Embedding gender factor in energy input–output analysis of paddy production systems in Mazandaran Province, Iran

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Received: 20 October 2016 / Revised: 23 January 2017 / Accepted: 28 February 2017 / Published online: 11 March 2017

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Abstract This study explores gender in the energy input–output analysis by comparing the energy indicators in paddy production in female-headed farms and male-headed farms during years of 2014–2015 in Mazandaran Province. Questionnaires were used to collect data from 120 paddy farmers (60 males and 60 females). Energy indicators were calculated for female- and male-headed farms. Results revealed noticeable variations in some important energy indicators between female- and male-headed farms. A significant difference was observed in terms of total energy input. The majority of energy input consumption for both female- and male-headed farms was devoted to diesel fuel, fertilizers, especially nitrogen fertilizers, and machinery. Results indicated that there was no significant difference between male-headed and female-headed farms in terms of net energy and specific energy, but energy use efficiency and energy productivity were significantly higher for female-headed farms. Then, it can be argued that gender factor had a significant impact on amount of direct, indirect, and renewable energy inputs. Based on our findings, female-headed rice systems were more efficient, where fossil-based inputs were used more environment friendly

than male-headed farms. Finally, targeted “soft” policies like gender-sensitive capacity-developing program were proposed.

Keywords Gender · Energy · Efficiency · Productivity · Agriculture

1 Introduction

Despite many attempts to specify the energy use efficiency in different agro-ecosystems (Bockari-Gevao et al. 2005; Kazemi et al. 2015; Keshavarz Afshar et al. 2013; Nabavi-Pelesaraei et al. 2014; Pishgar-Komleh et al. 2011; Rafiee et al. 2010), the gap of gender perspective in this kind of analysis has not been filled yet. This ignorance happened while the role of women in crop production has been considered as the foundation of studies regarding women’s participation in the development process since 1970s (e.g., Barrientos et al. 2005; Birah et al. 2016; Carr 2005; Egharevba and Iweze 2004; Jha 2004; Kerr et al. 2007; Lope-Alzina 2007). Women provide half of the world food production and agricultural labor (FAO 2009), while they have a limited access to essential production resources, such as land, labor, and inputs (FAO 2010; World Bank 2007). Fuentes and Wiig (2009) declared that land ownership and women’s access to it have a close and direct relationship with energy use efficiency. Therefore, it is obvious that gender factor can widely ridge individuals’ access to resources and their interactions with nature. It is also estimated that if rural women like men have an appropriate access to agricultural inputs, the yield of agricultural products can increase by 2.5% in developing

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countries and the number of total hungers across the world will decrease by 12–17% (FAO 2011). After decades of research, it is clear that women and men have a wide range of profits and priorities related to the issue of sustainability affected by multiple factors (Meinzen-Dick et al. 2014).

Although different studies (e.g., Barrientos et al. 2005; Birah et al. 2016; Carr 2005; Egharevba and Iweze 2004; Jha 2004; Kerr et al. 2007; Lope-Alzina 2007) provide valuable information regarding the role of women in agro-ecosystems sustainability, the wide gap in gender-based energy analysis has not been noted yet. This ignorance is not rational, while the excessive energy usage (Roy et al. 2009; Tandon and Singh 2009) in agro-ecosystems has profound and alarming effects on the environment and human health (Haas et al. 2001; Ju et al. 2009; Wood et al. 2006; Zhang et al. 2013). This is important then to examine the role of gender in agro-ecosystems' sustainability concerning energy analysis in particular for rice production where women role is critical. In this sense, in Iran, where about 2.35 million tons of paddy were produced in 2014–2015, about 77.21% of the total paddy production is supplied by three Northern provinces (Gilan, Mazandaran, and Golestan) (Ministry of Jihad-e-Agriculture 2015), and based on informal statistics, more than half of the paddy labor is covered by women. However, previous studies about energy analysis of rice production (Alipour et al. 2012; Cherati et al. 2011; Pishgar-Komleh et al. 2011) have ignored the effective role of women in this important crop production, while their practices in rice production systems with respect to many social, economic, and ecological issues are different. Therefore, the aim of this study is to probe the quantity of energy used for paddy production in female-headed and male-headed rice farms and the comparison of energy use pattern between them in Mazandaran Province of Iran.

2 Materials and methods

2.1 Study area

This study was conducted in Mazandaran Province (Babol County), Iran, in 2014–2015 production year. Mazandaran is located between 35°46' and 36°58' Lat. N and between 50°21' and 54°08' Lon. Table 1 displays the climatic variables and soil properties of the study region which has mild and humid climate due to 653.40 mm (mm) precipitation, 78% relative humidity, and 17.40 °C average temperature. The sunshine hours, a general indicator of cloudiness of a location, are 1898.80 in this region. The soil texture of the study area is silt loam categorized as a moderate texture with 10–35% clay. Organic carbon (OC) is 1.3% in this region soil which shows that there is the

proper amount of organic matter in the soil. The amount of phosphorus and potassium in the soil of the study area is 9.0 and 125.0 ppm, respectively. They are necessary macronutrients for the plant growth. Potential of hydrogen (pH) is a numeric scale used to specify the acidity or basicity of an aqueous solution. The soil pH is 7.4 in the study area. Solutions with pH less than 7 are acidic, and solutions with pH greater than 7 are basic. The soil electrical conductivity (EC), a measure of the amount of salts in soil, is 2.1 dS m⁻¹ in the study area soil (Kazemi et al. 2015).

Mazandaran Province was selected because of its vast rice-cultivated area. In Iran, this province, along with two other Northern provinces (Gilan and Golestan), supplied about 77.21% of the total paddy production in 2014–2015 (Ministry of Jihad-e-Agriculture 2015). Based on the informal statistics, women carry out more than half of the rice cultivation operations, i.e., mainly sterilizing seeds, seeding in treasury, transplanting, care nursery, weeding, fertilizing, spraying, harvesting, and transporting products to warehouse.

2.2 Data collection

The sample size constituted 120 respondents involving males and females from five villages. It was estimated by means of a formula adopted from Noordzij et al. (2010) where random sampling was employed to obtain a sample size of 120 rice growing households from five selected villages at confidence level of 95% and level of precision of 5%. Bailey (1994) stated that 30 cases are a simple minimum for studies in which statistical data analysis is to be done regardless of their population size. A total of 120 respondents were from a list of female-headed as well as male-headed households selected randomly. The five randomly selected villages were picked from two purposively selected wards of Babol County which were famous for rice production. Because we needed women who had the power and opportunity of making decisions on managing rice farms, especially on using energy inputs, it was preferred that all women in this study were widows and divorced women. Rural women (especially married women) mostly participate in rice production systems to provide labor force for various processes of rice production systems, rather than being given the chance of deciding about the use of agricultural inputs. They will mostly get the opportunity to personally manage the household farms after their divorce or spouses' death. Even in such circumstances due to cultural, economic, and social barriers women are often placed in a lower priority than other male relatives (brother, father, and else) to manage farms. Despite women, the marital status of men does not often affect their cash crop production systems management,

Table 1 Average soil properties and annual average of climatic variables in Mazandaran Province, Iran

Potential of hydrogen (pH)	Electrical conductivity (EC)	Potassium (K)	Phosphorous (P)	Organic carbon (OC)
7.4	2.1 dS m ⁻¹	125.0 ppm	9.0 ppm	1.3%
Dominant class of texture	Precipitation	Temperature	Sunshine hours	Relative humidity
Silt loam	653.40 mm	17.40 °C	1898.80 h	78%

Kazemi et al. (2015)

because men are placed in a higher priority than women to make decisions about household farms activities. The data were collected through questionnaire survey to female-headed and male-headed households which were designed for this purpose to cover a sample of 60 male-headed household respondents (comprising husband respondents) and 60 female-headed household respondents. All inputs and outputs of rice production were analyzed using SPSS software. Descriptive and inferential statistical treatments such as percentages, means, and Student's *t* test were applied to the data.

2.3 Energy analysis

All the detailed data from questionnaire were averaged and arranged. First, all inputs and outputs for paddy production were determined, quantified, entered into SPSS (var. 2012), and then transformed into energy units and expressed in mega joule per hectare (MJ ha⁻¹).

In this province, energy inputs for the paddy production were irrigation water, seed, human labor, diesel fuel, machinery, pesticides, and fertilizers; while energy outputs were paddy and straw. It must be noted that solar energy, either as radiation or as heat, was not taken into account, as it is considered a free subsidy in the energetic or economic analysis of agricultural systems (Tabar et al. 2010; Rafiee et al. 2010; An 2011). The energy equivalent of inputs and outputs, shown in Table 2, was used to estimate the energy values. Energy inputs in agricultural systems can be divided into direct and indirect or renewable and non-renewable forms. The sources of direct energy include human labor, diesel fuel, and irrigation water, while indirect energy sources include chemical fertilizers, manure, pesticides, seed, and machinery. Renewable energy consists of human labor, manure, seed, and irrigation water; and non-renewable energy sources consist of machinery, diesel fuel, pesticides, and chemical fertilizers. The energy use efficiency, energy productivity, specific energy, and net energy were calculated using the total energy equivalent of inputs and outputs per unit (MJ ha⁻¹) and paddy yield (kg ha⁻¹), applying the following equations (Demircan et al. 2006; Tabatabaefar et al. 2009):

1. Energy use efficiency = Total energy output (MJ ha⁻¹)/Total energy input (MJ ha⁻¹).
2. Energy productivity = Grain output (kg ha⁻¹)/Total energy input (MJ ha⁻¹).
3. Specific energy = Total energy input (MJ ha⁻¹)/Grain output (kg ha⁻¹).
4. Net energy = Energy output (MJ ha⁻¹) – Energy input (MJ ha⁻¹).

3 Results and discussion

3.1 Demographic information and economic condition

Based on outcomes displayed in Table 3, there was no significant difference between male and female farmers in terms of age (the average age of men = 51.65 years old and the average age of women = 53.15 years old). Results showed that few farmers (20% of men and 11.7% of women) were younger than 40 years old. OECD (2001) reported that the farmers were mostly older than 55 years old and only a few farmers had less than 35 years in many OECD countries. Mojarradi et al. (2008) indicated that the majority (23.4%) of farmers belonged to the age category of 41–50 years old. Despite the fact that the face of agricultural workforce gets old, agricultural sector cannot disregard younger and well-educated farmers because they can better adapt themselves to variations of financial and environmental conditions (OECD 2001). Our findings disclosed that women farmers highly suffered from poor education conditions. Most of them (65%) were educated up to alphabetic level, whereas just only a few (16.7%) men farmers belonged to this educational category. It is obvious that inappropriate educational conditions among women, compared with men, restrict their enterprise options and limit their ability to take up vocational and technical trainings (World Bank 2009). Tatlidil et al. (2009) demonstrated that the better education was considered as one of the most effective factors in promotion of the awareness about sustainable agricultural practices.

Table 2 Energy equivalent of inputs and outputs in agricultural production

Particulars	Unit	Energy equivalents (MJ unit ⁻¹)	Reference
Human labor	h	1.96	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Fertilizers			
Nitrogen (N)	kg	78.1	Pishgar-Komleh et al. (2011)
Phosphate (P ₂ O ₅)	kg	17.4	Pishgar-Komleh et al. (2011)
Potassium (K ₂ O)	kg	13.7	Pishgar-Komleh et al. (2011)
Manure	kg	0.3	Rafiee et al. (2010)
Pesticides			
Insecticides	kg	229	Pishgar-Komleh et al. (2011)
Fungicides	kg	115	Pishgar-Komleh et al. (2011)
Herbicides	kg	85	Pishgar-Komleh et al. (2011)
Diesel fuel	L	56.31	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Machinery	h	62.7	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Irrigation water	m ³	1.02	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Seed	kg	14.7	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Total energy input	MJ	–	–
Straw	kg	12.5	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Paddy	kg	14.7	AghaAlikhani et al. (2013) and Kazemi et al. (2015)
Total energy output	MJ	–	–

According to the results, men farmers had bigger family size (3.67) than women farmers (2.67). This significant difference between men and women in terms of family size may make male farmers profit from more labors. Results showed that the availability of financial credits was considerably poor in both men and women groups, but female farmers were even in a worse condition, i.e., 75% of women farmers suffered from a very low availability of financial credits. Parveen (2008) reported that there were many obstacles toward women's access to credit and productive resources in Bangladesh which is due to the lack of technical knowledge, restrictions on land ownership, heavy housework, and other social and cultural circumscriptions. With respect to the on-farm income, there was a significant variation between men and women farmers (male on-farm income = 3201.44\$ and female on-farm income = 1102.92\$). A total of 58.3% of women earned lower than 1000\$ on-farm income, while 43.3% of men earned more than 3000\$ on-farm income. This difference strongly was related to their farm size which was 0.78 ha for men and 0.48 ha for women. Horrell and Krishnan (2007) stated that female-headed households' income in Zimbabwe was 3/4 of male-headed households' income. Dadzie and Dasmani (2010) demonstrated that men farmers also benefited from much more off-farm income than women farmers in Ghana. They expressed that male farmers had a stronger tendency to reinvest their on-farm income compared with female farmers.

3.2 Energy inputs and outputs

Table 4 represents the average energy consumption of each input and output for paddy production in both female-headed and male-headed farms. The total average of energy input and output was computed 74,166.71 and 108,441.40 MJ ha⁻¹ in female-headed farms and 85,898.22 and 112,812.08 MJ ha⁻¹ in male-headed farms, respectively. The results demonstrated a significant difference between female-headed and male-headed farms in terms of the total energy input. The reason for this difference could be related to the fact FAO (2010) noted, i.e., women do not have equal access to inputs and production factors because of being subjected to more social and economic constraints than men are. Because of high tendency of paddy farmers (men and women) to plant high-yield variety of rice, there is no significant difference between female-headed and male-headed farms with respect to energy output. Thapa (2008) reported that utilizing high-yield seed significantly turns up more yield per hectare. The use of fuel energy was 30,156.01 and 32,752.85 MJ ha⁻¹ in female-headed and male-headed farms, respectively. According to the data collected from studied farms, in terms of fuel consumption, there was a significant difference between female-headed and male-headed farms. The data analysis showed that the highest energy use in rice agro-ecosystems belonged to fuel energy input, which allocated 40.66 and 38.13% of the total

Table 3 Demographic information and economic condition of women and men farmers

	Men				Women			
	Frequency	Percent	Mean	Frequency	Percent	Mean	Student's <i>t</i> test	Sig. (<i>P</i> = 0.05)
Availability of financial credits								
Very low	34	56.7	–	45	75	–	–	–
Low	17	28.3		13	21.7			
Medium	7	11.7		2	3.3			
High	1	1.7		0	0			
Very High	1	1.7		0	0			
Total	60	100		60	100			
Education								
Illiterate	10	16.7	–	39	65	–	–	–
No diploma degree	35	58.3		20	33.3			
Diploma degree	12	20		1	1.7			
University degree	3	5		0	0			
Total	60	100		60	100			
Age								
40≥	12	20	51.65	7	11.7	53.15	0.736	0.463
41–55	26	43.3		28	46.7			
56≤	22	36.7		25	41.7			
Total	60	100		60	100			
Family size								
2 persons≥	14	23.3	3.67	29	48.3	2.67	3.868	0.000
3–4 persons	33	55		25	41.7			
5 persons≤	13	21.7		5	10			
Total	60	100		60	100			
On-farm income per year								
1000\$≥	15	25	3201.44	35	58.3	1102.92	5.215	0.000
1000–3000\$	19	31.7		22	36.7			
3000\$<	26	43.3		3	5			
Total	60	100		60	100			

energy consumption in female-headed and male-headed farms, respectively (Fig. 1). Results of other studies (AghaAlikhani et al. 2013; Bautista and Minowa 2010; Bockari-Gevao et al. 2005; Cherati et al. 2011; Kazemi et al. 2015; Pishgar-Komleh et al. 2011) confirmed that the fuel input has an important and effective share among all types of energy used for the paddy production. Kazemi et al. (2015) reported that the high fuel consumption in agricultural systems of Iran is due to two main reasons: old machineries and irrigation pumps. They expressed that one of the principal reasons for the high utilization of fuel is a temporal depreciation of machinery. Applying new machineries and irrigation pumps with more energy use efficiency decreases the amount of energy usage.

Fuel energy was followed by the fertilizers (including N, P₂O₅, K₂O, and manure) energy with the share of 23.73 and 28.93% of the total energy input in female-headed and

male-headed farms (Fig. 1). This outcome was in accordance with many researches (AghaAlikhani et al. 2013; Bautista and Minowa 2010; Bockari-Gevao et al. 2005; Cherati et al. 2011; Keshavarz Afshar et al. 2013) which reported fertilizers, especially chemical fertilizers, had a high consumption in paddy farms. Although the use of fertilizers, except phosphorus fertilizer, significantly varied among female-headed and male-headed farms, the energy usage of fertilizers, particularly nitrogen fertilizer, was too high in male-headed farms (15,625.18 MJ ha⁻¹ in female-headed farms and 22,147.98 MJ ha⁻¹ in male-headed farms; Table 4). Because phosphorus causes development of strong and extensive roots, tight and thick stems, grain filling, the increase in quantity of production, and acceleration of crop growth, paddy farmers (men and women) always try to use enough phosphorus fertilizer. Kazemi et al. (2015) noted in their study that because the

Table 4 Amounts of input and output and their energy equivalent in paddy production systems

Input and output	Unit	Quantity per unit area (ha)		Total energy equivalent (MJ ha ⁻¹)		Student's <i>t</i> test	Sig. (<i>P</i> = 0.05)
		Male-headed farms	Female-headed farms	Male-headed farms	Female-headed farms		
Human labor	h	163.61	239.83	320.68 (0.37%)	470.08 (0.63%)	3.054	0.003
Fertilizers	kg	671.96	401.88	24,849.07 (28.93%)	17,598.91 (23.73%)	3.895	0.000
Nitrogen (N)	kg	283.58	200.07	22,147.98 (25.78%)	15,625.18 (21.07%)	3.736	0.000
Phosphorous (P ₂ O ₅)	kg	95.27	92.91	1657.71 (1.93%)	1616.56 (2.18%)	0.175	0.861
Potassium (K ₂ O)	kg	71.30	24.22	976.83 (1.14%)	331.76 (0.45%)	3.707	0.000
Manure	kg	221.80	84.69	66.54 (0.08%)	25.41 (0.03%)	3.152	0.002
Pesticides	kg	10.96	7.66	1608.38 (1.87%)	1096.58 (1.48%)	5.285	0.000
Insecticide	kg	4.19	2.79	959.71 (1.12%)	638.55 (0.86%)	3.923	0.000
Fungicide	kg	2.45	1.46	281.31 (0.33%)	167.48 (0.23%)	3.172	0.002
Herbicide	kg	4.32	3.42	367.37 (0.43%)	290.54 (0.39%)	3.459	0.001
Diesel Fuel	L	581.65	535.54	32,752.85 (38.13%)	30,156.01 (40.66%)	4.732	0.000
Machinery	h	275.37	253.23	17,265.79 (20.10%)	15,877.32 (21.41%)	5.245	0.000
Irrigation water	m ³	7989.27	7648.06	8149.05 (9.49%)	7801.02 (10.52%)	1.934	0.056
Seed	kg	64.79	79.37	952.39 (1.11%)	1166.79 (1.57%)	2.734	0.008
Total energy input	MJ			85,898.22 (100%)	74,166.71 (100%)	5.359	0.000
Straw	kg	2567.57	2405.10	32,094.58 (28.45%)	30,063.75 (27.72%)	1.091	0.277
Paddy	kg	5490.99	5331.81	80,717.50 (71.55%)	78,377.65 (72.28%)	0.497	0.620
Total energy output	MJ			112,812.08 (100%)	108,441.40 (100%)	0.667	0.506

Male-Headed Farms **Female-Headed Farms** **Fig. 1** Share of energy inputs for paddy production in female-headed and male-headed farms

energy use efficiency in the fields of Mazandaran is low due to the excessive consumption of fertilizers, fertilization should be reduced and optimized in this region. Pishgar-Komleh et al. (2011) noted two remarkable reasons for the high consumption of fertilizers in Iran: farmers' low knowledge and subsidies price. Regarding the lack of

knowledge and ineffective policies and programs of the Ministry of Agriculture Jihad, most of Iranian farmers do not have accurate information about the required quantity of fertilizers in different agro-ecosystems. This in turn promotes a prevalent opinion between them that the extreme use of fertilizers will increase the yield (Chauhan et al. 2006). In addition, the subsidies price of government has a considerable effect on fertilizers' consumption. Gladwin (1992) indicated farmers had less access to credit, especially women suffered more losses due to the removal of subsidies and the increase in fertilizers' prices. Therefore, the subsidy adjustment policies resulted in much more reduction in fertilizers' usage in female-headed farms than male-headed farms. In general, the energy management in rice agro-ecosystems, especially in female-headed agro-ecosystems, because of their ecology friendly attitude and reduced fertilizers and fuel consumption, is momentous. Optimizing fertilizers' usage in rice farms not only brings financial gains to farmers, but also can decrease environmental pollutions. Appropriate fertilization management, integrating a legume into the crop rotation, application of composts, chopped residues, and other soil managements can decrease the chemical fertilizers energy consumption (Nabavi-Pelesaraei et al. 2014). Hence, it is essential to focus more on fertilizers and fuel usage than other inputs, because these two factors efficiently reduce energy use in rice farms (Kazemi et al. 2015).

According to the data collected from studied farms, in terms of pesticide consumption, there was a significant difference between female-headed and male-headed farms. The amount of herbicides, fungicides, and insecticides consumption was calculated 290.54, 167.48, and 638.55 MJ ha⁻¹ in female-headed farms and 367.37, 281.31, and 959.71 MJ ha⁻¹ in male-headed farms, respectively (Table 4). Women were less reliant on excessive use of pesticides in pest control. This can be because women are more sensitive to environment and health of their family, more associated with pesticides risks, more aware of alternative methods of pest control such as the use of beneficial insects than men (Birah et al. 2016). Of course, it is necessary to mention the high prices of pesticides and low access of women to them, i.e., effective in reducing the consumption of this type of energy input (Doss and Morris 2000).

The results showed that 239.83 and 163.61 h of human labor and 253.23 and 275.37 h of machine power were required per hectare in female-headed and male-headed farms, respectively (Table 4). There was a significant difference between female-headed and male-headed farms with respect to human labor energy and machinery energy consumption. Higher amount of the energy input of human labor in female-headed farms can be connected to two factors: more management of weeds due to less consumption of herbicides and their limited access to machinery (mover and planter machines). The amount of seed energy consumption was, respectively, 1166.79 and 952.39 MJ ha⁻¹ in female-headed and male-headed farms. The usage of seed energy was higher in female-headed farms, because women often have low access to appropriate seed (FAO 2010). The required amount of seed can be decreased by improving its quality, which in turn reduces the energy waste. On the other hand, using the high-quality seed will help reducing the chances of pest and weed infestation and thus increasing the yield (Pishgar-Komleh et al. 2011). There was no significant difference between female-headed and male-headed farms with respect to

water energy input. The energy consumption of water was calculated 7801.02 and 8149.05 MJ ha⁻¹ in female-headed and male-headed farms, respectively.

3.3 Energy indicators

Energy use efficiency, specific energy, net energy, and energy productivity in female-headed and male-headed farms are tabulated in Table 5. Energy use efficiency is one of the best energy indices showing how efficient the energy has been used in paddy production. The average of energy use efficiency was, respectively, 1.48 and 1.30 in female-headed and male-headed farms. Due to the high consumption of energy inputs, especially fertilizers in rice farms of Northern provinces (Gilan, Mazandaran, and Golestan) of Iran (Kazemi et al. 2015), the energy use efficiency estimate was lower in this study area. Pishgar-Komleh et al. (2011) revealed that the energy ratio in rice farms of Gilan Province, Iran, was 1.53. AghaAlikhani et al. (2013) stated that the energy use efficiency was 1.72 in the traditional production system and 1.63 in the mechanized production system in Mazandaran. Rice production system ranges among the most energy-consuming crop production systems (Pimentel 2009). Energy input: output ratio of rice cultivated in some developing countries such as Valley of Garhwal (India), Malaysia, and Bangladesh were reported 1:0.79, 1:8.86, and 1:4.6–1:6.5, while this ratio was 1:1.42 in USA (Deutsche Gesellschaft für und Internationale Zusammenarbeit (GIZ) GmbH 2013). Although the energy use efficiency was low in the studied farms, and on the other hand, this indicator is very determining in environmental studies due to the excessive input usage, women farmers were able to achieve more energy output per each used energy unit and thus performed more efficiently in terms of energy consumption. Therefore, increasing the annual yield of paddy production and/or reducing the energy usage, particularly diesel fuel energy and fertilizers, would help optimizing the rice agroecosystems energy consumption. Many researchers

Table 5 Energy indicators in paddy production systems

Parameters	Unit	Quantity		Student's <i>t</i> test	Sig. (<i>P</i> = 0.05)
		Male-headed farms	Female-headed farms		
Total energy input	MJ ha ⁻¹	85,898.22	74,166.71	5.359	0.000
Total energy output	MJ ha ⁻¹	112,812.08	108,441.40	0.667	0.506
Net energy	MJ ha ⁻¹	26,913.86	34,274.70	1.253	0.213
Specific energy	MJ kg ⁻¹	16.69	15.47	1.352	0.179
Energy use efficiency	–	1.30	1.48	2.167	0.033
Energy productivity	kg MJ ⁻¹	0.06	0.07	2.343	0.021

Fig. 2 Average size of female-headed and male-headed rice farms

reported that applying sound farming management practices such as crop rotation and cultivating legumes improves energy use efficiency (Pishgar-Komleh et al. 2011; Rathke et al. 2007).

In this study, there was a significant difference between women and men farmers with respect to farm size ($P < 0.05$). As shown in Fig. 2, the average size of female-headed and male-headed farms was 0.47 and 0.78 ha, respectively. In terms of farm size effect on energy use efficiency, Iqbal (2007) and Nassiri and Singh (2009) indicated that small rice farms had the highest energy use efficiency and the lowest specific energy in comparison with other groups. Pishgar-Komleh et al. (2011) reported that the largest farm size group had higher energy ratio compared with medium and small farms. Therefore, one of the main factors that affect the energy use efficiency in paddy production systems can be the farm size which is smaller for women farmers than men farmers. In general, environmental constraints such as a combination of unsuitable land, weed and pest attack, bad weather, planting delay, and infertile soils significantly reduce crop yield and its energy efficiency (Rahman and Hasan 2014).

The energy productivity (the total yield obtained per unit of energy input) was lower in male-headed farms than female-headed farms (Table 5). The average energy productivity was 0.07 kg MJ^{-1} in female-headed farms and 0.06 kg MJ^{-1} in male-headed farms. The calculation of energy productivity rate is well documented in the literature such as stake tomato (1.0) (Esengun et al. 2007), cotton (0.06) (Yilmaz et al. 2005), sugar beet (1.53) (Erdal et al. 2007). The energy productivity is a measure of the environmental effects associated with the production crops. This variable can therefore be used to identify the optimum intensity of land and management from an ecological-friendly attitude (Hülsbergen et al. 2001). According to the calculated productivity indicator, women farmers took advantage of more ecological viewpoints in managing their paddy production systems than men farmers. The specific energy and net energy were calculated 15.47 and

34,274.70 MJ ha^{-1} in female-headed farms and 16.69 and 26,913.86 MJ ha^{-1} in male-headed farms, respectively (Table 5). Although there was no significant difference between female-headed and male-headed farms with respect to the specific energy and net energy, women farmers used energy for paddy production more efficiently. Kazemi et al. (2015) in their study in north of Iran, indicated that the lowest net energy corresponded to Mazandaran (25,795.39 MJ ha^{-1}). Canakci et al. (2005) has also reported the specific energy for field crops and vegetable production in Turkey as 5.24 MJ kg^{-1} for wheat, 11.24 MJ kg^{-1} for cotton, 3.88 MJ kg^{-1} for maize, 16.21 MJ kg^{-1} for sesame, 1.14 MJ kg^{-1} for tomato, 0.98 MJ kg^{-1} for melon, and 0.97 MJ kg^{-1} for watermelon.

The results indicated a low level of energy efficiency and productivity in Iran agro-ecosystems in accordance with the finding of other researchers (Banaeian and Zangeneh 2011; Kazemi et al. 2015; Mohammadi et al. 2008). Banaeian and Zangeneh (2011) stated that the energy wastage in Iran agro-ecosystems reached from 8816.26 to 26,151.94 MJ ha^{-1} during 2001–2007. Hence, there was a vast unreleased potential for improving energy use efficiency of paddy production in the region. Mousavi-Avval et al. (2011) proposed that for improving energy use efficiency in Iran, the farmers should be educated regarding the optimal use of inputs such as fertilizers, pesticides, and irrigation water as well as technologies. On the other hand, local agricultural institutes play a fundamental role to notify the farmers in terms of more efficient use of energy resources and increasing the sustainability level of agricultural production systems in the region.

3.4 Energy forms

Table 6 shows the distribution of total energy input as renewable, non-renewable, direct, and indirect forms. According to the obtained results, the direct energy usage was, respectively, 51.81 and 47.99% of the total energy input in female-headed and male-headed farms, while the share of indirect energy was 48.19 and 52.01% in female-headed and male-headed farms, respectively. Furthermore, 87.24 and 88.95% of all energy inputs in female-headed and male-headed farms was related to the non-renewable energy, while the share of renewable energy was calculated 12.76 and 11.05% in female-headed and male-headed farms, respectively. With respect to direct, indirect, and non-renewable energy usage, there was a significant difference between female-headed and male-headed farms. This means that female-headed farms were more environment friendly than male-headed farms. Several studies illustrated that the share of non-renewable energy of total energy input is much more than the share of renewable

Table 6 Total energy input and related components in the form of direct, indirect, renewable, and non-renewable energy for paddy production systems

Energy input components	Quantity		Student's <i>t</i> test	Sig. (<i>P</i> = 0.05)
	Male-headed farms	Female-headed farms		
Total energy input (MJ ha ⁻¹)	85,898.22 (100%)	74,166.71 (100%)	5.359	0.000
Direct energy ^a (MJ ha ⁻¹)	41,222.58 (47.99%)	38,427.10 (51.81%)	4.567	0.000
Indirect energy ^b (MJ ha ⁻¹)	44,675.64 (52.01%)	35,739.61 (48.19%)	4.564	0.000
Renewable energy ^c (MJ ha ⁻¹)	9488.67 (11.05%)	9463.29 (12.76%)	0.118	0.906
Non-renewable energy ^d (MJ ha ⁻¹)	76,409.56 (88.95%)	64,703.41 (87.24%)	5.513	0.000

^a Includes human labor, diesel fuel, and irrigation water energy sources

^b Includes chemical fertilizers, manure, seed, pesticides, and machinery energy sources

^c Includes human labor, seed, manure, and irrigation water

^d Includes diesel fuel, pesticides, chemical fertilizers, and machinery

energy (AghaAlikhani et al. 2013; Erdal et al. 2007; Mohammadi and Omid 2010; Pishgar-Komleh et al. 2011; Rafiee et al. 2010).

4 Conclusions

In Iran, although many researches have been conducted to determine the energy use efficiency in paddy production systems, there is no study as yet regarding the effect of paddy farmers' gender on energy indicators. This study investigated the effect of gender on energy flow in rice farms of Mazandaran Province (Babol County). The total energy input and output were 74,166.71 and 108,441.40 MJ ha⁻¹ in female-headed farms and 85,898.22 and 112,812.08 MJ ha⁻¹ in male-headed farms, respectively. The analysis of energy consumption for the paddy crop in female-headed and male-headed farms demonstrated that the energy input of diesel fuel, fertilizers, and machinery in both farms of men and women had the largest share of energy input from the total energy input. The energy use efficiency was higher in female-headed farms and varied from 1.48 for farms of women to 1.30 for male-headed farms.

Results revealed that although the energy productivity was significantly different between female-headed and male-headed farms, this index in rice farms like most Iran agro-ecosystems was in a low level. Regarding the low level of energy productivity in Iran agro-ecosystems, it can be caused by old and worn-out electric and diesel pumps, excessive machinery traffic in agro-ecosystems, the lack of attention to pest and soil analysis, and the relatively low price of diesel fuel. All these deficiencies lead to excessive and non-normative fuel, fertilizers, and chemicals consumption, which ultimately incurred higher energy consumption per unit of area, reducing energy efficiency and energy productivity.

Regarding the sustainable and efficient energy consumption in agricultural systems, one of the most important

and most influential factors is farmers' gender. Although women in terms of access to land, inputs, extension services, and financial credit face many constraints, according to the results of this study women paddy farmers in energy consumption compared with their counterparts performed more efficiently. Furthermore, the way women used inputs such as fertilizers and pesticides clearly demonstrated their ecological-friendly attitude and behavior. In other words, the attitude of using environment friendly and knowledge of women farmers are an effective leverage that policy makers will be able to benefit from to organize the state dysfunctional culture boom in the energy system and consequently reduce the risk of environmental crisis that has enveloped the country ecosystems.

However, one should not forget that women environment-friendly understanding and awareness would be fully useful when their social and economic concerns be reduced and their livelihoods and families under their supervision guaranteed. In this regard, targeted policies, such as providing training on ways to improve the performance and the use of new technologies and rural micro-funds, will have a great influence on women's empowerment. Of course, it is important and should be considered that the prerequisite for achieving the goals of sustainable development in every field is modifying and changing three aspects of cognitive (mental), structural (laws, regulations, etc.), and functional (objective-executive) community relation with the gender issue.

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