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Energy budgeting of crop-livestock-poultry integrated farming system in irrigated ecologies of eastern India

SANJEEV KUMAR[1], RAVI KUMAR[2] and AMITAVA DEY[3]

ICAR-Research Complex for Eastern Region, Patna, Bihar 800 014, India

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ABSTRACT

The purpose of this study was to determine energy input, output and energy use efficiency of an acre land based crop-livestock-poultry IFS model, developed at ICAR-Research Complex for Eastern Region, Patna during 2012–16. In the current investigation, total energy input in the experimental one-acre integrated farming model was calculated to be 45.08 GJ and total energy output obtained as 102.54 GJ, and resulted in energy use efficiency ratio as 2.27. Also, it was analysed that total energy input was required utmost for the goat rearing, i.e. 24.84 GJ/20 goats/year followed by field crops, vegetable, green fodders, fruits, poultry and mushroom cultivation. In the current IFS model labour, diesel and electrical energy inputs were required maximum in field crops. The direct and indirect energy sources were calculated and found to be invested utmost in field crops and goat rearing as 2.98 GJ and 24.53 GJ, respectively. Similarly, renewable and non-renewable energy sources were utilized in goat rearing and field crops as 24.39 GJ and 6.99 GJ, respectively. Moreover, energy use efficiency ratio was estimated highest in fodder crops (8.66) and lowest from goat rearing (0.17). It was found that goatry and poultry farming are of least energy efficient agricultural production systems, because they produced negative energy mileage. The energy use efficiency ratio for the main output has shown that green fodders and field crops yielded better energy productivity. The net energy gain was recorded maximum from field crops. The energy profitability analysis revealed that green fodders' cultivation was most profitable in terms of energy and produced EP ratio as 7.66 followed by field crops and vegetables, respectively.

Key words: Energy, Energy use efficiency, Fodder, Goatry, Mushroom, Poultry, Vegetables

India is primarily an agricultural country with about 70% population depending on agriculture (Singh *et al*. 2007). Agricultural productivity assessment using energy budgeting is essential to make efficient use of the available natural resources (Singh and Mittal 1992, Moraditochaee 2012, Soni *et al.* 2013). The energy consumption in agriculture has increased consistently in form of various inputs such as fossil fuel, fertilizers, pesticides, herbicides, electricity, machineries etc. causing environmental and human health problems (Chaudhary *et al*. 2009, Fadvi *et al.* 2011, Rahman and Barmon 2012). It has been realized that amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals and therefore, sufficient availability of the green energy and its effective and efficient use are prerequisites for improved agricultural production (Stout 1990). The efficient energy use in agriculture minimizes environmental problems, destruction of natural resources and promotes sustainable agriculture as an economical production system (Erdal *et al*. 2007). The best way to lower the environmental hazard of energy use is to increase the energy use efficiency (Esengun *et al.* 2007). Hence, to maximize the efficiency of modern agricultural technology to farms in a specific region, the farming system should be first characterized to capture the diversity of farming systems (Fadvi *et al.* 2011). It has been concluded in many studies that the yield and economical parameters increased linearly as level of fertility increased, while reverse trend is observed with energy use efficiency and energy productivity (Erdal *et al*. 2007, Tuti *et al*. 2012, Shahamat *et al*. 2013). An input-output energy analysis provides farm planners and policy makers an opportunity to evaluate economic intersection of energy use (Ozkan *et al.* 2004). Nowadays, increasing demand for food resulted in intensive use of energy inputs in modern agricultural production systems than earlier (Shahamat *et al*. 2010).

Since, crop-livestock-poultry integrated farming system is one of the most common farming practices in the eastern region, and majority of the farmers in this region are marginal farmers. Therefore, the present study was undertaken to estimate the energy input and output of crops (cereals, pulses, vegetables and fruits)-livestock (goat)-poultry in an acre integrated farming system model, and to measure its energy use efficiency.

[1,3]Principal scientist (shiv_sanjeev@yahoo.co.in, amitavdey_icar@yahoo.co.in), ICAR, Patna; [2]Scientist (ravi.gautam@icar.gov.in), ICAR, Moitihari.

MATERIALS AND METHODS

An experimental based one-acre integrated farming model was developed at the research farm of the ICAR-Research Complex for Eastern Region, Patna (Bihar) during 2012–16 and assessed for its energy use efficiency. The IFS model consists of different agricultural production sub-systems such as field crops (rice-wheat-maize-lentil-moong), vegetables (okra-onion-tomato-cauliflower-cabbage), fruits (lemon, guava and banana), green fodder crops (sorghum-cowpea-berseem-oat), mushroom, poultry (50 broilers) and goatry (20 goats, Black Bengal) (Table 1). The IFS model was developed only after characterising the major agricultural production systems in the eastern parts of the country which has been mostly practised by the small and marginal farmers in the rainfed ecologies. There are 3 cropping seasons observed in this region, i.e. *kharif* (June-Oct.), *rabi* (Nov.-Feb.) and summer (March- May). The soil was sandy loam. The geographical location of the site was 25.5941° N, 85.13°E and 50 m AMSL. The field experiment was set up to estimate the energy input-output, energy use efficiency, net energy gain and other energy indices for the different agricultural components. These energy indices are:

1. Energy use efficiency ratio(EUE)= Total energy output (TEout)/Total energy input (TEin)
2. . Net energy gain (NEG)= Total energy output – Total energy input
3. . Energy profitability (EP)= Net energy gain / Total energy input
4. . Direct energy (DE)= Labor+Fuel+Electricity
5. . Indirect energy (IE)= Seed+Feed+Fertilizers+Chemicals+Machineries+Water
6. . Renewable energy (RE)=Labor+Organic Fertilizers+-Feed
7. . Non renewable energy (NRE)= Fuel+Electricity+-Seed+Fertilizers+Chemicals+Machinery
8. . Human energy profitability (HEP)= Total output energy/ Labour energy input

Table 1 Details about the one acre IFS model and its components

Sub-system	Area (m^2)	Component	Season	Days
Field crops	2000	Rice	June-Nov	135-140
		Wheat	Nov-Mar	140-145
		Maize	Nov-Apr	160
		Lentil	Nov-Mar	130
		Moong	Nov-Mar	120-125
Fodder crop	500	Sorghum	June-Sep	90-100
		Cowpea	June-Sep	80-100
		Berseem	Oct-Mar	60-150
		Oat	Oct-Mar	60-135
Vegetables	500	Okra	May-Aug	95-100
		Tomato	Oct-Mar	130-140
		Onion	Oct-Mar	100-110
		Cauliflower	Oct-Feb	70
		Cabbage	Oct-Feb	100-110
Fruit crops	500	Lemon		
		Guava		
		Banana		
Mushroom				
Poultry		50 nos.	60 days/cycle	
Goatry		20 nos.	One year	

Various inputs such as labour, fossil fuel, electricity, feed, seed, organic manures and inorganic fertilizers, chemicals, machineries, water etc. and yield as grains, fruits, vegetables, fodder, meat, manure and other products and by-products were taken into consideration to calculate total energy input and output. The energy output for the green fodder crops was estimated based on the dried mass. The average input and output data for the duration of 4 years

Table 2 Resource input and their energy equivalent in MJ/unit

Resource Input	Unit	Equivalent (MJ/unit)	Reference
Labour	hr	1.96	Singh & Mittal (1992)
Diesel fuel	l	47.87	Singh & Mittal (1992)
Electricity	kWh	3.60	Ozkan *et al*. (2004)
Nitrogen (N)	kg	60.60	Singh & Mittal (1992)
Phosphorous (P_2O_5)	kg	11.10	Singh & Mittal (1992)
Potassium (K_2O)	kg	6.70	Singh & Mittal (1992)
Zinc sulphate ($ZnSO_4$)	kg	20.90	Singh & Mittal (1992)
Manure/FYM	kg	0.30	Taki *et al*. (2012)
Vermi-compost	kg	0.50	Ram & Verma (2015)
Farm machinery	kg	62.70	Tuti *et al*. (2012)
Herbicides	kg	254.45	Pimentel (1980)
Insecticides	kg	184.63	Pimentel (1980)
Water	m^3	1.02	Tutiet al. (2012)
Minerals	kg	2.00	Wells C (2001)
Seed			
Rice, wheat, maize, lentil, moong, sorghum, cow pea, oat	kg	14.70	Singh & Mittal (1992)
Okra, tomato, cauliflower, cabbage	kg	0.80	Tuti *et al*. (2012)
Onion*	kg	1.6	Gopalan *et al.* (1971)
Banana*	kg	5.35	Singh & Mittal (1992)
Lemon*	kg	2.88	
Guava*	kg	2.60	
Berseem	kg	10.0	Singh & Mittal (1992)
Chick (poultry)	kg	4.56	Gopalan *et al.*(1971)
Goat	kg	8.12	Gopalan *et al*. (1971)
Mushroom	kg	1.62	Salehi *et al.*(2014)

* Energy equivalent calculated from energy equivalent of the product (Gopalan *et al*. 1971) plus 0.5 (Singh & Mittal 1992).

Table 3 Resource output and their energy equivalent

Output	Unit	Equivalent (MJ/unit)	Reference
Rice, wheat, maize, lentil, moong, tomato, cabbage, cauliflower, chicken and goat meat	kg		Same as input
Okra	kg	1.9	Tuti *et al.*(2012)
Onion	kg	1.6	Singh & Mittal (1992)
Lemon, guava	kg	1.9	Singh & Mittal (1992)
Banana	kg	4.85	Gopalan *et al.* (1971)
Sorghum, berseem, oat and maize (dry mass)	kg	18.0	Singh & Mittal (1992)
Manure	kg	0.30	Taki *et al*. (2012)
By-product (dry mass)			
Straw (Rice and Wheat)	kg	12.5	Singh & Mittal (1992)
Fuel wood (lemon, guava)	kg	18.0	Singh & Mittal (1992)
Okra, tomato, cabbage, cauliflower, onion, banana (leaves and stem)	kg	10.0	Singh & Mittal (1992) Soni *et al* (2013)
Lentil, moong	kg	11.25	Soni *et al*. (2013)

with similar components were considered for the energy analysis. Various farm machineries used for different purposes therefore, their energy was estimated based on distributed weight utilized. Distributed weight was derived as [machinery unit weight/(economic life*365 (366 for leap year)*8))] (Soni *et al.* 2013). The resource inputs and outputs converted from physical to energy unit (MJ) through various published conversion coefficients (Table 2, 3). The recommended dose of fertilizers and chemicals were applied as per the need of different crops. The land preparation for all crops was done with a tractor drawn disc harrow, cultivator, rotavator and manually. A log book was maintained for each and every input in different agricultural components and once the crop was grown up, harvested yields of main and by-products of each component were measured and recorded. The details of all inputs used in different agricultural components under the IFS model through various activities and their outputs as main and by-products are shown in Table 4 and 5.

RESULTS AND DISCUSSION

In the study, total energy input in the current integrated farming system model was calculated to be 45.08 GJ, whereas total energy output, net energy gain and energy profitability was recorded to be 102.54 GJ, 57.46 GJ and 1.27 GJ, respectively. In the current one-acre IFS model, the energy use efficiency ratio was estimated to be 2.27 GJ/GJ. The other researchers have analysed the energy use efficiency of various agriculture productions like sugarcane, maize, cucumber, apple and broiler production in isolation and recorded energy use efficiency ratio as 1.34, 1.86, 0.38, 0.36 and 0.16–0.17, respectively (Lorzadeh *et al*. 2011, Fadavi *et al*. 2011, Shahamat *et al*. 2013, Alizadeh *et al*. 2015, Amini *et al*. 2015). Also, energy output-input ratio

Table 4 Resource input in different agricultural components under the IFS model

Activity	Unit	Crops	Vegetables	Fruits	Fodder	Mushroom	Poultry	Goatry
Area	m^2	2000	500	500	500	100	100	300
Direct								
Labour	man hr	544.00	288.00	128.00	168.00	97.00	129.00	158.00
Diesel	l	22.00	6.50	0.00	10.50	0.00	0.00	0.00
Electricity	kWh	240.00	85.00	32.00	125.00	0.00	58.00	0.00
Indirect								
Seed	kg	*	*	*	*	10.00	5.00	55.00
Feed	kg						**	**
Fertilizers								
• Nitrogen (N)	kg	45.50	18.20	14.50	15.00			
• Phosphorus (P_2O_5)	kg	30.50	10.50	18.20	15.50			
• Potassium (K_2O)	kg	18.00	8.50	12.50	5.50			
• Micronutrient ($ZnSO_4$)	kg	7.50						
• Vermicompost	kg	160.00	120.00	250.00				
• Manure/FYM	kg	2000.00	1400.00	600.00				
Insecticides	kg	1.00	0.25	0.25				
Water	m^3	2500.00	725.00	220.00	264.00	3.00	2.00	4.50
Machinery (all)	kg	0.89	0.18	0.04	0.10			

* Consists more than one component which have different energy equivalent, hence energy is calculated separately then summed up

Table 5 Details of output as main and by-products from different agricultural components under the IFS model

Sl. No.	Integration	Component	Output main (kg)	By-product (kg)
1	Field crops	Rice	1080.0	1250.0
		Wheat	260.0	320.0
		Maize	340.0	480.0
		Lentil	120.0	155.0
		Moong	110.0	210.0
2	Vegetables	Okra	422.0	125.0
		Onion	395.0	95.0
		Tomato	465.0	223.0
		Cauliflower	402.0	125.0
		Cabbage	568.0	155.0
3	Fruit crops	Lemon	135.0	-
		Guava	325.0	-
		Banana	145.0	280
4	Fodder crop	Sorghum	465.0	-
		Cowpea	315.0	-
		Berseem	280.0	-
		Oat	255.0	-
5	Mushroom	-	190	120
6	Poultry	-	65.0	265.0
7	Goatry	-	450.0	1890.0

of greenhouse vegetables like tomato, pepper, cucumber and eggplant production in Turkey was found to be 0.19 to 1.26 (Ozkan *et al*. 2004, Canakci and Akinci 2006). Therefore, it can be evidently said that the current IFS model is energy efficient. The share of direct and indirect energy inputs in this model was estimated as 15% and 85%, respectively, whereas renewable and non-renewable energy inputs were recorded as 35% and 65%, respectively. The analysis revealed that nitrogen fertilizer, diesel, irrigation and labour energy inputs shared together more than 31% of total energy input in the IFS model, whereas the share of feed energy in goatry component under the IFS model was estimated to be 96% of total energy invested for goat rearing and 55% to the total energy input of IFS model (Table 6). Therefore, it is advisable to use more organic fertilizers, improved irrigation technology and precision agriculture to enhance energy use efficiency of the IFS model (Jackson *et al*. 2010, Mohammadi *et al*. 2014).

Amongst the different components in IFS model, it was found that total energy input was required utmost for the goat rearing, i.e. 24.84 GJ/20 goats/year followed by field crops, vegetables, green fodders, fruits, poultry and mushroom cultivation, respectively. Moreover, the energy use efficiency ratio was estimated and found to be highest in fodder crops (8.66) followed by field crops, vegetables, fruits, mushroom, poultry and goatry, respectively (Table 7). It is important to mention that goat rearing and poultry farming were least energy efficient agricultural production systems which have produced negative energy mileage, similar results were obtained from a broiler production in Iran (Amini *et al*. 2015). The goat and poultry rearing, required utmost energy input in the form of feed, and energy analysis indicated that their feeds' energy efficiency was lesser, and requires improvement in the feed nutrition (Safeedpari 2012) and poultry (Amini *et al*. 2015).

Among different agricultural production sub-systems, labour energy input was recorded maximum in field crops

Table 6 Energy input (in MJ) in different agricultural components under the IFS model

Energy source	Crops	Vegetables	Fruits	Fodder	Mushroom	Poultry	Goatry
Direct							
Labour	1066.24	564.48	250.88	329.28	190.12	252.84	309.68
Diesel	1053.14	311.16	0.00	502.64		0.00	
Electricity	864.00	306.00	115.20	450.00		208.80	
Indirect							
Seed	213.15	0.85	28.15	54.1	16.20	51.65	446.60
Feed						967.00	24082
Fertilizers							
• Nitrogen (N)	2757.30	1102.92	878.70	909.00			
• Phosphorus (P_2O_5)	338.55	116.55	202.02	172.05			
• Potassium (K_2O)	120.60	56.95	83.75	36.85			
• Micronutrient ($ZnSO_4$)	156.75						
• Vermicompost	80.00	60.00	125.00				
• Manure/FYM	600.00	420.00	180.00				
Insecticides	120.00	30.00	30.00				
Water	2550.00	739.50	224.40	269.28	3.06	2.04	4.59
Machinery (all)	55.80	11.29	2.51	6.27			

Table 7 Energy indices used for analysis in IFS model

Energy indices	Crops	Vegetables	Fruits	Fodder	Mushroom	Poultry	Goatry
TE input (GJ)	9.98	3.72	2.12	2.73	0.21	1.48	24.84
TE output (GJ)	60.44	9.35	4.18	23.63	0.34	0.38	4.22
TE output main (GJ)	28.08	2.12	1.38	23.63	0.31	0.31	3.65
EER	6.06	2.51	1.97	8.66	1.62	0.26	0.17
EERm (main output)	2.81	0.57	0.65	8.66	1.48	0.21	0.15
NEG	50.46	5.63	2.06	20.90	0.13	-1.10	-20.62
EP	5.06	1.51	0.97	7.66	0.62	-0.74	-0.83
DE	2.98	1.18	0.37	1.28	0.19	0.46	0.31
ID	6.99	2.54	1.75	1.45	0.02	1.02	24.53
RE	1.75	1.04	0.56	0.33	0.19	1.22	24.39
NR	8.23	2.68	1.56	2.40	0.02	0.26	0.45
HEP	56.69	17.15	16.66	49.47	1.79	1.50	13.63

followed by vegetables, green fodder, goatry, poultry (broiler), fruit and mushroom cultivation, respectively. Moreover, diesel and electrical energy inputs were recorded maximum in field crops and followed by green fodder and vegetable crop production systems, etc. The direct and indirect energy sources were calculated and found to be invested utmost in field crops and goat rearing as 2.98 GJ and 24.53 GJ, respectively. Similarly, renewable and non-renewable energy sources were utilized in goat rearing and field crops as 24.39 GJ and 6.99 GJ, respectively (Table 7). The net energy gain was recorded maximum from field crops subsequently followed by green fodder crops, vegetables, fruit crops and mushroom production, whereas goatry and poultry have resulted negative trends in terms of net energy gain. The energy profitability of different agricultural components was analysed and it was found that green fodder cultivation was most profitable in terms of energy and produced EP ratio as 7.66 followed by field crops and vegetables, respectively (Table 7).

The increasing demand for food to meet food, nutritional and health security has resulted in intensive use of energy inputs in agricultural productions which is threatening public health as well as environment, therefore energy budgeting in agricultural production systems is very essential to get sustainability, profitability in the farming practices and to identify the best performing agricultural practice that can be adopted in the specific regions (Erdal *et al*. 2007, Taki *et al*. 2012, Soni *et al*. 2013). The renewable source of energy input can be maximised to lower down the non-renewable sources of energy inputs in agricultural production systems so as to enhance productivity and to bring sustainability in the integrated farming systems (Moreno *et al*. 2011, Zarini *et al*. 2015). The present study revealed that crops (cereals, pulses, vegetables and fruits)-livestock (goat)-poultry in an acre land based IFS model is an energy efficient model and can be promoted and adopted in the eastern region of India. Moreover, the education, awareness and training about the energy use efficiency of farming systems and its importance in agriculture can be provided to the farmers to bring the sustainability in the agriculture sector in India.

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