RESEARCH ARTICLE

Life cycle assessment of rice cropping systems in traditional and semi-mechanized planting patterns in northern Iran

Sahar Youseftabar*, Hossein Heidari Sharifabad, Islam Majidi Heravan

Youseftabar S, Sharifabad HH, Heravan IM. Life cycle assessment of rice cropping systems in traditional and semi-mechanized planting patterns in northern Iran . AGBIR. 2021;37(5):195-202.

The life cycle of rice crop in different cropping systems was assessed in Mazandaran province, in northern Iran from 2016 to 2017. All the management practices/inputs of local ('Tarom Hashemi') cultivar were monitored without interference in farmer's practices. The experiment was carried out as factorial based on a Randomized Complete Blocks Design (RCBD) with four replications. Five cropping systems including conventional, low-input, high-input, improved and organic systems were used as main plots. Two planting patterns (traditional and semi-mechanized) were considered as subplots, respectively. According to the findings, the share of non-renewable energy demand, CC, and GWP 100a in both methods was low for low-input and organic systems, which could increase the share of renewable energy by incorporating conservation planting approaches. Fossil CO2 eq, biogenic CO2 eq, Global Warming Potential 100a (GWP), Terrestrial Acidification (TA) and Fossil Depletion (FD) of semi mechanized method were higher than traditional method. The most Cumulative Energy Demand (CED) in both methods was observed in high input system followed by conventional system. The lowest amount of GWP 100a was calculated in low input and organic systems for traditional method. In both methods, the most and lowest amount of TA, Freshwater Eutrophication (FEU), Ozone Depletion (OD) and FD were emitted in high input and low input systems, respectively. Among the cropping systems, low input and high input systems had significantly lowest and most emission of heavy metal in the air, water and soil, respectively. As a result, as the findings of this research revealed that emission of environmental pollutants is directly related to the application of inputs and method of field management. Therefore, to increase the sustainability of agro-ecosystems, as well as to reduce the environmental impacts of pollutant, reforming the pattern of chemical input consumption and reducing the use of non-renewable energy sources are essential.

Key Words: *Acidification; Cropping systems; Eutrophication; Environmental pollutants; Heavy metals*

INTRODUCTION

Rice (*Oryza sativa L.*) is the earliest stable food crops with the global cultivation area of 165 million hectares, accounting for more than one tenth of the worldwide-cultivated area [1]. Mazandaran province have a high share of rice production area in Iran, which requires optimization of inputs application and identification of the best production system in order to reduce the emission of environmental pollutant.

Life Cycle Assessment (LCA) is an appropriate way for achieving sustainable agriculture goals to study the environmental impact of a crop producing in its whole life cycle in production systems [2,3]. LCA used in crop planting systems is an attempt to estimate all GHGs emission and environmental pollutants of the production chain of life cycle [4]. Several studies have been found in this regard. Dastan et al. by using LCA assessed transgenic Bt. and non-Bt. rice cultivars in northern Iran. They reported that the amount of the environmental pollutants emission is directly related to the application of inputs and method of field management, based on which the least amounts of these indices were obtained in the production of transgenic cultivars. Habibi et al. [5] by using LCA to assess 200 rice production fields in Mazandaran and Guilan provinces, Iran reported that the most Global Warming Potential (GWP 100a), Climate Change (CC) and Cumulative Energy Demand (CED) in both regions were observed in high-input system for semi-mechanized method. The result for the impact categories of Freshwater Eutrophication (FE), Agricultural Land Occupation (ALO), Terrestrial Acidification (TA), Marine Eutrophication (ME), Metal Depletion (MD), Fossil Depletion (FD) and Water Depletion (WD) was similar to the GWP, CC and CED where the highest amounts in both regions statistically went to high-input system. They reported that in both regions, high-input and conventional systems emitted higher heavy metals than low-input system. Pelesaraei et al. assessed 240 paddy fields in Guilan province, Iran [6]. Their LCA demonstrated that rice production leads to 1166.09 kg CO_2 eq. emission per ton. They found that rice production is hotspot in terms of energy utilization, GWP, TA, and FE impact categories. Using LCA, Mohammadi et al. [7] assessed 82 rice paddy fields in northern Iran, and found that spring cultivation had a weaker environmental impact ("GWP, TA, FE, CED and WD") than summer. The main cause for these results was lower application of inputs and higher paddy yield production of springer rice cultivation compared to summer. Using LCA, Bacenetti et al. [8] assessed 70 hectares of organic rice production fields located in Lomellina of Italy, and found that compost production, CH_4 emissions from the flooded fields, nitrogen associated emissions and the mechanization of the paddy field practices were the main environmental hotspots for organic rice production. Using LCA-ReCiPe method in Bangladesh. Jimmy reported that the magnitude of impact per kg of paddy produced from the harvested field; a CO_2 eq emission of 3.15 kg as GWP, FD of 0.68 kg oil eq, a N eq emission of 0.0154 kg as ME a P eq emission of 0.00122 kg as FE, a 1, 4-DCB-kg oil eq emission of 1.15 kg as human toxicity and use of 2.97 m^3 of water for irrigation purpose. Literature interview indicated that there are numerous studies about the environmental assessment for rice production in countries such as USA, Italy, Taiwan, Japan and China [9-14]. Similar studies were done based on LCA in order to make comparisons between the production systems of wheat and rice [15-17].

The scientific literature reviewing showed that it is of great necessity to assess the life-cycle of rice cropping systems to determine emissions of environmental pollutant. The findings of this study can be very effective in increasing the rice ecosystem's sustainability, as well as reducing the environmental impacts resulting from the application of chemical inputs and the achievement of sustainable agricultural objectives. Therefore, this study was undertaken with the following objectives:

(i) to assess the life-cycle of rice cropping system; (ii) to compare the life-cycle of local rice cultivar in different cropping systems; and (iii) to identify sustainable and environmentally safer rice cropping systems for production of local and improved rice cultivars in northern Iran.

MATERIALS AND METHODS

Description of the experimental site

Field trials were conducted in Babol region (in the central part of Mazandaran province) located in north of Iran between the Alborz Mountains and the Caspian Sea during the year 2016 and 2017. Babol region is geographically situated at 36°, 32' to 36°, 39' N latitude and 52°, 45' to 52°, 58' E longitude. In the rice growing season (from April to September), its climate is temperate sub-humid and its average maximum and minimum temperature and solar

Department of Agronomy, Science and Research Branch, University of Islamic Azad, Tehran, Iran

Correspondence: *Youseftabar S, Department of Agronomy, Science and Research Branch, University of Islamic Azad, Tehran, Iran, E-mail: h.heydary.sharifabad@gmail.com*

Received: 06 August, 2021; **Accepted:** 20 August, 2021, 2021; **Published:** 27 August, 2021

radiation, and rainfall are 25.9 and 18.5°C, 17.9 MJ m^{-2} d^{-1}, and 93.4 mm, respectively [18]. Rice is usually harvested in September in research area and after that the clover, canola or wheat crops is cultivated in the rice field in a double cropping system or manage the rice residue for ratoon harvesting. The soil properties of the experimental sites are shown in Youseftabar et al.

Description of the experiment

The experiment was carried out as factorial based on a Randomized Complete Blocks Design (RCBD) with four replications. Five cropping systems including conventional, low-input, high-input, improved and organic systems were used as subplots. Two planting patterns (traditional and semi-mechanized) were considered as main plots, respectively. All the paddy fields systems pertain to local rice cultivar ('Tarom Hashemi') were five cropping systems along with two planting patterns considered as treatments. The size of each plot was 5 × 10 m^2.

In the semi-mechanized planting method, the agricultural practices (puddling, irrigation regimes, fertilization, and weeds control and plant protection) were carried out traditionally by farmers' practice and the planting operations (using seedling box and mechanized transplanting) and harvesting practice (by combine and harvester machine) were mechanized. In the traditional planting methods, all the agricultural practices except harvest were carried out by farmers' practice without machine.

The paddy fields were selected for the conventional, low-input, high-input and improved systems based on the soil characteristics analysis done in each region. But, the paddy fields were selected for the organic system according to the International Federation of Organic Agriculture Movements (IFOAM) protocols under the supervision and control of the experts and the inspector of IFOAM. Each cropping system was selected according to all social, economic, environmental and agricultural issues. Details of each cropping system are described in and more details of cropping systems are shown with Youseftabar et al. (Table 1) [19].

LCA methodology

"LCA is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, use, and disposal or recycling", and transportation [20]. LCA is carried out in four main phases: definition of goals and scope; analysis of inventory; impact assessment; interpretation. In this regard, four phases which are goal and scope definition, inventory analysis, impact assessment, and interpretation, were designed to assess life cycle index.

Goal and scope

This LCA study aimed to evaluate and compare the environmental impact of producing local and improved rice cultivars for cover crop-rice rotations. The functional unit was one ton of paddy yield (with 12%moisture content). Since straw is a co-product of paddy farms, economic allocation and environmental impact was assessed by the LCA method of SimaPro8.2.3 software [21,22]. Based on economic allocation, about 90% and 10% of dry matter of experimental farms were attributed to paddy and straw, respectively [23,24].

Life Cycle Inventory (LCI)

In this step, all emissions due to the production of inputs (indirect emission) and application of inputs (direct emission) in local and improved rice cultivars for cover crop-rice rotations produced were calculated using the Eco invent 3.1 database. Items that were considered are: (i) infrastructures, comprising construction, maintenance and depreciation of machinery and buildings (shelters for machinery); (ii) all agricultural practices including bed preparation for cultivation, fertilization, protection, irrigation, harvest, transportation supply and utilization of fuel for the practices; (iii) production of fertilizers, herbicide and fungicide and (iv) transportation of all inputs.

Life Cycle Impact Assessment (LCIA)

"LCIA aims to evaluate environmental impacts based on inventory analysis within a framework of the goal and scope of the study. In this phase, the inventory results are assigned to different impact categories" [25]. To do more comprehensive and accurate environmental impact assessment, which involves characterizing, normalizing and weighing, in the production of local rice cultivar in different cropping systems, different methods including ReCiPe 2016, Ecopoints 97 CH, Cumulative Energy Demand (CED), and Cumulative Energy Demand (CExD) were used in SimaPro8.2.3 software. Characterization, which is the first step of LCIA, is the assessment of environmental impacts of each. Inventory flow ("e.g., modeling the potential impact of carbon dioxide (CO_2) and methane (CH_4) on global warming), and provides the ability to compare LCI results within each category". For instance, CO_2, nitrous oxide (N_2O) and CH_4 have different environmental impacts on global warming. The global warming potential of CO_2, N_2O and CH_4 are 1, 265 and 28 kg CO_2 eq, respectively. There are different classifications for impact categories depending on the method used. The most important impact categories in this study were GWP, TA, FE, ME, WD, CED and CExD. In addition, to conduct a deeper analysis, the amount of NH_3, N_2O and CH_4 emissions and heavy metals and other materials emitted in the air (Pb, Cd, Zn, Hg), water (Cr, Zn, Cu, Cd, Hg, Pb, Ni) and soil (nitrate, metals and pesticide) are reported separately in the results section. For each impact category, corresponding characterization factors were used based on the IPCC 2013 GWP 100a, ReCiPe2016, Ecopoints 97 CH, CED and CExD methods in SimaPro8.2.3 software.

Interpretation

One of the aims of LCA is to provide comprehensive information for decision makers. To achieve this goal, LCA results of a study must be interpreted. In this step, the LCA results of different cropping systems for local ('Tarom Hashemi') rice cultivar were assessed and compared.

RESULTS

Interpretation of LCA results

Data analyses of LCA by ReCiPe method in different rice cropping systems are presented in are shown heavy metal and other emissions of Ecopoint 97 (CH) method (Figure 1). Displayed non-renewable and renewable Cumulative Energy Demand (CED) (Figure 2).

TABLE 1

Contribution of non-renewable cumulative energy demand of rice cropping systems in traditional and semi-mechanized planting method

Cropping system			Cropping system				
			Organic	Improved	Low-input	Conventional	High-input
Seed usage	Traditional method		55 kg ha^{-1}	60 kg ha^{-1}	65 kg ha^{-1}	75 kg ha^{-1}	70 kg ha^{-1}
	Semi-mechanized method		40 kg ha^{-1}	45 kg ha^{-1}	45 kg ha^{-1}	55 kg ha^{-1}	50 kg ha^{-1}
Seedling age			35 days old	25 days old	30 days old	30 days old	25 days old
			4-5 leaves	3-4 leaves	4-5 leaves	5-6 leaves	4-5 leaves
Plant density			16 plant per m^2	22 plant per m^2	25 plant per m^2	25 plant per m^2	25 plant per m^2
Planting arrangement			25 × 25 cm^2	25 × 20 cm^2	20 × 20 cm^2	20 × 20 cm^2	20 × 20 cm^2
Fertilizer amount	N (Urea)	0	120 kg ha^{-1}	50 kg ha^{-1}	150 kg ha^{-1}	250 kg ha^{-1}	ALT

	P (Triple super phosphate)	0	75 kg ha-1	0	50 kg ha-1	100 kg ha-1
	K (Potassium sulfate)	0	75 kg ha-1	50 kg ha-1	50 kg ha-1	100 kg ha-1
	Zn (Zinc sulfate)	0	25 kg ha-1	0	0	30 kg ha-1
	Bio-fertilizer	Azotobarvar-1 (300 gr)	Azotobarvar-1 (200 gr)	0	0	0
		Phosphate Barvar-2 (300 gr)	Phosphate Barvar-2 (100 gr)	0	0	0
		Pota Barvar-2 (300 gr)	Pota Barvar-2 (100 gr)	0	0	0
Weed control		Manual	Manual+weedicide	Manual+weedicide	Manual+weedicide	Manual+weedicide
Pests control		Trichogrammabee+light trap+pheromone trap	Pesticides	Trichogramma bee+light trap	Pesticides	Pesticides
Irrigation regime		Flooding+interval	Flooding+interval	Flooding+drainage	Flooding	Flooding+drainage

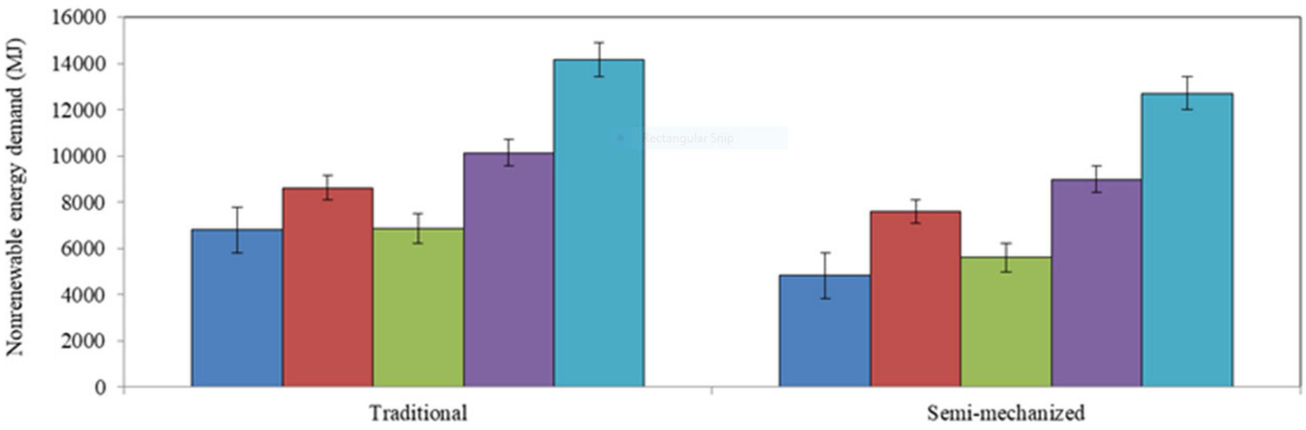

Figure 1) *Contribution of non-renewable cumulative energy demand of rice cropping systems in traditional and semi-mechanized planting method.* **Note:** ( ) *Organic*, ( ) *Improved*, ( ) *Low input*, ( ) *Conventional*, ( ) *High input*

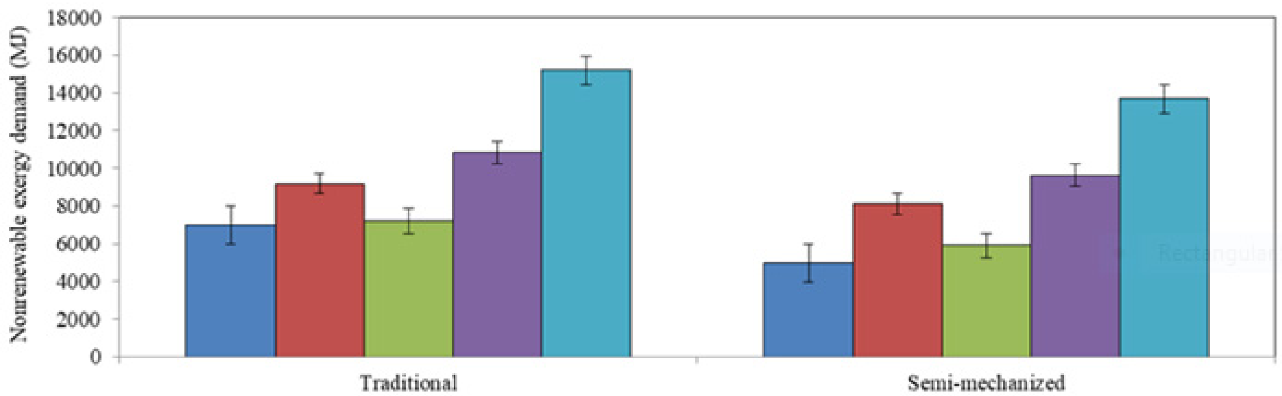

Figure 2) *Contribution of non-renewable cumulative energy demand of rice cropping systems in traditional and semi-mechanized planting method.* **Note:** ( ) *Organic*, ( ) *Improved*, ( ) *Low input*, ( ) *Conventional*, ( ) *High input*

ReCiPe method

In the ReCiPe method, the most important impact categories including Climate Change (CC), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Marine Eutrophication (MEU), Ozone Depletion (OD), Water Depletion (WD), Metal Depletion (MD), Fossil Depletion (FD), Human Toxicity (HT), Photochemical Oxidant Formation (POF), Particular Matter Formation (PMF), Terrestrial Ecotoxicity (TE), Freshwater Ecotoxicity (FE), Marine Ecotoxicity (ME), Ionising Radiation (IR) and Agricultural Land Occupation (ALO) were assessed. Findings of ReCiPe method indicated that all the investigated impact categories were significantly different under the effect of cropping systems and planting method. According to findings, all the impact categories of ReCiPe method for high input system were significantly higher than other systems. In both planting method, the most CC, TA, FE, HT, FE and POF was emitted in high input system and the conventional and improved systems got ranks next. The least amount of CC, TA, FE, HT, FE and POF was observed in low input and organic systems, respectively (Table 2). In both planting method, other impact categories (PMF, TE, FE, ME and IR) was varied that high input and conventional systems demonstrated higher amounts than other systems which the lowest amount was observed in organic and low input systems (Table 3). In both cultivation methods, high input system showed the highest ALO, OD, WD, MD and FD, respectively. The lowest amount of ALO, OD, WD, MD and FD was recorded in organic and low input systems, respectively (Table 4).

Cumulative Energy Demand (CED)

According to findings, all the impact categories of CED including non-renewable, fossil; non-renewable, nuclear; non-renewable, biomass; total non-renewable energy; renewable, biomass; renewable, wind, solar, geothe; renewable, water; and total renewable energy were statistically significant by cropping systems (data not shown). The most CED in both cultivation methods was observed for high input and conventional systems and improved system got rank next. The least amount of CED was observed in organic and low input system (Figure 1).

TABLE 2

Description of rice cropping systems for local rice cultivar in traditional and semi-mechanized methods by ReCiPe method

Treatment		Climate change $kgCO_2eq$	Terrestrial acidification kg SO_2 eq	Freshwater eutrophication kg Peq	Marine eutrophication kg N eq	Human toxicity kg1,4-DB eq	Photochemical oxidant formation kg NMVOC
Traditional method	**Cropping system**						
	Organic	219.29	1.26	0.0152	0.1913	21.22	1.06
	Improved	399.76	1.54	0.0313	1.46	100.34	1.34
	Low input	282.43	1.18	0.0153	0.8427	42.76	1.03
	Conventional	482.88	1.65	0.0219	1.91	88.97	1.49
	High input	703.01	2.43	0.0444	2.88	169.25	2.13
	Mean	417.47	1.61	0.0256	1.45	84.5	1.41
	SD	189.49	0.4965	0.0123	1.02	57.44	0.4462
	SE	63.16	0.1655	0.0041	0.3419	19.14	0.1487
	CV	4.53	3.08	4.83	7.04	6.79	3.16
Semi-mechanized method	**Cropping system**						0
	Organic	138.1	0.835	0.0092	0.135	12.18	0.6452
	Improved	350.56	1.3	0.0274	1.39	93.72	1.1
	Low input	215.83	0.8649	0.0101	0.7584	35.1	0.7277
	Conventional	414.43	1.34	0.0167	1.8	80.31	1.19
	High input	636.26	2.13	0.0394	2.75	159.64	1.84
	Mean	351.03	1.29	0.0205	1.36	76.19	1.1
	SD	192.99	0.52	0.0127	0.9986	57.17	0.4746
	SE	64.33	0.1744	0.0042	0.3328	19.05	0.1582
	CV	5.49	4.045	6.22	7.3	7.5	4.31

TABLE 3

Description of rice cropping systems for local rice cultivar in traditional and semi-mechanized methods by ReCiPe method

Treatment		Particulatematter formation kgPM10 eq	Terrestrial ecotoxicity kg 1,4-DB eq	Freshwater ecotoxicity kg 1,4-DB eq	Marine ecotoxicity kg 1,4-DB eq	Ionising radiation kBq U235 eq
Traditional method	**Cropping system**					
	Organic	0.6328	0.0248	0.2236	0.2834	26.51
	Improved	0.8885	0.1196	0.4319	1.45	42.09
	Low input	0.6618	0.0633	0.2891	0.6224	31.73
	Conventional	0.992	0.1353	0.5185	1.32	52.58
	High input	1.45	0.2203	0.77	2.49	74.36
	Mean	0.925	0.1126	0.4466	1.23	45.45
	SD	0.3301	0.0746	0.2147	0.8528	19
	SE	0.11	0.0248	0.0715	0.2842	6.33
	CV	3.56	6.62	4.8	6.91	4.18
Semi-mechanized method	**Cropping system**					
	Organic	0.3866	0.0162	0.155	0.172	19.33
	Improved	0.7484	0.1123	0.3918	1.373	38.18
	Low input	0.4688	0.0546	0.2409	0.5296	27.22
	Conventional	0.8001	0.1251	0.47	1.22	48.31
	High input	1.27	0.2087	0.7115	2.36	68.56
	Mean	0.7347	0.1033	0.3938	1.13	40.32
	SD	0.3474	0.0735	0.2163	0.8453	19.22
	SE	0.1158	0.0245	0.0721	0.2817	6.4
	CV	4.72	7.12	5.49	7.47	4.76

TABLE 4

Description of rice cropping systems for local rice cultivar in traditional and semi-mechanized method by ReCiPe method

Treatment	Agricultural landoccupation m^2a		Ozone depletion g CFC-11 eq	Water depletion m^3	Metal depletion kg Fe eq	Fossil depletion kg oil eq
	Cropping system					
	Organic	30.79	0.0877	12.09	59.55	149.21
	Improved	66.41	0.3096	11.6	80.22	168.85
	Low input	12.45	0.189	13.11	55.04	139.07
	Conventional	106.73	0.4383	13.86	73.6	195.75
	High input	176.84	0.6495	14.15	114.67	269.02
	Mean	66.32	0.3348	12.96	76.61	184.38
	SD	80.9	0.2194	1.1	23.59	52.01
	SE	26.96	0.0731	0.3672	7.86	17.33
	CV	12.1	6.55	8.49	3.07	28.21
Semi-mechanized method	Cropping system					
	Organic	21.09	0.0577	8.34	28.63	106.24
	Improved	71.29	0.2893	8.84	63.16	146.86
	Low input	21.88	0.1654	8.84	30.87	112.42
	Conventional	112.48	0.4098	9.97	49.55	172.13
	High input	180.39	0.6159	10.53	94.04	238.63
	Mean	72.99	0.3076	9.3	53.25	155.25
	SD	78.35	0.217	0.9091	26.84	53.72
	SE	26.11	0.0723	0.303	8.94	17.9
	CV	10.73	7.05	9.77	5.04	3.46

Cumulative Exergy Demand (CExD)

The results of Figure 2 indicated that all the investigated impact categories of renewable and non-renewable CExD were significantly different under the effect of cropping systems. Non-renewable CExD indices (non-renewable, fossil; non-renewable, nuclear; non-renewable, primary; non-renewable, metals; non-renewable, minerals and total non-renewable energy) for semi mechanized method were higher than traditional method, respectively (Figure 2). For both method, high input system shows the highest amount of total non-renewable energy and conventional and improved systems got ranks next, respectively. The minimum total non-renewable energy was utilized in organic and low input systems, respectively (Figure 2).

Ecopoints 97 (CH) method

The results of this method showed that all the investigated emission in the air, water and soil were significant under the effect of cropping systems. The findings in which are derived from the Eco points 97 method with impact categories related to the emission of heavy metals and other environmental pollutants in air, water and soil, showed that the heavy metals emitted in air (Pb, Cd, Zn and Hg), water (Cr, Zn, Cu, Cd, Hg, Pb, Ni and AOX) and soil (nitrate, metals and pesticides) were statistically less in traditional method than semi mechanized method (Table 5).

Among the crop systems, high input system showed highest heavy metal emission than other systems in the air, water and soil. But, the lowest heavy metals emission in the air and water were recorded in organic and low input systems, respectively. In addition, emission of pollutants from soil (nitrate, metals and pesticide) in high input system was higher than others for both cultivation methods. Emission of NH_3, COD and dust PM10 of both methods in different systems in high input and conventional systems was higher than other systems and organic and low input systems showed lowest amount (Table 6).

TABLE 5

Heavy metals emission of rice cropping system for local cultivar in the air and water and soil by Ecopoints 97 (CH) method

Treatment		Pb (air) g	Cd (air) g	Zn (air) g	Hg (air) g	Cr (water) g	Zn (water) g	Cu (water) g	Cd (water) g	Hg (water) g	Pb (water) g	Ni (water) g
Traditional method	Cropping system											
	Organic	0.328006	0.01955	0.524369	0.008967	0.447035	0.56294	0.053403	0.00496	0.000729	0.043039	0.069887
	Improved	1.460906	0.072157	11.88288	0.02949	0.381806	1.073142	-0.06216	0.010198	0.001697	-1.1546	-0.02026
	Low input	0.39738	0.036092	0.463895	0.008006	0.397781	0.620938	-0.02	-0.00262	0.000808	-0.66233	0.017465
	Conventional	0.668789	0.073761	0.587952	0.010514	0.475717	0.997812	-0.12677	-0.0138	0.000958	-1.8192	-0.04485
	High input	2.029281	0.125189	14.31598	0.038165	0.535345	1.719462	-0.18985	0.000305	0.002207	-2.61021	-0.09015
	Mean	0.976872	0.06535	5.555015	0.019028	0.447537	0.994859	-0.06908	-0.00019	0.00128	-1.24066	-0.01358
	SD	0.7405	0.0407	6.94	0.0138	0.0618	0.463	0.094	0.009	0.0006	1.02	0.0608
	SE	0.2468	0.0135	2.31	0.0046	0.0206	0.1543	0.0313	0.003	0.0002	0.3415	0.0202
	CV	7.58	6.24	1.24	7.29	1.38	4.65	1.36	4.73	5.03	8.25	4.48
Semi-mechanized method	Cropping system											

Organic	0.172481	0.011097	0.277719	0.005098	0.234163	0.386771	0.030072	0.002703	0.000425	0.024728	0.037733
Improved	1.352154	0.066452	11.50341	0.026954	0.265132	0.970339	-0.07324	0.008846	0.001494	-1.13853	-0.03591
Low input	0.272575	0.029088	0.270944	0.005027	0.226287	0.499584	-0.03797	-0.0042	0.000537	-0.65646	-0.00668
Conventional	0.539858	0.065986	0.397302	0.0076	0.308708	0.882407	-0.1406	-0.01497	0.000698	-1.7786	-0.06619
High input	1.887592	0.117077	13.80563	0.034953	0.394298	1.574829	-0.19985	-0.00103	0.00195	-2.55354	-0.10663
Mean	0.844932	0.05794	5.251002	0.015926	0.285718	0.862786	-0.08432	-0.00173	0.001021	-1.22048	-0.03553
SD	0.7445	0.0408	6.8	0.014	0.0687	0.4683	0.0892	0.0088	0.0006	0.9954	0.0552
SE	0.2481	0.0136	2.26	0.0046	0.0229	0.1561	0.0297	0.0029	0.0002	0.3318	0.0184
CV	8.81	7.04	1.29	8.81	2.4	5.42	1.05	5.11	6.53	8.15	1.55

TABLE 6

AOX, nitrate, metals and pesticides emission of rice cropping systems for local cultivar in the air, water and soil by Eco points 97 (CH) method

Treatment		NOxg	SOxg SO2 eq	Dust PM10g	CO2g CO2 eq	Nitrate (soil) g	Metals (soil)g Cd eq	Pesticide soil g act. subst.
Traditional method	Cropping system							
	Organic	459.17	902.7	340.16	229382	717.78	0.0069	1.18
	Improved	810.27	1343.45	478.09	402377	620.66	0.0023	1.05
	Low input	537.24	972.57	363.05	287462	793.55	0.0053	1.32
	Conventional	868.06	1530.27	546.28	486996	814.63	0.0024	1.34
	High input	1342.91	2263.64	785.6	706753	723.31	-0.00043	1.23
	Mean	803.53	1402.52	502.64	422594	733.99	0.0033	1.22
	SD	348.07	546.81	179.2	187679	76.27	0.0028	0.1195
	SE	116.02	182.27	59.73	62559	25.42	0.0009	0.0398
	CV	4.33	3.89	3.56	4.44	10.39	8.62	9.74
Semi-mechanized method	Cropping system							
	Organic	293.57	589.31	194.38	143849	510.08	0.0049	0.8279
	Improved	712.52	1166.76	395.04	351156	456.66	0.0009	0.7783
	Low input	408.77	740.03	246.05	217857	534.32	0.0031	0.8928
	Conventional	739.61	1300.77	428.51	415571	580.82	0.0005	0.962
	High input	1211.38	2026.69	680.21	637759	506.23	-0.0021	0.8746
	Mean	673.17	1164.71	388.84	353238	517.62	0.0014	0.8671
	SD	356.94	564.12	190.2	191711	45.21	0.0027	0.0691
	SE	118.98	188.04	63.4	63903	15.07	0.0009	0.023
	CV	5.3	4.84	4.89	5.42	8.73	1.84	7.97

DISCUSSION

Agricultural and non-agricultural practices such as the production and transfer of fertilizers and pesticides in rice production play roles in global warming by producing 80-98 and 16-91 kg CO_2 eq ha^{-1},y respectively [26]. Different natural and human causes create global warming but global warming is mostly considered to be due to an increase in emission of greenhouse gases because of human activities which induces many changes in global climate patterns [27]. In order to report the amount of produced GHGs, all the produced gases with a CO_2 which reflects the GWP, are reported. Pelesaraei et al. demonstrated that diesel, at 44.34%, had the highest share of energy utilization in paddy rice production in Guilan province, and total energy input was equal to 51585 MJ ha^{-1}. In another study in rice diesel-based production in Iran, diesel accounted for about 46.41% of the total energy utilization in Guilan province, and 29.67% of total energy utilization in Mazandaran province [28]. Komleh et al. showed that the largest energy utilization in rice production was related to fuel (46% of total energy utilization) which included diesel, natural gas and electricity. Soltani et al. reported the emissions with GWP to be 621 kg CO_2 eq for producing a ton of wheat in Gorgan, Iran. GWP impact category in the farming section was reported to be 119.5 kg CO_2 eq for wheat production in China (Wang et al. 2009), 1484-1847 kg CO_2 eq for rice in Rasht, Iran 340 kg CO_2 eq for wheat in Marvdasht, Iran and 381 kg CO_2 eq for wheat in Switzerland [29,30]. The demand for non-renewable energy in wheat production in Gorgan, Iran was 6641 MJ t^{-1}. The total energy utilized, which depended on the type of soil and field practices and production systems, was 274 to 557 MJ t^{-1} in the

UK and 521 MJ t^{-1} for sugar beet production in Japan [31,32]. The reason for the high or low share of non-renewable energy in different scenarios was the difference in fuel usage, fertilizer, and machinery performance, which was also reported by other researchers on similar issues [33]. The share of NH_3 in acidification potential was more significantly than that of N_2O and SO2. In fact, the NH_3 emission resources are urea fertilizer. Ammonia sublimation has an important impact on eutrophication and acidification [34]. The release of NH_3 in sublimation from urea is a physical and chemical process, and it is more sensitive than N_2O to the management of fertilizer application. In a study on rice in China, it was observed that the depletion of fossil resources for fossil fuel consumption was 106 MJ t^{-1} and the final eco-index was 0.008 [35]. To produce one ton of crops, the following amount of diesel fuel needs to be consumed: 25.63 L for canola in Turkey 87.78 L for soybean in Iran and 25.08 L for rice in Guilan, Iran [36]. The water consumption during rice production in China was 379 cm t^{-1}, and the final eco-index obtained was 0.14 for the reduction of water resources. In another study in the north of China, the final eco-index for the reduction of fossil resources was 0.02 for one ton of wheat production and 0.009 for one ton of corn production. To produce one ton of wheat in Germany, acidification and global warming are the main environmental impacts [37].

CONCLUSION

Different impact categories of life cycle assessment were evaluated in three rice production systems in the two semi-mechanized and traditional planting methods. Thus far, no report has been shown on various production systems with different planting methods. Hence, the findings of this study can be very effective in increasing the rice ecosystem's sustainability, as well as reducing the environmental impacts resulting from the use of chemical inputs and the achievement of sustainable agricultural objectives. The findings of this study indicate that the share of inputs and outputs was different in each rice production systems. The main reason for the observed difference was the amount of input and output, diversity of farm management practice, and input consumption. According to the findings, the share of non-renewable energy demand, CC, and GWP 100 a in both methods was low for low-input and organic systems, which could increase the share of renewable energy by incorporating conservation planting approaches. This issue is of great importance from the ecological point of view, because the source of non-renewable energies, which is mostly fossil fuels, and the reliance on these resources in the future, are fraught with great risks.

REFERENCES

1. UN Food and Agriculture Organization. Crops/Regions/World List/Production Quantity (pick lists), Rice (paddy), 2014. Corporate Statistical Database. 2017.
2. Iriarte A, Rieradevall J, Gabarrell X, et al. Life cycle assessment of sunflower and rapeseed as energy crops under Chilean conditions. J Clean Prod. 2010;18(4):336-445.
3. Goossens Y, Annaert B, de Tavernier J, et al. Life cycle assessment (LCA) for apple orchard production systems including low and high productive years in conventional, integrated and organic farms. Agric Syst. 2017;153(5):81-93.
4. Dastan S, Ghareyazie B, Pishgar SH, et al. Environmental impacts of transgenic Bt rice and non-Bt rice cultivars in northern Iran. Biocatal Agric Biotechnol. 2019;20(5):101160.
5. Habibi E, Niknejad Y, Fallah H, et al. Life cycle assessment of rice production systems in different paddy field size levels in north of Iran. Environ Monit Assess. 2019;191(4):1-23.
6. Nabavi-Pelesaraei A, Rafiee S, Mohtasebi SS, et al. Integration of artificial intelligence methods and life cycle assessment to predict energy output and environmental impacts of paddy production. Sci Total Environ. 2018;631(6):1279-1294.
7. Mohammadi A, Rafiee S, Jafari A, et al. Joint life cycle assessment and data envelopment analysis for the benchmarking of environmental impacts in rice paddy production. J Clean Prod. 2015;106(5):521-532.
8. Bacenetti J, Fusi A, Negri M, et al. Organic production systems: Sustainability assessment of rice in Italy. Agric Ecosyst Environ. 2016;225(7):33-44.
9. Yamani K, Hazzab A, Sekkoum M, et al. Mapping of vulnerability of flooded area in arid region. Case study: Area of Ghardaia-Algeria. Model. Earth Syst Environ. 2016;2(3):1-7.
10. Linquist B, van Groenigen KJ, Pittelkow C, et al. An agronomic assessment of greenhouse gas emissions from major cereal crops. Glob Change Biol Bioenergy. 2012;18(1):194-209.
11. Blengini GA, Busto M. The life cycle of rice: LCA of alternative agri-food chain management systems in Vercelli (Italy). J Envi Manag. 2009;90(3):1512-1522.
12. Yang SS, Lai CM, Chang HL, et al. Estimation of methane and nitrous oxide emissions from paddy fields in Taiwan. Renew Energy.2009;34(8):1916-1922.
13. Pålsson H, Pettersson F, Hiselius LW. Energy consumption in e-commerce versus conventional trade channels-Insights into packaging, the last mile, unsold products and product returns. J Clean Prod. 2017;164(7):765-778.
14. Zhang A, Cui L, Pan G, et al. Effect of biochar amendment on yield and methane and nitrous oxide emissions from a rice paddy from Tai Lake plain, China. Agric Ecosyst Environ. 2010;139(4):469-475.
15. Brentrup F, Kusters J, Lammel J, et al. Environmental impact assessment of agricultural production systems using the life cycle assessment (LCA) methodology: II. The application of N fertilizer use in winter wheat production systems. Eur J of Agron. 2004;20(3):265-279.
16. Nabavi-Pelesaraei A, Rafiee S, Mohtasebi SS,et al.Energy consumption enhancement and environmental life cycle assessment in paddy production using optimization techniques. J Clean Prod. 2017;162(5):571-586.
17. Morandini NP, Petroudi ER, Mobasser HR, et al. Life cycle assessment of crop rotation systems on rice cultivars in Northern Iran. Int J Plant Prod. 2020;14(3):531-548.
18. Youseftabar S, Heidari Sharifabad H, Majidi Heravan I, et al. Rice cropping system in semi-mechanized and traditional planting patterns in Northern Iran. J Plant Nutr. 2020;44(7):970-987.
19. Martínez E, Sanz F, Pellegrini S, et al. Life-cycle assessment of a 2-MW rated power wind turbine: CML method. Int J Life Cycle Assess. 2009;14(1):52-63.
20. Rebitzer G, Ekvall T, Frischknecht R, et al. Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications. Environ Int. 2004;30(5):701-720.
21. Sharma A, Saxena A, Sethi M, et al. Life cycle assessment of buildings: A review. Renew Sustain Energy Rev. 2011;15(1):871-875.
22. Pishgar-Komleh SH, Sefeedpari P, Rafiee S, et al. Energy and economic analysis of rice production under different farm levels in Guilan province of Iran. Energy. 2011;36(10):5824-5831.
23. Soltani A, Rajabi MH, Zeinali E, et al. Energy inputs and greenhouse gases emissions in wheat production in Gorgan, Iran. Energy. 2013;50(6):54-61.
24. Roy P, Nei D, Orikasa T, et al. A review of life cycle assessment (LCA) on some food products. J Food Eng. 2009 ;90(1):1-0.
25. Pathak H, Wassmann R. Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. Agric Syst. 2007;94(3):807-825.
26. Bare J, Young D, Hopton M, et al. Tool for the reduction and assessment of chemical and other environmental impacts (TRACI) user's manual. Environmental Protection Agency: Washington, DC, USA. 2012.
27. Kazemi H, Kamkar B, Lakzaei S, et al. Energy flow analysis for rice production in different geographical regions of Iran. Energy. 2015;84:390-396.
28. Nabavi-Pelesaraei A, Abdi R, Rafiee S, et al. Applying data envelopment analysis approach to improve energy efficiency and reduce greenhouse gas emission of rice production. EAEF. 2014;7(4):155-162.
29. Nabavi-Pelesaraei A, Hosseinzadeh-Bandbafha H, Qasemi-Kordkheili P, et al. Applying optimization techniques to improve of energy efficiency and GHG (greenhouse gas) emissions of wheat production. Energy. 2016;103:672-678.
30. Tzilivakis J, Warner DJ, May M, et al. An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. Agric Syst. 2005;85(2):101-19.

31. Koga N. An energy balance under a conventional crop rotation system in northern Japan: Perspectives on fuel ethanol production from sugar beet. Agric Ecosyst Environ. 2008;125(4):101-110.

32. Pazouki TM, Ajam Noroui H, Ghanbari Malidareh A,et al. Energy and CO_2 emission assessment of wheat (Triticum aestivum L.) production scenarios in central areas of Mazandaran province, Iran. Appl Ecol Environ Res. 2017;15(4):143-161.

33. Engström R, Wadeskog A, Finnveden G, et al. Environmental assessment of Swedish agriculture. Ecol Econ. 2007;60(3):550-563.

34. Wang M, Xia X, Zhang Q, et al. Life cycle assessment of a rice production system in Taihu region, China.Int J Sustain Dev World Ecol. 2010;17(2):157-161.

35. Unakitan G, Hurma H, Yilmaz F, et al. An analysis of energy use efficiency of canola production in Turkey. Energy. 2010;35(9):3623-3627.

36. Ramedani Z, Rafiee S, Heidari, et al. An investigation on energy consumption and sensitivity analysis of soybean production farms. Energy. 2011;36(11):6340-6344.

37. Wang M, Wu W, Liu W, et al. Life cycle assessment of the winter wheat-summer maize production system on the North China Plain. Int J Sustain Dev. 2007;14(4):400-407.