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Integration of life cycle assessment and Cobb-Douglas modeling for the environmental assessment of kiwifruit in Iran

Amin Nikkhah [a,*,1,2], Bagher Emadi [a], Hamzeh Soltanali [a], Saeed Firouzi [b], Kurt A. Rosentrater [c], Mohammad Sadegh Allahyari [d]

[a] Department of Biosystems Engineering, Ferdowsi University of Mashhad, Mashhad, Iran
[b] Department of Agronomy, College of Agriculture, Rasht Branch, Islamic Azad University, Rasht, Iran
[c] Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA 50011, USA
[d] Department of Agricultural Management, Rasht Branch, Islamic Azad University, Rasht, Iran

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ABSTRACT

This paper aimed at evaluating the environmental impacts of kiwifruit production in Guilan province of Iran using Life Cycle Assessment (LCA) methodology and Cobb-Douglas (CD) modeling. For this purpose, a functional unit (FU) equal to one tonne kiwifruit was applied based on ISO 14,040 methods. Data were obtained from 84 kiwifruit producers using a questionnaire during 2012–2013. Seven impact categories were selected to be evaluated using the life cycle of kiwifruit in the region. The results of data analysis revealed that the amounts of emissions, including NH_3, N_2O, NOx, CO_2, CH_4 and SO_2, for one tonne production of kiwifruit were 2.00, 0.34, 0.30, 45.08, 0.06 and 0.15, respectively. Characterization indices included global warming potential, acidification, terrestrial eutrophication, land use, the depletion of fossil resources, the depletion of phosphate, and the depletion of potash were calculated as 152.18 kg CO_2eq, 3.53 kg SO_2eq, 9.15 kg NO_xeq, 0.32 ha, 531.23 MJ, 2.57 kg P_2O_5 and 0.83 kg K_2O, respectively. Indicators for environmental index (Eco-indeX) and resource depletion (RDI) were 0.35 and 0.45, respectively. High potentials for environmental impacts due to depletion of phosphate resources and eutrophication in the RDI and Eco-indeX Indicators were found. The results of LCA + CD showed that the impacts of inputs, including diesel fuel, phosphate and potash fertilizers on the yield of kiwifruit were positive, while the impacts of urea fertilizer on the yield was negative. To conclude, due to the high environmental impacts of urea fertilizer and its negative effect on kiwifruit yield, it is recommended to replace urea with other sources of nitrogen fertilizer which have lower environmental impacts.

1. Introduction

Growing demand for food products has resulted in an increased attention to agricultural production (Tilman et al., 2002; Ebrahimi-Nik and Ghasemzade, 2014). Producing a constant and sustainable energy supply for the present century has prompted many countries to develop new policies on energy, including bio-sources (Tilman et al., 2009; Jaruwongwittaya and Chen, 2010; Fiala and Bacenetti, 2012; Hosseini et al., 2013; Khojastehpour et al., 2015; Ghadiryanfar et al., 2016). Considering limited cultivable land, genetic modification of seeds, mechanization of agriculture, and using inputs such as fossil fuels and chemical fertilizers more effectively are all ways to increase agricultural productivity and to increase food security. So far, such inputs and their environmental impacts have only begun to be investigated (Tzilivakis et al., 2005; Nguyen et al., 2007; Soltani et al., 2013). The aim of many of these studies was to evaluate the environmental impacts of agricultural production in terms of global warming potential, because climate change has become a key challenge facing humanity.

In estimating environmental impacts of agricultural production, various methods and models may be implemented (Röös et al., 2010; Nabavi-Pelesaraei et al., 2016a, 2016b), and various parameters and effects can be calculated. Life Cycle Assessment (LCA) can be an appropriate methodology for examining the environmental consequences of agricultural production, because this approach

* Corresponding author. Department of Biosystems Engineering, College of Agriculture, Ferdowsi University of Mashhad, Iran.

E-mail addresses: Farnood.nickhah@gmail.com, amin.nikkhah@stu.um.ac.ir (A. Nikkhah), karosent@iastate.edu (K.A. Rosentrater).

[1] https://www.researchgate.net/profile/Amin_Nikkhah
[2] http://orcid.org/0000-0002-3008-2401

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takes a cradle-to-grave perspective for products, systems, and activities (Canals et al., 2006; Roy et al., 2009; Noori et al., 2013; Ashworth et al., 2015).

In fact, several researchers have used LCA methodology to evaluate the environmental impacts associated with fruit production (Cerutti et al., 2011, 2014; Vinyes et al., 2015). For example, Canals et al. (2006) applied LCA to apple production in New Zealand; they concluded that fuel consumption during apple production had greater negative effects on the environment for most impact categories examined. In a similar study, Mouron et al. (2006) performed an LCA study on apple production in Switzerland, and reported the high potentials for environmental impacts in terms of energy use, aquatic ecotoxicity, and aquatic eutrophication impact categories, respectively. Liu et al. (2010), as a result of their LCA study on pear production, reported that a list of choices is available to reduce environmental impacts of pear production. For instance, substitution of the conversion from conventional farming to organic farming and using manure for biogas production were mentioned. Page et al. (2011) studied the carbon footprints of organic kiwifruit and apple production systems in New Zealand, and reported that organic kiwifruit and apple orchards can gain a monetary benefit by earning carbon credits. Additionally, LCA was used for the environmental assessment of peach orchards in Italy (Ingrao et al., 2015). It was revealed that there are multiple opportunities to reduce greenhouse gas emissions from these orchards through improving various practices and machinery.

Although LCA is a powerful tool, it is difficult to program multiple scenarios and examine a range of possibilities, because each scenario can be time consuming to generate. Combining LCA with other computer models can contribute to a greater understanding of environmental impacts, because it can allow for an expanded capability and a greater range of scenarios and systems analyzed (Mohammadi et al., 2015; Khoshnevisan et al., 2015; Egilmez et al., 2016). For example, the Cobb-Douglas (CD) model has been widely used for energy modeling in agricultural systems: reviewing the literature has revealed that many researchers have used the Cobb-Douglas approach for modeling resource management of agricultural production (Ramedani et al., 2011; Mousavi-Avval et al., 2011; Pishgar-Komleh et al., 2013; Salehi et al., 2014). However, the combination of LCA and Cobb-Douglas modeling for modeling and estimating environmental impacts of agricultural systems has not been investigated yet, and is a novel approach to environmental assessment.

Furthermore, kiwifruit is one of the main horticultural products in Iran, and it is very popular worldwide. The sustainable production of kiwifruit requires a thorough consideration of resource management in the production systems and a greater understanding of multiple environmental impacts. Thus, the objective of this research was to investigate environmental impacts of kiwifruit production in Guilan province of Iran (as a case study) using a combination of LCA and Cobb-Douglas modeling.

2. Materials and methods

2.1. Selection of case study area and data collection

In Iran, there are more than 10,156 ha cultivated with kiwifruit, and Guilan province is the second largest producer of kiwifruit after Mazandaran province (Ministry of Jihad-e-Agriculture of Iran, 2014). This study was focused on Talesh city (within 37° 33′ and 38° 16′north latitude and 48° 32′and 49° 03′ east longitude), within the Gulian province of Iran. Guilan is located in northern region of Iran, south of the Caspian Sea, and it is one of the most important agricultural provinces in Iran (Zareiforoush et al., 2010; Bagheri et al., 2011; Mohammadi-Torkashvand et al., 2014; Firouzi, 2015; Allahyari et al., 2016). The annual average temperature and rainfall in Talesh city are almost 19 °C and 1585 mm, respectively. The agricultural sector accounts for approximately 48 percent of direct employment in this city (Ministry of Jihad-e-Agriculture of Iran, 2014). The required sample size for producer data collection was calculated using the Cochran method (Snedecor and Cochran, 1989):

$$n = \frac{N(s \times t)^2}{(N-1)d^2 + (s \times t)^2} \tag{1}$$

$$d = \frac{t \times s}{\sqrt{n}} \tag{2}$$

where n is the required sample size; N is the number of holdings in target population (4610), t is the reliability coefficient (1.96), S^2 is the variance of studied qualification in population, and d is the acceptable error (permissible error 5%). Therefore, data were collected from 84 kiwifruit producers using a face-to-face survey in the 2012–2013 production years. Table 1 shows a summary of the data collected, including type and date of different operations for kiwifruit production in Guilan province.

2.2. Life Cycle Assessment (LCA)

In recent years, LCA has been frequently used for environmental impact studies to show the effects of different agricultural and industrial production processes on the environment (Carlsson-Kanyama et al., 2003; Meisterling et al., 2009; Roy et al., 2009; Sherwani et al., 2010; Björklund, 2012; Zhou et al., 2013; Bojacá et al., 2014; Suleiman and Rosentrater, 2014; Kucukvar et al., 2014; Khoshnevisan et al., 2014; Pang et al., 2015; Meier et al., 2015; Bacenetti et al., 2016; Fusi et al., 2016). According to standard practice, LCA is divided into four main steps, including: goal and scope definition, inventory analysis, impact assessment, and interpretation (Iriarte et al., 2010; Abeliotis et al., 2013; Kouchaki-Penchah et al., 2015; Noori et al., 2015).

2.2.1. Goal and scope definition

According to ISO14040 (ISO, 2006), Brentrup et al. (2004a) presented the guidelines for the evaluation of environmental impacts of crop production based on the LCA methodology. The first step in LCA is defining the goal of the research and the scope of the study (Fusi et al., 2014; Soheili-Fard and Kouchaki-Penchah, 2015; Khanali et al., 2016). Specifically, the goal of this study was to determine the environmental impacts of kiwifruit production in Guilan province of Iran by examining seven impact categories. These included global warming potential, acidification, terrestrial eutrophication, land use, depletion of fossil resources, the depletion of potash, and the depletion of phosphate.

Table 1
Operations for kiwifruit production in Guilan province, Iran.

Operations type	Date
First manual pruning of trees	20 Nov to 15 Feb
First plowing (manual)	15 Feb to 15 March
Second plowing (moldboard or Rotary tiller)	20 Nov to 15 Feb
Farmyard manure application	15 Feb to 15 March
Mean number of fertilizer applications	2.24 times
Mean number of sprayings	1.22 times
Mean Frequency of weeding	2.97 times
Manual Harvesting (one time)	5 Nov to 20 Dec

2.2.2. Inventory analysis

The inputs for the kiwifruit production system were determined for one functional unit (FU). One tonne of produced kiwifruit was selected as the functional unit. In this research, the consumption of nitrogen, phosphorus and potash fertilizers, and diesel fuel were used as the inputs for the production system of kiwifruit. The amounts of these inputs consumed are shown in Table 2.

The emissions were considered as either background (cradle-to-gate) emissions or foreground (gate-to-gate) emissions (see Fig. 1.). The emitted pollutants of the system were NH_3, N_2O, NOx, CO_2, CH_4 and SO_2. The emissions of pollutants for background data (data related to production of input materials) used in this study were adapted from the Swedish SPINE@CPM database (CPM, 2007). Coefficients of emission for foreground were according to previous studies (Brentrup et al., 2000; Goebes et al., 2003; Tzilivakis et al., 2005; Dehghani, 2007; Snyder et al., 2009). Table 3 shows the potential of pollutants in the various impact categories.

2.2.3. Impact assessment

The third step, estimating the potential environmental impacts of emitted pollutants in the various impact categories, was to calculate the characterization index. The normalization index was calculated by dividing the characterization index by a normalization factor (Fallahpour et al., 2012). The weighting index was calculated by multiplying these numbers by an appropriate normalization factor.

Mirhaji et al., (2013) determined the normalization factors for the impact categories of global warming potential, acidification and terrestrial eutrophication for Iran, and were 8143 kg CO_2eq, 52 kg SO_2eq, and 63 kg NOxeq, respectively. In addition, weighting factors for these groups were reported to be 1.05, 1.8 and 1.4, respectively. Normalization indices for impact categories of land use, depletion of fossil resources, depletion of potash, and depletion of phosphate were according to the study by Brentrup et al. (2004a), which were reported as 1.86×10^4 ha, 39,167 MJ, 7.66 kgP_2O_5eq, and 8.14 kgK_2Oeq, respectively. Weighting factors for these groups were reported as 1, 1.14, 1.20 and 0.30, respectively.

The impact categories of depletion of fossil resources, the depletion of potash, and the depletion of phosphate affect the resource depletion index (RDI), and the impact categories of global warming potential, acidification, land use and terrestrial eutrophication affect environmental impacts (Eco-indeX). The difference between (Eco-indeX) and (RDI) impact categories is that the latter affects future generations of humans (Soltanali et al., 2015).

2.3. Combination of LCA and Cobb-Douglas modeling

The Cobb-Douglas (CD) model which can be expressed as:

$$y = f(x)\exp(u) \tag{3}$$

Eq. (3) can be linearized and expressed as Eq. (4) (Qasemi-Kordkheili, and Rahbar, 2015):

$$Ln(y_i) = a_0 + \sum_{j=1}^{n} \alpha_j \ln(x_{ij}) + e_i i = 1, 2, \ldots, n \tag{4}$$

where y_i denotes the yield of the i_{th} farmer; x_{ij} is an input in the production process; a_0 is a constant term; a_j represents coefficients of the inputs which are estimated from the model, and e_i is the error term. The yield model for inputs, Eq. (4), can be further expanded to Eq. (5):

$$Ln(y_i) = a_0 + \alpha_1 lnx_1 + \alpha_2 lnx_2 + \alpha_3 lnx_3 + \alpha_4 \ln x_4 + e_i \tag{5}$$

where x_1 is nitrogen fertilizer; x_2 is phosphate fertilizer; x_3 is potash fertilizer; x_4 is diesel fuel.

In production systems, returns to scale (RTS) refers to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the CD model, RTS is indicated by the sum of the elasticities derived in the form of

Table 2
The inputs–output for kiwifruit production in Guilan province, Iran.

Inputs-output	Amount (Unit per ha)		Amount (Unit per tonne)	
	Average	Standard deviation	Average	Standard deviation
Diesel fuel (L)	209.23	104.88	9.43	6.22
Nitrogen (Kg)	184.04	103.47	9.73	9.02
Phosphate (Kg)	198.54	96.08	10.28	8.58
Potash (Kg)	162.55	92.19	7.96	6.13
Kiwifruit yield (kg)	25,281.06	2017.61	–	–

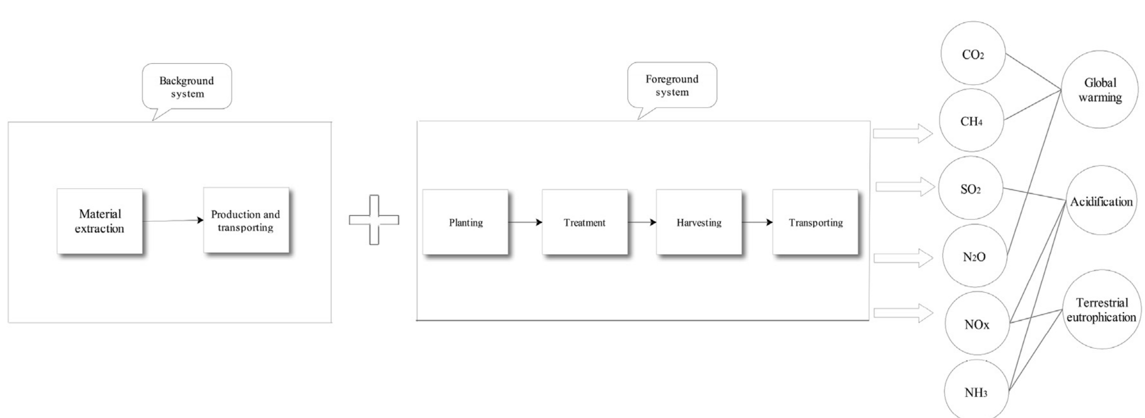

Fig. 1. Cradle-to-gate emissions during kiwifruit production.

Table 3
Potential of emitted pollutants in different impact categories.

Impact category	Potential of compounds	Reference
Global warming potential	$CO_2 = 1$, $CH_4 = 21$, $N_2O = 310$	(Snyder et al., 2009)
Acidification	$SO_2 = 1.2$, $NO_X = 0.5$, $NH_3 = 1.6$	(Brentrup et al., 2004a)
Terrestrial eutrophication	$NH_3 = 4.4$, $NO_X = 1.2$	(Brentrup et al., 2004a)
Land use (ha)	0.8	(Brentrup et al., 2004a)
Depletion of fossil resources (MJ)	42.86	(Brentrup et al., 2004a)
Depletion of phosphate source (kg P_2O_5 eq)	0.25	(Brentrup et al., 2004a)
Depletion of potash source (kg K_2O eq)	0.105	(Brentrup et al., 2004a)

regression coefficients. If the RTS value is more than, equal to, or less than unity, it implies that there are increasing, constant, or decreasing RTS, respectively (Pishgar-Komleh et al., 2013; Salehi et al., 2014).

The influence of different inputs on the kiwifruit yield was quantified using standard beta. Finally, the sensitivity of yield in the region to different inputs was investigated using the Marginal Physical Productivity (MPP) method, which shows the change in yield for one unit change for a given set of inputs, keeping all other factors constant (Pishgar-Komleh et al., 2013; Soltanali et al., 2016). The MPP of the inputs was calculated as reported previously (Rafiee et al., 2010; Mohammadi-Barsari et al., 2016):

$$MPP_{xj} = \frac{GM(Y)}{GM(X_{ij})} \times \alpha_{ij} \tag{6}$$

where MPP_{ij} is the marginal physical productivity of jth input; α_j is the regression coefficient of jth input; GM(Y) is geometric mean of the yield, and GM (X_j) denotes the geometric mean of jth input on a per hectare basis (Royan et al., 2012).

3. Results and discussion

3.1. Input-output analysis

The obtained amounts of diesel fuel, nitrogen, phosphorus and potash fertilizers for producing 1000 kg kiwifruit were 9.43 L, 9.73, 10.28 and 7.69 kg, respectively (Table 2). Nikkhah et al. (2014) concluded that the amounts of gasoline fuel, nitrogen, phosphorus and potash fertilizers to produce 1000 kg tea were 30.3 L, 27.8, 10.7 and 18.34 kg, respectively. Pishgar-Komleh et al. (2011) reported that the amount of diesel fuel to produce 1000 kg rice was 25.1 L. Our results showed that the inputs consumption for kiwifruit production were less than those of the other crops. Moreover, the average yield of kiwifruit in Guilan province was 25,281.06 kg (Table 2).

3.2. Emitted pollutants

The amounts of cradle-to-gate emissions from diesel fuel sources (including NH_3, CO_2, CH_4, SO_2, N_2O and NOx) for one tonne production of kiwifruit (one FU) were determined to be 4×10^{-4}, 29.52, 0.04, 0.06, 0.22, 0.22 kg, respectively. The emissions from nitrogen sources, such as NH_3, N_2O and NOx, for one functional unit were determined to be 2.00, 0.34, and 0.04, respectively. The contribution of emissions from the various impact categories (global warming potential, acidification and terrestrial eutrophication) for one tonne production of kiwifruit is shown in Fig. 2. NH_3 showed a large effect on the acidification and eutrophication impact categories. In fact, NH_3 accounted for 90% and 96% of the acidification and eutrophication impact categories, respectively. Also, N_2O showed the largest degree of environmental impact in the global warming potential impact category.

3.3. Interpretation of LCA results

Table 4 displays the characterization indices for one tonne kiwifruit production in Guilan province. The characterization indices for global warming potential, acidification, terrestrial eutrophication, and land use were, 152.18 kg CO_2eq, 3.53 kg SO_2eq, 9.15 kg NO_xeq, and 0.32 ha, respectively (Table 4). Characterization indices for depletion of fossil resources, the depletion of potash, and the depletion of phosphate were 531.23 MJ, 2.57 P_2O_5, 0.83 kg K_2O, respectively (Table 5).

Weighted indices of global warming potential, acidification, terrestrial eutrophication, land use, depletion of fossil resources, depletion of phosphate potash and depletion of potash were estimated 0.02, 0.12, 0.20, 0.00002, 0.01, 0.40 and 0.03, respectively (see Fig 3 and Table 5). Moreover, the environmental index (Eco-indeX), considering the impact categories of global warming potential, acidification, terrestrial eutrophication and land use, was determined to be 0.35 for the production based on one tonne

Table 4
The amounts of characterization and normalization indices for one functional unit production of kiwifruit.

Impact category	Characterization index	Normalization index
Global warming potential	152.18 kg CO_2 eq	0.02
Acidification	3.53 kg SO_2 eq	0.06
Terrestrial eutrophication	9.15 kg NO_x eq	0.14
Land use	0.32 ha	0.00002

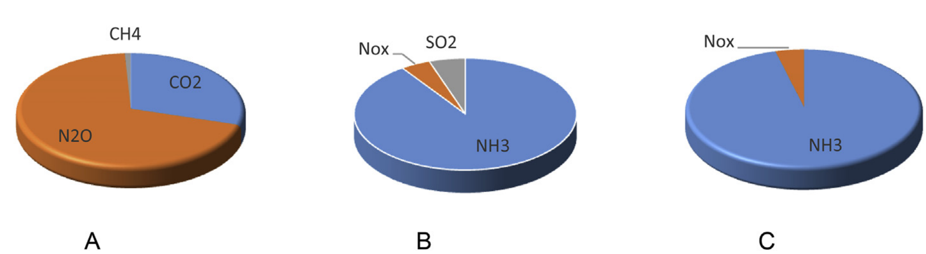

Fig. 2. Contribution of emissions from impact categories A) Global warming potential, B) Acidification, C) eutrophication for terrestrial ecosystems for a functional unit production in kiwifruit production system in Guilan province, Iran.

Table 5
Impact assessment for kiwifruit production in terms of resource depletion.

Impact category	Characterization index	Normalization index	Final index
Depletion of fossil resources	531.23 (MJ)	0.01	0.01
Depletion of phosphate resources	2.57 (kg P_2O_5)	0.33	0.40
Depletion of potash resources	0.83 (kg K_2O)	0.10	0.03

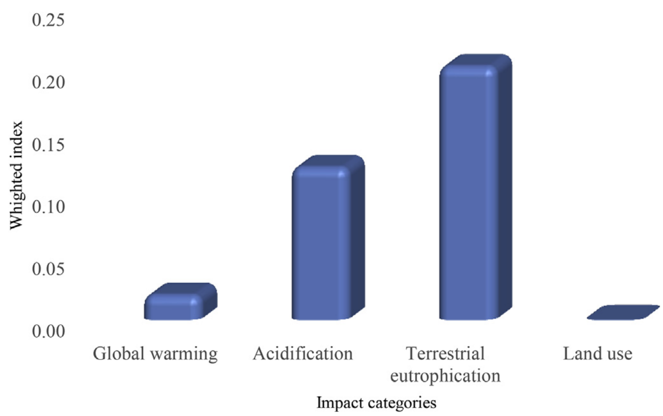

Fig. 3. Weighted indices of Eco-indeX impact categories for one functional unit of kiwifruit production.

kiwifruit under Guilan's climate conditions. The RDI index, considering three impact categories of depletion of fossil resources, the depletion of potash, and the depletion of phosphate, was determined to be 0.45 for one functional unit.

The amount of N_2O emission per functional unit was 0.34 kg (see Fig 2). Urea source accounted for about 99.74% of N_2O emission. Emission of this pollutant is important in two ways: According to the ministry of energy, 36.5 percentage of the N_2O emission is caused by agricultural applications (MOE, 2012), and according to a study conducted by Tzilivakis et al. (2005), the impact of one kg of N_2O on global warming potential is 310 times greater than that of 1 kg of carbon dioxide.

The characterization indices for global warming potential for one tonne production of wheat in Gorgan and Marvdasht of Iran, Swaziland and China were determined to be 620, 262.2, 381 and 119.5 kgCO_2eq, respectively. This index was reported as 311.2 kgCo$_2$eq for peanut production in Guilan, Iran. Moreover, the characterization index of acidification for one tonne production of these aforementioned crops were calculated as 6.7, 7.3, 2.8, 4 and 6.2 kgSO_2eq, respectively (Charles et al., 2006; Wang et al., 2007; Soltani et al., 2010; Mirhaji et al., 2013; Nikkhah et al., 2015). Due to the high yield of kiwifruit, it was expected that characterization indices of global warming potential and acidification would be less than those of some other crops. According to Mirhaji et al. (2012), characterization index of global warming potential and acidification for one tonne production of sugar beet in Marvdasht were 22.9 and 0.81 kgCO_2eq, respectively. In this case, the characterization indices of these groups were more than those of kiwifruit. De-Menna et al. (2015) investigated the potential of using byproducts from the nectar chain to generate energy from anaerobic digestion or combustion, which is then consumed to substitute electricity and heat. The authors concluded that this strategy would allow a 13–15% damage reduction. They also claimed that it could be easily replicated in other food supply chain.

The Eco-indeX and RDI were determined to be 0.35 and 0.45 for one tonne Iranian kiwifruit production, respectively. Brentrup et al. (2004b) reported that the amount of Eco-indeX with 144 kg nitrogen to produce one tonne of wheat was 0.2. These indices for peanut production in Guilan province, according to the study conducted by Nikkhah et al. (2015), were calculated to be 0.62 and 4.30. The Eco-indeX for kiwifruit production was lower than that of peanut production but was higher than that of wheat production. Also, the RDI index of kiwifruit production was lower than peanut production. Depletion of phosphate resource was the environmental hotspot in RDI group. Thus, the greatest potential to mitigate the environmental impact of kiwifruit production is to reduce the phosphate consumption. Koppelaar and Weikard (2013) claimed that phosphate rock reserves are sufficient to meet demand into the 22nd century. But it is necessary to manage of this input in the agricultural sector.

The highest potential for environmental impact during kiwifruit production was determined to be the terrestrial eutrophication category, according to the Eco-indeX. This was similar to Nikkhah et al. (2015) research's results which indicated that for one tonne production of peanut in Guilan province of Iran, eutrophication had the most severe environmental impact. In the study conducted by Ingrao et al. (2015), LCA on peach cultivation was performed and they concluded that the highest impact was attributed to irrigation, because of the large volumes of water and energy required. The other impacts were land use, fertilizer production and consumption. Large proportion of urea fertilizer emissions during kiwifruit production affected the terrestrial eutrophication impact category, hence management and reducing consumption of this input is necessary to make the production more environmentally friendly. In addition, the review of literature also shows that the emissions of urea fertilizer had the key role in environmental impact of Iranian crops production (Khojastehpour et al., 2015; Nikkhah et al., 2015; Mohammadi-Barsari et al., 2016).

3.4. LCA + Cobb Douglas results

Table 6 illustrates the impacts of the inputs on the yield of kiwifruit in Guilan province. The R^2 value was 0.70 for the estimated equation, implying that around 0.70 of the variability of yield could be explained by this model. The results showed that the impacts of P_2O_5, K_2O and diesel fuel were positive on the yield, while the effect of nitrogen (urea) fertilizer on kiwifruit yield was negative. By summation of the regression coefficient, the RTS value was computed to be 0.45, which implies a decreasing return to scale.

The results of the sensitivity analysis showed that increasing

Table 6
Impacts of the inputs on the yield of kiwifruit in Guilan province of Iran.

Independent variables	Coefficient	t-ratio	P-Value	MPP	Standard beta
Model : $Lny_i = a_0 + \alpha_1 lnx_1 + \alpha_2 lnx_2 + \alpha_3 lnx_3 + \alpha_4 lnx_4 + e_i$					
N	−1.3	−3.86	0.009	190.06	−2.34
P_2O_5	0.69	3.05	0.016	89.06	0.82
K_2O	0.15	0.70	0.495	24.65	0.18
Diesel fuel	0.01	0.12	0.742	1.30	0.09
R^2	0.70				
R^2_{Adj}	0.57				
Return to scale	−0.45				
Durbin-Watson	1.91				

one unit in the inputs of P_2O_5, K_2O or diesel fuel, would result in an additional increase in yield by 89.06, 24.65 and 1.30 kg, respectively. But, an increase equal to one unit in nitrogen fertilizer would result in a decrease in yield by 190.06 kg.

The greatest effect on kiwifruit yield belonged to nitrogen fertilizer (beta standard = −2.34), followed by P_2O_5 (beta standard = 0.82) and K_2O fertilizer (beta standard = 0.18). The effect of nitrogen fertilizer on kiwifruit yield was statistically significant at the 1% level. Based on the results of this study, for instance, although nitrogen fertilizer had a high effect on kiwifruit yield, farmers with lower consumption of urea fertilizer obtained more kiwifruit yield in the studied area. So, it can be concluded that kiwifruit producers can reach high yield with lower levels of inputs, consumption, and emissions in Guilan province. Accordingly, due to the high environmental impacts of urea fertilizer and its negative effect on the kiwifruit yield, it is recommended to agricultural policy makers and farmers to replace urea with other sources of nitrogen fertilizer which have lower environmental impacts.

4. Conclusions

The purpose of this study was to investigate the environmental impacts of kiwifruit production in Guilan province of Iran through integration of Life Cycle Assessment and Cobb-Douglas modeling. Impact categories studied included global warming potential, acidification, eutrophication for terrestrial ecosystems, land use, depletion of fossil sources, depletion of phosphate sources, and depletion of potash sources. The results highlighted that the greatest negative environmental impact of kiwifruit production belonged to eutrophication. Urea fertilizer had a statistically significant negative effect on kiwifruit yield, and farmers with lower consumption of urea fertilizer actually had higher kiwifruit yield in the studied area. So, it appears that kiwifruit producers in Guilan province of Iran can actually reach higher yields with lower levels of emissions from the nitrogen source. It seems that management systems based on low inputs (such as using alternative sources of nitrogen fertilizer, like organic fertilizers) could be regarded as an alternative management strategy to reduce problematic environmental impacts of kiwifruit production.

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