Original Research Article

Comparative study of energy utilization and green house gas emission by Hybrid Rice Grown under Two different Cultivation systems in Red lateritic zone of West Bengal

ABSTRACT

A field experiment was carried out at Agriculture Farm, Palli Siksha Bhavana, Visva-Bharati, Sriniketan, West Bengal, India during *kharif* season of 2015 to compare rice cultivation in conventional transplanting (CT) and system of rice intensification (SRI) in terms of energy use, energy input output relationship and green house gas emission. Result showed that regardless of cultivars conventional transplanting consumed 62.39% higher energy over SRI. Maximum energy input was associated with non renewable and indirect sources. Owing to utilization of higher fertilizer, the contribution of nitrogen fertilizer to total energy input was accounted for about 32.35% and 26.26% in CT and SRI respectively. Energy use efficiency (13.22), energy productivity (6.94 kg MJ^{-1}), energy profitability (12.22) and energy intensity (4.60 MJ Rs^{-1}) of hybrid rice varieties were noted higher in SRI. Maximum green house gas emission from rice field was also attributed to fertilizer nitrogen followed by diesel in both the system. Total green house gas emission in CT was estimated to 834.85 (kg CO_2ha^{-1}) i.e. 1.8 times of SRI.

Keywords: Hybrid rice, Conventional transplanting, System of Rice Intensification, Energy utilization, Green House Gas (GHG) emission

INTRODUCTION

Agriculture is one of the most important key sectors and influenced by direct and indirect energy use (Nautiyal *et al*., 2007; Omid *et al*., 2011). Among different agricultural crops, rice is world's single most important food crop, being the primary food source for more than one third of global population. Mishra and Salokhe (2010) estimated that the growing population will require 40% more rice production by the year 2050. Increased population coupled with low arable land and higher standers of living, driven farmers towards high energy intensive cultivation practices such as high amount of chemical fertilizer, plant protection chemicals, diesel, electricity and irrigation. Although energy use depends largely on resource availability and the capacity of farmers to afford, rice itself a high energy intensive crop and contributor to greenhouse gas (IPCC, 2007). Along with other inputs conventional rice cultivation demands huge water, that is one of the most important energy intensive inputs for agricultural production (Chizari and Omani, 2009). Besides requirement of high water, land preparation also contributes to high energy inputs. Efficient energy use not only reduces environmental degradation and cost of production (Singh *et al.*, 2004) but also helps in increasing production, productivity, profitability and sustainability (Singh, 2002).Estimation of energy input output relationship i.e. energy budgeting is crucial for development of energy efficient and sustainable agricultural production system in present day agriculture (Chaudhary *et al.*, 2006). Energy efficient agricultural system can be achieved by reduced special and temporal use of current resources coupled with broad term tightly defined technologies (Topp *et al.*, 2007).among the different systems of rice production, system of rice intensification (SRI) can be grouped as one of the most energy efficient rice cultivation practice. So, this study was taken to compare rice cultivation under two different systems of rice production in terms of energy utilization and green house gas emission in red and lateritic zone of West Bengal.

MATERIALS AND METHODS

The field experiment was conducted at Agriculture Farm, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal during *kharif* season of 2015. The experiment consisted of ten treatments combination was laid out in split plot design with three replications including two systems of rice cultivation viz. conventional transplanting (CT) and system of rice intensification (SRI) as main plot treatments and five rice hybrids – four Bayer’s hybrids namely 6129 Gold, Tej Gold, 6444 Gold, Prima Gold and one hybrid check (PHB 71) in sub plot.

Energy budgeting

The input energy(Table 3) was calculated by adding the energy requirement for labour, farm machineries, diesel, seed, fertilizers, plant protection chemicals, irrigation and electricity used in systems and expressed in MJ ha^{-1}. Amount of main product (grain) and byproduct (straw) was multiplied with their corresponding energy equivalents (Table 1) to calculate total energy output (Table 4).

Sources of energy were categorized in terms of direct and indirect energy input (Alam *et al*., 2005, Mandal *et al*., 2002, Singh *et al*., 2003) or renewable and non-renewable energy input. Human labour, diesel, electricity and irrigation water were grouped as direct energy whereas seed, plant protection chemical, fertilizer, manures and machinery capitalized as indirect energy sources. Renewable energy sources include human labour, seed, irrigation water and manure; while non-renewable sources are diesel, electricity, plant protection chemical, fertilizer and machinery.

$$\text{Net Energy Gain (MJ ha}^{-1}\text{)} = \text{Energy output} - \text{Energy input}$$

$$\text{Energy Use Efficiency} = \frac{\text{Energy output (MJ ha}-1\text{)}}{\text{Energy input (MJ ha}-1\text{)}}$$

$$\text{Specific Energy (SE)} = \frac{\text{Energy input (MJ ha}-1\text{)}}{\text{Crop economic yield (Kg ha}-1\text{)}}$$

$$\text{Energy Productivity (EP)} = \frac{\text{Crop economic yield (Kg ha}-1\text{)}}{\text{Energy input (MJ ha}-1\text{)}}$$

$$\text{Energy Intensity (EI)} = \frac{\text{Energy input (MJ ha}-1\text{)}}{\text{Cost of production (Rs ha}-1\text{)}}$$

$$\text{Energy Profitability} = \frac{\text{Net energy (MJ ha}-1\text{)}}{\text{Energy input (MJ ha}-1\text{)}}$$

Estimation of green house gas emission

Green house gas emission was calculated by multiplying inputs with their corresponding CO_2 emission equivalent (Table 2).

Table 1. Energy equivalents of different inputs involved in Rice production

Particulars		Unit	Equivalent energy (MJ)	Reference
Inputs				
Human labour	Adult man	Hour	1.96	Rafiee *et al*. (2010)
Fuel (Diesel)		litre	56.31	Canakci *et al*. 2005
Farm machinery		hour	62.7	Mittal *et al*. (1985)

Fertilizers	Nitrogen	kg	60.6	Mittal *et al*. (1985)
	Phosphorus	kg	11.1	Mittal *et al*. (1985); Demircan *et al*. (2006); Alam *et al*. (2005)
	Potassium	kg	6.7	Mittal *et al*. (1985)
	Zinc	kg	8.40	Rafiee *et al*. (2010)
	Sulphur	kg	1.12	Mohammadi *et al*. (2010)
FYM		ton	0.30	Rafiee *et al*. (2010)
Plant protection chemicals	Fungicides and insecticides	kg	120	Mittal *et al*. (1985)
Irrigation water		M^3	1.02	Taylor *et al*. (1993)
Electricity		kWh	3.60	Taylor *et al*. (1993)
Seed		kg	3.60	BeheshtiTabar *et al*. (2010)
Output				
Rice grain		kg	15.70	Ozkan *et al*. (2004)
Rice straw		kg	12.50	

Table 2. Carbon dioxide equivalent values of different inputs used in rice cultivation

Inputs	**Unit**	**GHG coefficient (kg CO_{2equ}/unit)**	**References**
Machinery	Hour	0.071	Dyer and Desjardins (2006)
Diesel	L	2.76	Dyer and Desjardins (2003)
Nitrogen	Kg	3.27	Kim and Dale (2003)
Phosphorus	Kg	1.34	Kim and Dale (2003)
Potassium	Kg	0.642	Kim and Dale (2003)

Zinc	Kg	4.18	IPCC (2014)
Sulphur	Kg	0.06	Safa and Samarasinghe (2012)
Plant protection chemicals	Kg	5.1	Lal (2004), Pathak and Wassman (2007)

RESULT AND DISCUSSION

The amount of total input energy was more under conventional transplanting method (22481.2 MJ) as compared to SRI system (13844.02 MJ) (Table 3). Result revealed that out of total input energy, the contribution of nitrogen fertilizer was maximum in both CT (32.35%) and SRI (26.26%). The sharing of irrigation water (19.06%) was also the higher followed by diesel fuel (13.78%) and electricity (12.10%) in CT, whereas the trend of contribution was different in SRI i.e. the diesel fuel (22.37%) being the second highest consumer followed by irrigation water (13.26%) and human labour (12.46%). Erdal *et al*. (2007) and Mobtaker *et al*. (2010) also reported that diesel fuel and fertilizers were the most intensive inputs in terms of energy consumption. Total energy consumption was 62.39% higher in CT as compare to SRI due to its higher seed rate, irrigation, chemical fertilizers and plant protection chemical demands (Table 3). Although hybrids recorded higher straw yield under CT but their performance was better in SRI in terms of Grain yield. Production of higher straw yield in CT leaded to 17.03% higher output energy than SRI (Table 4). Jayadeva *et al*. (2010) and Babu *et al*. (2014) also recorded higher grain yield and lower energy requirement of SRI but in contrast with the present study the straw yield was also noted higher in SRI.

Table 3. Energy consumption in Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Input	Quantity per unit area (ha)		Energy Equivalent	Total energy equivalent (MJ)		Percentage of total energy input	
	CT	SRI		CT (energy)	SRI (energy)	CT	SRI
Human labour (h)	784	880	1.96	1536.64	1724.80	6.84	12.46
Machinery (h)	11	11	62.7	689.70	689.70	3.07	4.98
Diesel fuel (L)	55	55	56.31	3097.05	3097.05	13.78	22.37
Chemical Fertilizer (kg)							
(a) Nitrogen	120	60	60.6	7272.00	3636.00	32.35	26.26

(b) Phosphate	60	30	11.1	666.00	333.00	2.96	2.41
(c) Potassium	60	30	6.7	402.00	201.00	1.79	1.45
(d) Zinc	25	0	8.4	210.00	0.00	0.93	0.00
(e) S	45	0	1.12	50.40	0.00	0.22	0.00
Farmyard manure (kg)	0	10	0.3	0.00	3.00	0.00	0.02
Chemicals (kg)	12.5	9.5	120	1500.00	1140.00	6.67	8.23
Water for irrigation (m^3)	4200	1800	1.02	4284.00	1836.00	19.06	13.26
Electricity (kWh) are	755.40	323.74	3.6	2719.42	1165.47	12.10	8.42
Seeds (kg)	15	5	3.6	54.00	18.00	0.24	0.13
Total Input				22481.21	13844.02	100.00	100.00

Table 4. Total energy equivalent of outputs in two systems of Rice production

Variety	CT	SRI	Energy Equivalent	Total energy equivalent (MJ)	
				CT	SRI
Grain (kg ha^{-1})					
H1: 6129 Gold	4814	5586	15.7	75580	87700
H2: Tej Gold	5547	4622		87088	72565
H3: 6444 Gold	5995	6838		94122	107357
H4: Prima Gold	6166	6901		96806	108346
H5: PHB 71	6565	6668		103071	104688
Straw(kg ha^{-1})					
H1: 6129 Gold	4768	4277	12.5	59600	53463
H2: Tej Gold	6760	5557		84500	69463

H3: 6444 Gold	8062	7745		100775	96813
H4: Prima Gold	10139	9365		126738	117063
H5: PHB 71	9148	7817		114350	97713

Except specific energy all other energy indices viz. net energy, energy use efficiency, energy productivity, energy intensity and energy profitability was higher in SRI (Table 5). SRI had gained 2% more net energy compared to CT due to its lesser energy input. Energy use efficiency ranged from 6.0 to 9.9 in five hybrids under CT with maximum for hybrid Prima Gold(9.9) whereas the range varies from 10.2 to 16.3 in SRI with utmost value in same variety (table 5). Energy intensity was 4.60 MJ Rs^{-1} in SRI which was 5.5% higher than CT. SRI also recorded 70.94% and 65.36% more energy productivity and energy profitability respectively over CT. The variety Prima Gold showed superiority in terms of net energy, energy use efficiency, energy intensity and energy profitability in both the systems of rice cultivation. Khan *et al*. (2009) concluded that environmental impact of crop production associated with Specific energy and energy input output ration.

Table 5. **Energy input – output relationship and Energy indices for Conventional Transplanting (CT) and System of Rice Intensification (SRI)**

		Net energy (MJ ha^{-1})	**energy use efficiency**	**Specific energy (MJ kg^{-1})**	**energy productivity (Kg MJ^{-1})**	**Energy Intensity (MJ Rs^{-1})**	**energy profitability**
CT	H1	112698.6	6.0	0.30	3.4	3.1	5.0
	H2	149106.7	7.6	0.26	3.9	4.0	6.6
	H3	172415.3	8.7	0.24	4.2	4.5	7.7
	H4	201062.5	9.9	0.23	4.3	5.2	8.9
	H5	194939.3	9.7	0.22	4.6	5.1	8.7
Mean		166044.47	8.39	0.25	4.06	4.36	7.39
SRI	H1	127319	10.2	0.16	6.3	3.6	9.2
	H2	128184	10.3	0.19	5.2	3.6	9.3

	H3	190325	14.7	0.13	7.8	5.1	13.7
	H4	211564	16.3	0.13	7.8	5.7	15.3
	H5	188556	14.6	0.13	7.6	5.1	13.6
Mean		169189.58	13.22	0.15	6.94	4.60	12.22

Experiment disclosed that the sharing of direct energy source were 51.6% and 56.8% in CT and SRI respectively which was higher than indirect sources (table 6). Among two systems of rice cultivation SRI consumed more direct energy than CT whereas the pattern was just reverse in case of indirect energy, i.e. CT consumed 11% more indirect energy over SRI. Total energy consumption was further divided into renewable and non renewable energy. Overall non renewable energy consumption was much higher in both the systems of rice cultivation. Percent share of renewable energy was slight lesser for SRI (25.9%) as compared to CT (26.1%). This was attributed to higher seed rate and irrigation water requirement in CT.

Table 6: Types of energy and percent sharing in Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Types of energy	CT		SRI	
	Total energy equivalent (MJ ha^{-1})	Percentage of total energy input	Total energy equivalent (MJ ha^{-1})	Percentage of total energy input
Drect Energy	11637.1	51.8	7823.3	56.8
Idirect energy	10844.1	48.2	6020.7	43.5
Renewable Energy	5874.6	26.1	3581.8	25.9
Non renewable Energy	16606.6	73.9	10262.2	74.1

The study pointed out that highest green house gas emission in rice cultivation was associated with nitrogen fertilization followed by diesel fuel (table 7). Nitrogenous fertilizer alone contributed 47% (Figure 1) and 43% (Figure 2) to the green house gas emission in CT and SRI system of rice cultivation respectively. Due less inputs requirement in SRI, sharing of nitrogen and diesel in emission of green house gas was more in SRI. Total green house gas emission in Conventional transplanting was 834.85 kgCO_2 ha^{-1} and emitted 82.8% more than SRI (456.69 kgCO_2 ha^{-1}) method of cultivation. Green house gas emission per unit of output was 6.14% for CT whereas it was 3.49% in case of SRI.

Table 7. Amount of greenhouse gas emission from inputs of Conventional Transplanting (CT) and System of Rice Intensification (SRI)

Inputs	GHG coefficient (kg CO_2equ/unit)	
	CT	SRI
Machinery (h)	0.78	0.78
Diesel fuel (L)	151.80	151.80
Nitrogen(kg)	392.40	196.20
Phosphate(kg)	80.40	40.20
Potassium(kg)	38.52	19.26
Zinc(kg)	104.50	0.00
Sulphur(kg)	2.70	0.00
Chemicals (kg)	63.75	48.45
Total emission(kgCO_2 ha^{-1})	834.85	456.69
Average yield of five hybrids (kg ha^{-1})	13592.80	13075.20
Emission (kgCO_2e kg^{-1} rice yield) (%)	6.14	3.49

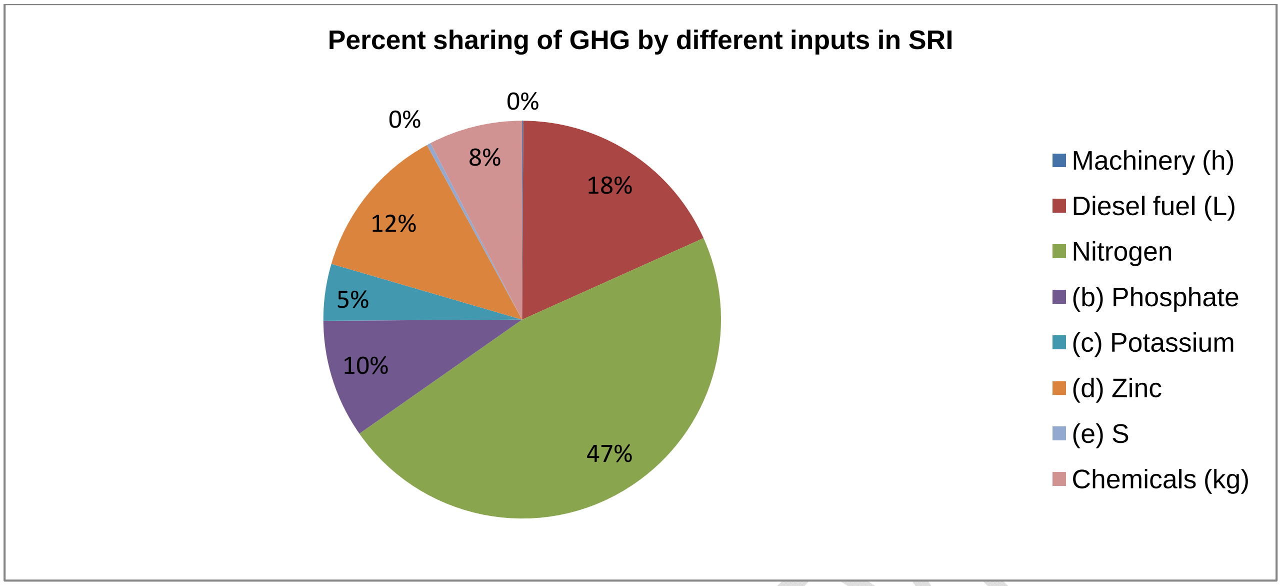

Figure 1

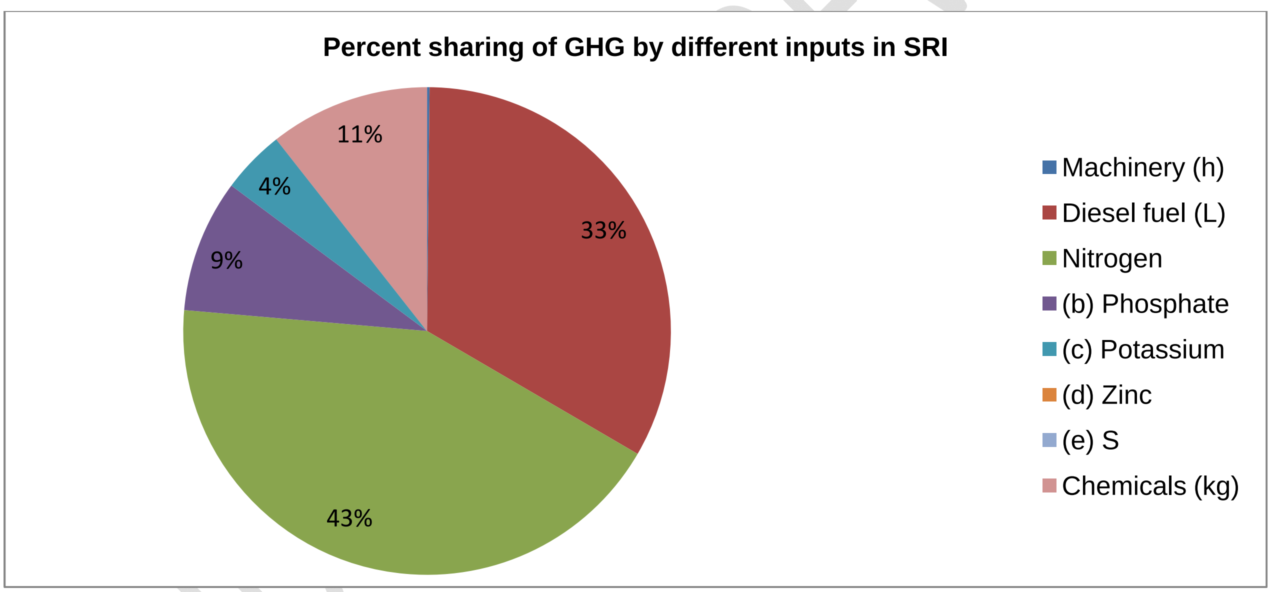

Figure 2

CONCLUSION

Low input intensive rice cultivation, i.e. SRI not only superior on the view of total energy consumption, net energy, energy use efficiency, energy productivity, energy intensity and energy profitability but also in terms of green house gas emission. Conventional method expended 62.39% higher energy and emitted 1.8 times more greenhouse gas over SRI. In conventional rice cultivation higher amount of inputs, specially fertilizer, diesel and irrigation contributes to more CO_2 emission. From the study it can be inferred that SRI is highly efficient rice production system in terms of grain yield, energy indices and emission of green house gas over conventional transplanting method.

REFERANCES:

1. Alam MS, Alam MR, Islam KK. Energy flow in agriculture: Bangladesh. American Journal of Environmental Sciences. 2005;1: 213–220.
2. Babu S, Singh R, Avasthe RK, Yadav GS and Chettri TK. Production potentional, economics and energetic of rice (*Oryza sativa*) genotypes under different methods of production in organic management conditions of Sikkim Himalayas. Indian Journal of Agronomy. 2014;59(4): 602–606.
3. Beheshti Tabar I, Keyhani A, Rafiee S. Energy balance in Iran's agronomy. Renew Sustain Energy Rev. 2010;14: 849–85.
4. Canakci M, Topakci M, Akinci I, Ozmerzi A. Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Convers Manag. 2005;46: 655–666.
5. Chaudhary VP, Gangwar B, Pandey DK. Auditing of energy use and output of different cropping systems in India. Agricultural Engineering International. 2006;8: EE05001.
6. Chizari M, Ommani AR. The analysis of dryland sustainability, Sustain Agri. 2009;33: 848-861.
7. Demircan V, Ekinci K, Keener HM, Akbolat D, Ekinci C. Energy and economic analysis of sweet cherry production in Turkey: a case study from Isparta province. Energy Conversion and Management. 2006;47: 1761–1769.
8. Dyer JA, Desjardins RL. Simulated farm fieldwork, energy consumption and related greenhouse gas emissions in Canada. Biosystems Engineering. 2003;85(4): 503–513.
9. Dyer JA, Desjardins RL. Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. Biosystems Engineering. 2006;93: 107–118.
10. Erdal G, Esengün K, Erdal H, Gündüz O. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy. 2007;32 (1): 35–41.

11. IPCC. Intergovernmental Panel on Climate Change. Fourth assessment report on climate change 2007: Climate Change Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge, UK. 2007.
12. IPCC. file:///I:/Papers/Energy/Energy%20SRI/Appendix%207.pdf. 2014.
13. Jayadeva HM, Setty TKP, Bandi AG and Gowda RC. Water use efficiency, energtics and economics of rice as influenced by crop establishment techniques and sources of nitrogen. Crop Research 2010;39(1, 2 and 3): 14–19.
14. Khan S, Khan MA, Hanjra MA, Mu J. Pathways to reduce the environmental footprints of water and energy inputs in food production. Food Policy. 2009; 34: 141–149.
15. Kim S, & Dale B. Cumulative energy and global warming impact from the production of biomass for Biobased products. Journal of Industrial Ecology. 2003;7: 147–162.
16. Lal R. Carbon emissions from farm operations. Environment International.2004; 30: 981–990.
17. Mandal KG, Saha KP, Ghosh PK, Hatik M and Bandyopadhyay KK. Bio-energy and economic analysis of soybean-based crop production systems in central India. Biomass Bioenergy. 2002;23: 337–345.
18. Mishra A & Salokhe VM. Effect of planting patern and water regim on root morphology physiology and grain yield of rice. Journal of Agronomy and Crop Sci.2010. (DOI: 10.1111/J. 1439ro3 7x.2010. 00421x).
19. Mittal VK, Mittal JP, Dhawan KC. Research digest on energy requirements in agricultural sector. Co-ordinating cell, AICRP on energy requirements in agricultural sector. Punjab Agricultural University, Ludhiana, India, 1985; p 42.
20. Mobtaker HG, Keyhani A, Mohammadi A, Rafiee S, Akram A. Sensitivity analysis of energy inputs for barley production in Hamedan province of Iran. Agr Ecosyst Environ. 2010;137: 367–372.
21. MohammadiA, Rafiee S, Mohtasebi SS, Rafiee H. Energy inputs-yield relationship and cost analysis of kiwifruit production in Iran. Renewable Energy.2010;35: 1071e5.

22. Nautiyal S, Kaechele H, Rao KS, Maikhuri RK, Saxena KG. Energy and economic analysis of traditional versus introduced crops cultivation in the mountains of the Indian Himalayas: A case study. Energy. 2007;32: 2321–2335.

23. Omid M, Ghojabeige F, Delshad M and Ahmadi H. Energy use pattern and benchmarking of selected greenhouses in Iran using data envelopment analysis. Energy Conversion and Management.2011; 52: 153–162.

24. Ozkan B, Akcaoz H, Fert C. Energy input-output analysis in Turkish agriculture. Renew Energy.2004;29: 39–51.

25. Pathak H and Wassman R. Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. generation of technical coefficients. Agricultural Systems. 2007;94: 807–825.

26. Rafiee S, Mousavi Avval S H and Mohammadi A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy. 2010;35: 3301–3306.

27. Safa M and Samarasinghe S. CO_2 emissions from farm inputs "Case study of wheat production in Canterbury, New Zealand". Environmental pollution, 2012.;171, pp.126-132.

28. Singh G. Energy conservation through efficient mechanized farming. Agric Eng Today. 2002;24(2).

29. Singh G, Singh S and Singh J. Optimization of energy inputs for wheat crop in Punjab. Energy Convers Manag. 2004;45: 453–465.

30. Singh H, Mishra D, Nahar NM and Ranjan M. Energy use pattern in production agriculture of a typical village in arid zone India: part II. Energy Convers Manag. 2003; 44: 1053–1067.

31. Taylor EB, O'Callaghan PW and Probert SD. Energy audit of an English farm. Applied Energy. 1993;44: 315–335.

32. Topp CFE, Stockdale EA, Watson CA and Rees RM. Estimating resource use efficiencies in organic agriculture: a review of budgeting approaches used. J Sci Food Agric.2007;87: 2782–2790.