Grapefruit is a fruit in the citrus family. As seen in Figure 22, energy analysis values in grapefruit were calculated on 3 different studies and with 14 input parameters.

Figure 22 shows the input rates in grapefruit produced in Turkey and the World. Grapefruit production was carried out in Hatay (Turkey) and the United States. The rate of human labor, which is one of the input parameters, calculated as 16.21% in Hatay (Turkey). In developed countries where fuel is not an economic problem, such as the USA, input rates are also high. The highest diesel consumption is in the USA with a rate of 45.85%. The input rate in farm machinery use is seen in Hatay (Turkey) with a rate of 4.73% in Figure 22. Although no pesticides were used in Hatay (Turkey), they were used in the USA with a rate of 18.12%. The input rates of herbicides, insecticides and fungicides from the energy input parameters are shown in Figure 22. Insecticide was used only in Hatay (Turkey) with a rate of 1.57%. Herbicide is at its highest value in Hatay (Turkey) (1.74%). Fungicide is in the USA with a rate of 1.17%. Among the chemical fertilizers used in grapefruit production are nitrogen, phosphate and potassium. With a rate of 13.64% in nitrogen fertilizer, input parameter was used more in the USA. Although the input rates in phosphate and potassium are close to each other, the highest phosphate input is in Hatay (Turkey) with a rate of 1.47% and the highest potassium input is in the USA with a rate of 2.10%. Although lime is not used in Hatay (Turkey), it is seen in Figure that it is used the most in the USA with a rate of 23.37%. Electricity and water were used only in Hatay (Turkey) with a value of 26.48% and 24.45%, respectively.

Maximum and minimum GHG emission values are given in Figure 23. The fruit with the highest GHG emission value is strawberry (34517.75 kg $CO_{2\text{-eq}}$ per ha). After strawberry fruit, plum (31109.13 kg $CO_{2\text{-eq}}$ per ha), wolfberry (20718.66 kg $CO_{2\text{-eq}}$ per ha) and orange (14183.87 kg $CO_{2\text{-eq}}$ per ha) fruits come respectively. The fruit with the lowest GHG emission value is mandarin (399.89 kg $CO_{2\text{-eq}}$ per ha). There are big differences between minimum and maximum emission values in different regions or countries. Because different practices are applied during production in each region or country. In fact, while no fertilizer is used in one location, all types of fertilizers can be used in another location. This difference in inputs also affects the total greenhouse gas emission values produced.

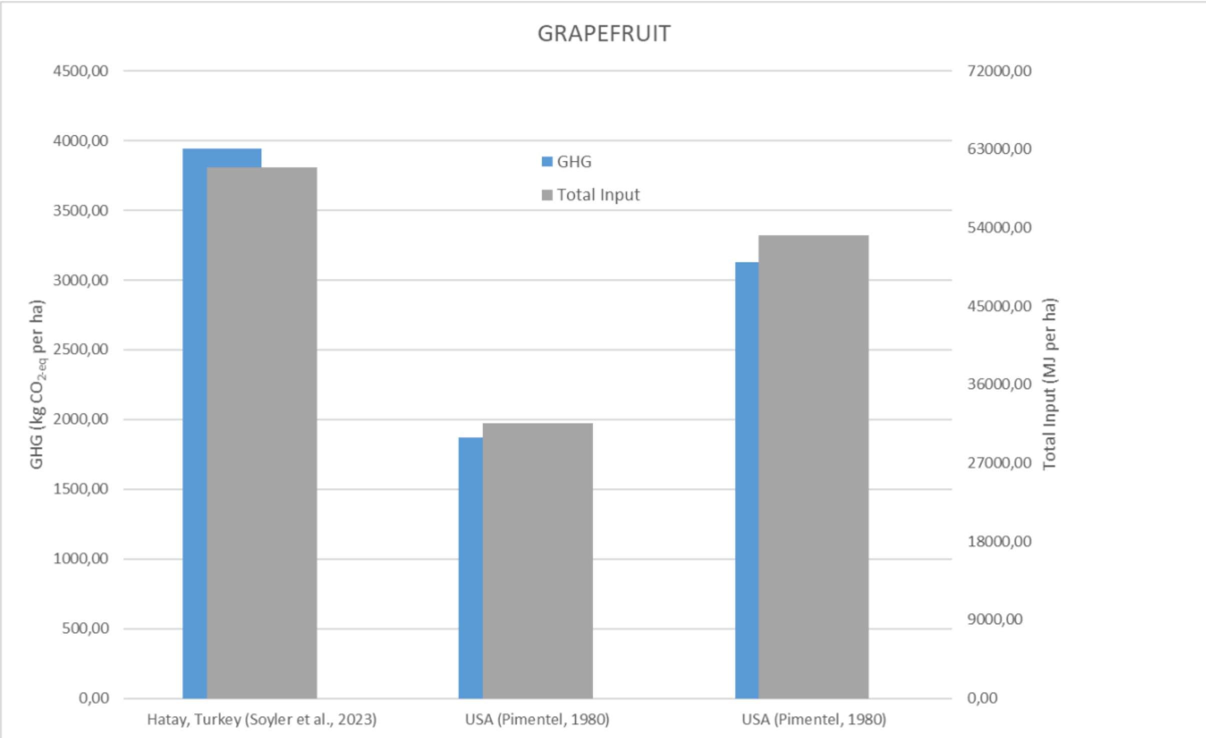

Figure 21. $CO_{2\text{-eq}}$ and total energy input values in grapefruit production in the USA and Turkey

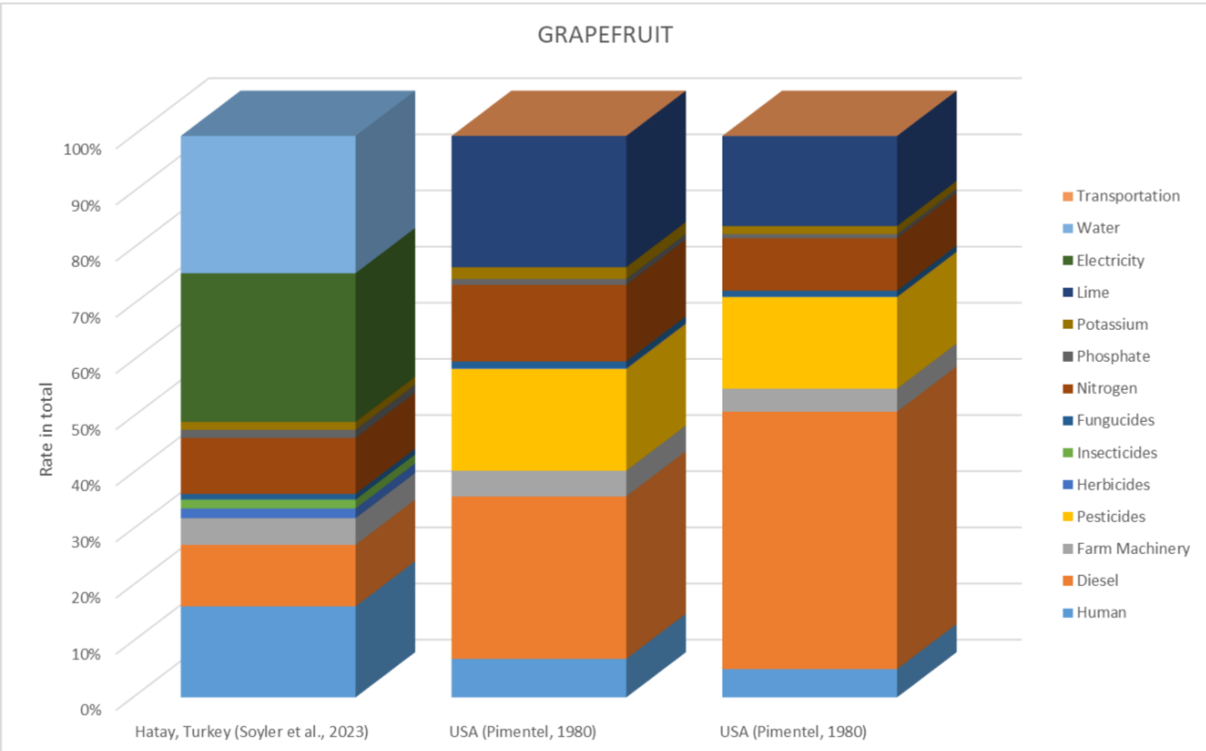

Figure 22. Percentage of input parameters s in grapefruit production in the USA and Turkey

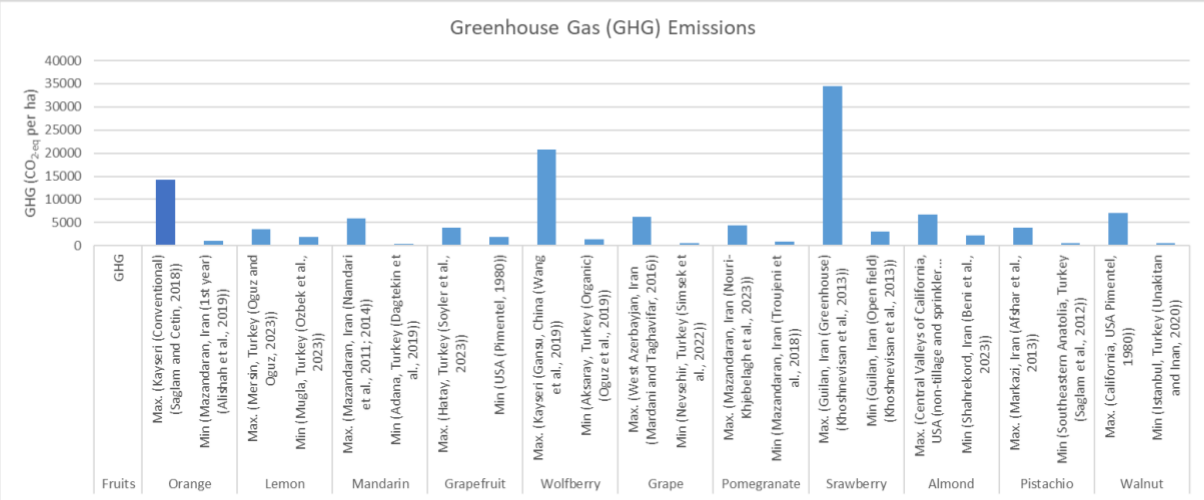

Figure 23. Maximum and minimum Greenhouse Gas (GHG) emission values

CONCLUSIONS

Global warming and climate changes occurring on earth pose a threat to living and non-living beings. The human factor is of great importance in this regard among living beings on Earth. In addition, the amount of greenhouse gas emissions does not positively affect global warming and climate change. The amount of greenhouse gas emissions generated in agricultural processes is also not negligible. Under the headings of berry, nut and citrus fruit; greenhouse gas emission values in grape, pomegranate, strawberry, wolfberry almond, pistachio, walnut, orange, lemon, mandarin/tangerine and grapefruit were calculated. GHG value reached the highest amount in strawberry fruit, while mandarin fruit has the lowest greenhouse gas emission value. The biggest part of the emissions comes from chemical fertilizers, pesticides, fuels and human. So, these input parameters usage could be reduced to a reasonable level with high yield. It contributes to agriculture against the harmful effects of greenhouse gas emissions. Renewable energy carbon footprint is positively affected by greenhouse gas emission values. It also provides financial support to farmers. Minimum tillage processing could be adviced to reduce $CO_{2\text{-eq}}$ values. Reducing ferlizer usage and especially avoiding excess nitrogen usage after appliying soil analysis can improve in reducing $CO_{2\text{-eq}}$ values. Low carbon farm machinery usage and improved human labor efficiency could have other alternatives to reduce GHG emissions.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Conflict of interest

The authors state there is no competing interest.

Author contribution

Authors' individual contributions to the article are equal.

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