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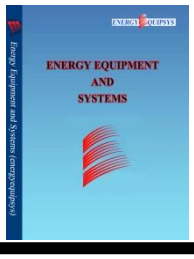

Comparison of energy consumption and greenhouse gas emission footprint caused by agricultural products in greenhouses and open field in Iran

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ABSTRACT

Decisions can be taken to increase energy efficiency and to mitigate the emissions to the environment by examining the energy audit and greenhouse gas (GHG) emissions footprint of crop production in different ways and in different regions, with comparable principles. In this study, energy consumption and energy indices of tomatoes production in four regions of Iran including East Azerbaijan province (open field), the provinces of Kermanshah, Tehran and Isfahan (greenhouse) were compared using related articles data. Chemical fertilizers and irrigation water in tomato production in open field and diesel fuel and chemical fertilizers in the tomato production in greenhouses system was greatest energy consumer in Iran. Energy consumption of irrigation water for tomato production in open field was markedly higher than the production in the greenhouse. In this study, the inputs of diesel fuel, chemical fertilizers, chemicals, plastics, and electricity used in the production of tomatoes, which contribute to the GHG emission footprint, were calculated via coefficients related to GHG emission. The highest and lowest greenhouse gas emissions in greenhouse tomato production in Tehran province and East Azerbaijan province farms were determined to be 13661.37 $kgCO_2eq\ ha^{-1}$ and 1274.02 $kgCO_2eq\ ha^{-1}$, respectively. Overall, tomato production in open field leads to lower greenhouse gas emissions and energy consumption per unit area, but according to more energy output in cultivation of tomato in greenhouse, energy efficiency of tomato production in greenhouse was higher.

Keywords: Energy Efficiency, Energy Audit, Environment, Pollutants.

1. Introduction

Area under cultivation and production rates of tomato in Iran is estimated about 158,000 hectares and 6.2 million tons, respectively, that is 1.34 and 8.4 percent of the total harvested area and production rates of agricultural crops. This is 31.6% of the total vegetable production in Iran [15]. Figure 1 demonstrates the atlas of tomato production in different province of Iran According to the occurred energy crisis, considering the energy flow of agricultural crop production will be of great importance in recent years, whereas consumption of energy resources has a direct relationship with various aspects such as

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environmental impacts that depends on the technology used in the consumption of energy resources. In this regard, in recent years, studies on the review of the energy flow and environmental impact of different agricultural crops production have been done in various regions of Iran [12, 8, 7, 19]. A study was conducted to investigate the energy input and output of 19 major agricultural products in Iran between the years 1990 and 2006. The results of the study showed that the energy efficiency increased from 0.95 in 1996 to 1.17 in 2006 during this period. The average energy efficiency of tomato production in this period was reported as 0.47 [1]. Many studies have been conducted on energy audit and greenhouse gases (GHG) emissions footprint produced by agricultural products in Iran. The amount of GHG emissions, in investigating the GHG emissions and energy analysis of cotton production in Golestan province were calculated as 1430.18 $kgCO_2eq\ ha^{-1}$ and energy efficiency of 1.58 were reported [23].

Brentrup et al. (2001) reported that greenhouse cultivation has an advantage in that environmental parameters affecting plant growth, like air temperature, sunlight and composition, can be controlled, but some material inputs, especially the use of chemical fertilizers, can result in significant environmental hazards. Khoshnevisan et al. (2013) studied environmental impacts of cucumber and tomato cultivation under greenhouse in Iran. They claimed that greenhouse cucumber production had higher environmental burdens than that of tomato. Cetin et al. (2008) performed a research on the energy audit of tomato production in open field system in Turkey. The results highlighted that the energy use efficiency and energy productivity were 0.8 and 0.99 $kgMJ^{-1}$, respectively. In another study that carried out by Hatirli et al. (2006), these indices for tomato production in greenhouse system in Turkey were reported 1.2 and 0.09 $kgMJ^{-1}$, respectively.

Investigation of energy audit and GHG emissions footprint of crop production in different ways and in different regions with systematic comparison makes it possible to achieve the best practices and methods production and to make decisions to increase energy efficiency and to reduce emissions of pollutants to the environment. The review of the literature disclosed that the comparison of energy consumption and GHG emissions caused by agricultural products in

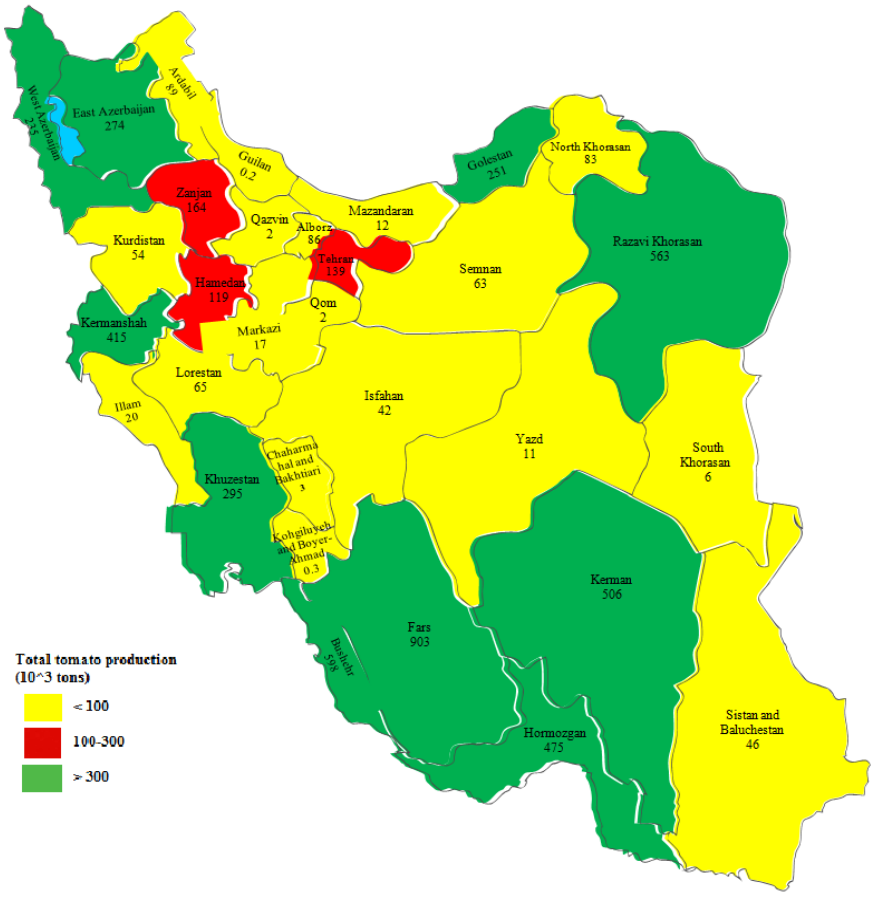

Fig.1. Atlas of tomato production in different provinces of Iran

greenhouses and open field in Iran has not been studied. Therefore, this study aims to estimate GHG emissions caused by the consumption of inputs in the production system of tomatoes and to compare the input and output energies and energy indicators in the greenhouse and open field tomatoes production in Iran.

2.Materials and methods

2.1. Site of study

In this study, the energy consumption of tomato production in four regions of East Azerbaijan province (open field), the provinces of Kermanshah, Tehran and Isfahan (greenhouse) were evaluated. The sites of study are shown in Fig. 2. Produced energy tomatoes and energy indices in four regions of East Azerbaijan province (open field), the provinces of Kermanshah, Tehran and Isfahan (greenhouse) were compared using related articles data.

2.2. Energy and GHG emission analysis

Data input and output energies and energy indices were taken from conducted studies [22, 10, 24, 21]. In this study, greenhouse gas emissions inputs of machinery, diesel fuel, chemical fertilizers, chemicals, plastics and electricity were evaluated. The CO_2 emission coefficients for agricultural inputs are applied to calculate GHG emissions from kiwifruit production. GHG emissions footprints for tomato production in these four regions were calculated via coefficients related to greenhouse gas emissions as shown in Table1. The GHG emission of agricultural machinery contributes to the emissions in manufacturing and using these inputs in the farm [11,17]. All calculations were conducted using Microsoft Excel 2010 and JMP8.

3.Results and discussion

3.1. Energy input-output results

The input and output energies of tomato production systems in four regions of Iran including East Azerbaijan province, Kermanshah, Isfahan, and Tehran provinces are shown in Table 2. The inputs of chemical fertilizers was the largest consumer of energy in the East Azerbaijan province and Kermanshah province, and then the input diesel fuel in Kermanshah and input water for irrigation in the East Azerbaijan province were considered as the largest consumers of energy in the tomato production. The two inputs of diesel fuel and chemical fertilizers

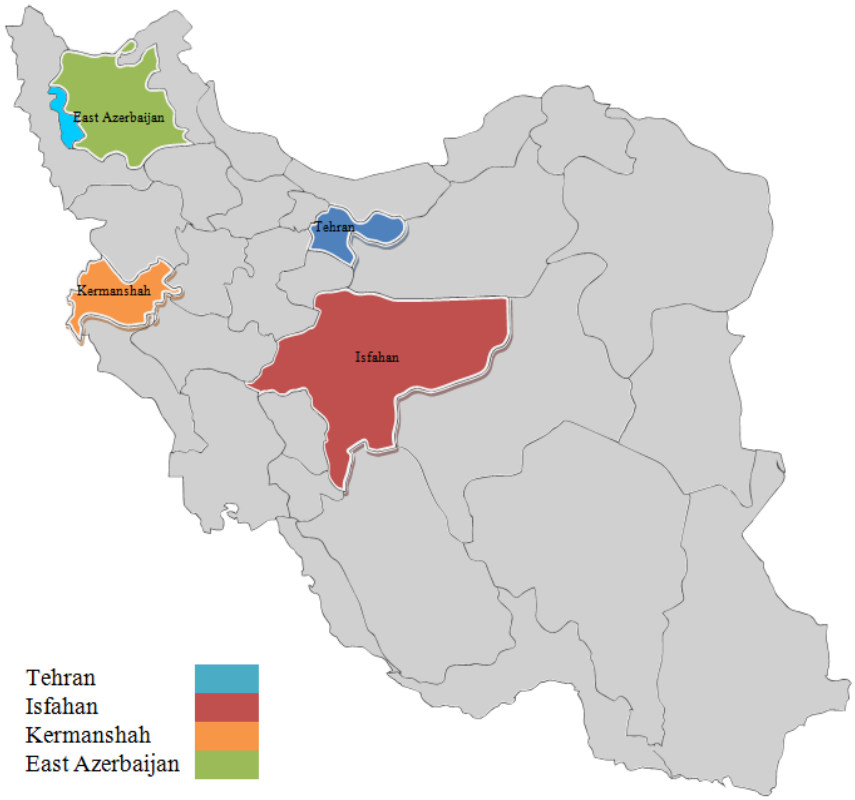

Fig.2. The studied regions

Table 1. Greenhouse gas emission coefficients of agricultural inputs

Inputs	Unit	Greenhouse gas emission coefficients ($kg\ CO_2eq\ unit^{-1}$)	Reference
Machinery	MJ	0.071	(Dyer and Desjardins, 2006)
Diesel fuel	Li	2.76	(Dyer and Desjardins, 2006)
Nitrogen	Kg	1.3	(Lal, 2004)
Phosphate	Kg	0.2	(Lal, 2004)
Potassium	Kg	0.2	(Lal, 2004)
Fungicide	Kg	3.9	(Lal, 2004)
Insecticide	Kg	5.1	(Lal, 2004)
Herbicide	kg	6.3	(Lal, 2004)
Plastic	kg	90	(Canakci and Akinci, 2006)
Electricity	kWh	0.608	(Lal, 2004)

Table 2. The energy audit of tomato production in Iran

	East Azerbaijan (open field)		Tehran (greenhouse)		Isfahan (greenhouse)		Kermanshah (greenhouse)	
	Energy ($MJha^{-1}$)	Percent	Energy ($MJha^{-1}$)	Percent	Energy ($MJha^{-1}$)	percent	Energy ($MJha^{-1}$)	percent
Seed	0.3	0	0.10	0	0.1	0	0.1	0
Human labor	2142.6	3.28	13342.09	10.14	11397	9.76	11045.58	8.9
Machinery	2900.9	4.45	440.66	0.33	3389	2.90	1347.19	1.09
Diesel fuel	8641.7	13.25	65521.94	49.02	47106	40.34	16258.59	13.34
Chemical fertilizers	33261.04	50.98	3160.72	24.02	28626	24.52	49141.36	39.59
-Nitrogen	26877.09	41.19	22010.11	16.72	20834	17.84	43674.4	35.19
-Phosphate	5206.1	7.98	5391.25	4.10	4615	3.95	1969.57	1.59
-Potassium	1177.8	1.80	4202.37	3.19	3177	2.72	3497.39	2.82
Biocide	268	0.41	90	6.89	1716.9	1.47	14723.93	11.86
Farmyard manure	4536.4	6.95	-	-	6425	5.50	16266.37	13.11
Electricity	-	-	2595.96	1.96	14316	12.26	14253.86	11.48
Water for irrigation	13487.9	20.67	1059.86	0.81	3790	3.25	1083.46	0.87
Plastic	-	-	9000	6.84	-	-	-	-
Total energy input	65238.9	100	131634.19	100	116768.4	100	123098.6	100
Total energy output	38581.9	-	156185.64	-	108000	-	121873.2	-

inputs were the greatest energy consumers of inputs in provinces of Isfahan and Tehran. It is in agreement with Hatirli et al (2006) and Cetin et al (2008) who suggested that the diesel fuel and chemical fertilizers inputs were the highest consumer of energy in the production of tomato in open field and greenhouse production systems in Turkey.

Pishgar-Komleh et al (2013) on cucumber production in Yazd province of Iran and Mohammadi and Omid (2010) on cucumber production in Tehran province of Iran reported that the diesel fuel had the biggest contributions in the total energy inputs.

The amounts of water for irrigation for tomato production in the East Azerbaijan province, Isfahan province, Kermanshah province and Tehran province were 13,222.55, 3,715.69, 1062.22 and 1039.08 m^3, respectively. As can be seen in Table 2, the amount of water for irrigation for tomato production in open field is much more than the production of tomato in greenhouse conditions. Such as 20.67 percent of the input energy of tomato production in the East Azerbaijan province is allocated to water for irrigation. Total energy inputs in tomato production in Tehran province, Kermanshah

province, Isfahan province and the East Azerbaijan province were obtained at 131634.2, 123098.6, 116768.4 and 65238.9 MJ ha^{-1}, respectively. Tomato yield in Tehran province, Kermanshah province, Isfahan province and the East Azerbaijan province were reported as 195232.05, 152341.47, 135000 and 47228.3 $kg.ha^{-1}$, respectively. The highest and lowest energy outputs were reported for Tehran province and East Azerbaijan province. The results highlighted that the energy consumption for tomato production under greenhouse system was higher than that of open field systems. The energy consumption for tomato production in open field and greenhouse systems in turkey were reported as 45539 and 127749 $MJha^{-1}$ respectively [9, 4].

3.2. Energy indices

Energy indices of tomato production in these four regions are shown in Table 3. Energy efficiency of tomato production in Tehran province, Kermanshah province, Isfahan province and East Azerbaijan province were 1.48, 0.99, 0.92 and 0.54, respectively. Results showed that energy use efficiency of tomato production in open field production system in East Azerbaijan province was lower than that of greenhouse production in other studied regions.

The shares of renewable and non-renewable energy in tomato production in each of the provinces of Iran are shown in Fig. 3. The most used renewable energy in the tomato production is related to Kermanshah province with the amount of 28395.41 MJ ha-1. This is because of frequently farmyard manure use (containing %11.3 of input energy) that is the third most used input in this region. Also the highest consumption of non-renewable energy with 117232.14 MJ ha-1 was obtained for Tehran province and this is due to the high consumption of diesel fuel with the amount of 1445.83 L. ha-1. The share of renewable energy for greenhouse tomato production system was 12 percent [9].

3.3. GHG emission footprint of tomato production

The amount of GHG emissions for tomato production in these four regions are provided in Table 4. Whereas the amount of GHG emissions for the production of 1000 kg of

Table 3. Energy indices of tomato production in Iran

	Unit	East Azerbaijan (Open field)	Tehran (Greenhouse)	Isfahan (Greenhouse)	Kermanshah (Greenhouse)
Energy efficiency	-	0.59	0.92	1.48	0.99
Energy productivity	Kg. MJ^{-1}	0.74	1.16	1.38	1.24
Net energy	MJ. Kg^{-1}	1.35	0.86	0.72	0.81
Specific energy	MJ. ha^{-1}	-26657	-8768	63597.86	-1225.43
Direct energy	MJ. ha^{-1}	24279.29	76610	80459.99	42641.5
Indirect energy	MJ. ha^{-1}	40966.66	40158	50114.34	81478.84

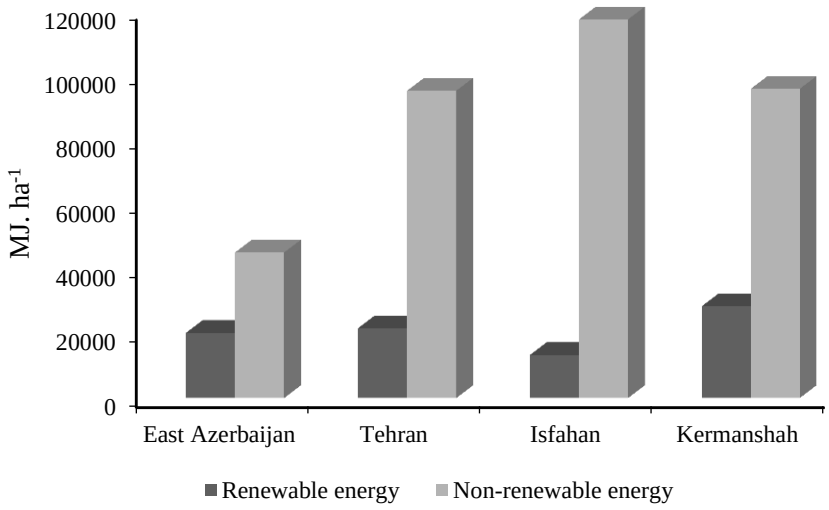

Fig. 3. The share of renewable and non-renewable energy in tomato production in each of the provinces of Iran

Table 4. Amount of greenhouse gas emission during tomato production in Iran (kg CO_2eq ha^{-1})

	East Azerbaijan (Open field)		Tehran (Greenhouse)		Isfahan (Greenhouse)		Kermanshah (Greenhouse)	
		Percent		Percent		Percent		Percent
Machinery	95.69	16.17	240.62	0.23	31.29	5.56	205.96	1.19
Diesel fuel	796.90	33.25	2719.98	23.51	3211.52	62.78	423.57	15.95
Chemical fertilizers	952.83	49.69	540.7	4.34	594.67	12.48	633.10	19.08
-Nitrogen	858.43	41.47	409.5	3.17	432.61	9.45	528.28	17.19
-Phosphate	31.66	6.57	74.2	0.63	86.68	1.71	83.70	0.63
-Potassium	62.73	1.66	57	0.55	75.38	1.32	21.13	1.26
Chemicals	95.65	0.89	240.62	2.82	31.29	1.17	205.96	14.86
Electricity	0	0	729.6	3.21	438.43	16.84	2407.32	48.20
Plastic	0	0	9000	65.88	0	0	0	0
Total emissions	1274.02	100	13661.37	100	4332.72	100	4994.72	100

tomatoes in Tehran province, Kermanshah province, Isfahan province and the East Azerbaijan province were obtained 69.97, 32.79, 32.09 and 26.42 kg CO_2eq. ha^{-1}, respectively, the total GHG emission footprint for tomato production in Tehran province, Kermanshah province, Isfahan province and East Azerbaijan province were calculated 13661.37, 4994.72, 4332.72 and 1274.02 kg CO_2eq. ha^{-1}, respectively.

Chemical fertilizers and diesel fuel, plastics and diesel fuel, diesel fuel and electricity, electricity and chemical fertilizers were inputs that had the highest rate of greenhouse gas emissions in East Azerbaijan province, Tehran, Isfahan and Kermanshah provinces, respectively and among all these inputs, Plastic input had the highest rate of greenhouse gas emissions with the amount of 9000 kg CO_2eq ha^{-1}. Pishgar-Komleh et al (2013) analyzed the GHG emissions of cucumber cultivation in Yazd province of Iran and found that the diesel fuel had the highest GHG emissions, followed by electricity.

4.Conclusion

The aim of this study was to evaluate the energy consumption and GHG emission footprint of tomato production in open field and under greenhouse systems. The results highlighted that the open field production system had the lower energy inputs than greenhouse. However, due to high yield of tomato production under greenhouse, the energy efficiency of tomato production under greenhouse was higher than that of open field production system. From the evaluated results it becomes obvious that the diesel fuel consumption of open field tomato production is the main input for improving the energy efficiency and GHG emission footprint of production.

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