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ENERGY USE EFFICIENCY AND GREEN HOUSE GAS EMISSIONS FROM INTEGRATED CROP-LIVESTOCK SYSTEMS IN SEMI-ARID ECOSYSTEM OF DECCAN PLATEAU IN SOUTHERN INDIA

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Greenhouse gas (GHG) emission

Energy use

Sustainability

Input energy

Positive energy balance

ABSTRACT

Integrated crop-livestock system is the default in vogue farming system followed in semi arid Deccan plateau in Southern India. Energy flow and environmental impact plays an anchor role for the sustainability of any farming system. The objective of the present study is to know the energy use and greenhouse gas (GHG) emission in the integrated crop-livestock systems in study area. Primarily data was collected from 36 farmers by bench mark survey questionnaire. The study area includes 54.53 ha of cultivated land, 177 dairy cattle, 466 sheep and 129 poultry birds. Total input energy required for crop production and livestock management was 1598441.0 and 6168311.9 MJ respectively, output energy generated was 9063909.8 and 408331.0 MJ respectively. Even livestock enterprise have shown negative energy balance (-5759980.9 MJ), overall system has shown positive energy balance of 1705487.9 MJ as crop enterprise offset the ill energy efficiency of livestock enterprise. Rice emits highest amount of CO_{2eq} (3099.4 kg CO_2eq ha^{-1}) among crops in study, around 50% is contributed by submergence (continuous flooding). Total GHG emission from the study area was 532215.3 kg CO_2eq. Out of which, 26.1% and 73.9% of the emissions were emitted by crop (138637.3 kg CO_2eq) and livestock enterprise (393578.0 kg CO_2eq). Both the cases crop enterprise has greater advantage over the livestock enterprise. The key policy implication from the current study was integrated crop-livestock system will sustain in long run, as less energy use and higher GHG emissions of livestock enterprise will be nullified by the crop enterprise.

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1 Introduction

Agriculture is the base for livelihood of 66% of the Indian population and it contributes 20% of national gross domestic products. It is the source for national food security (ICAR, 2015). In 1970's, with advent of green revolution in India, one side it increased the food grain production. It directly or indirectly increased the livestock population, as the energy availability increased. Other side fertilizer and other external inputs usage increased manifold resulted in deterioration of soil health, thereby paradism shift in energy use and GHG's (green house emissions) emissions over a period. Agriculture requires large energy and potent source of GHG as stated by Hoffman et al. (2018).

Nearly 85% of the Indian farmers fall under the category of small and marginal farmers with acreage less than 1 ha. Initial investment capacity of the Indian farmers is very low. Investment should not impair the crop productivity. So, the cost of cultivation should be kept low. In addition to economic analysis, energy analysis which indicates the inputs to be minimized and energy use has to be increased. Farming uses the energy in different capacities e.g. machinery, human power, seed, diesel, animal power, irrigation etc. An agricultural production system is to be efficient, if it produces more output (output energy) with minimum input energy (especially non reneweable inputs). This makes the agricultural production system viable in environmental and economic terms (Sefeedpari et al., 2012). It is very useful to analyse crops in terms of energy. This should be done without impairing the yield of the crops.

Livestock and land utilization are the critical factors for the GHG emissions. Farming contributes around 10-12% of the GHG globally (IPCC, 2007). The share in India context is a bit higher side at 18% (INCCA, 2010). Farming is in third line after energy and industry sector in GHG emissions in India. In Indian agriculture system, farmers cultivate versatile crops and maintain livestock for the livelihood and nutrition security to family. Mixed crop-livestock farming is age old practice, which provides food for more than half of the world's population (Ghahramani & Bowran, 2018). So, such farming systems environmental impact assessment is also an important factor. Most part of GHG from farming in India is contributed by the livestock (Steinfeld et al., 2006). From global food security point of view livestock plays a very critical role, as it is meeting the 17% of global energy and 33% of protein requirement (Rosegrant et al., 2002). Animal protein demand is increasing day by day globally in general and semi arid deccan plateau in Southern India in particular. Increased per capita income is also playing a pivotal role for the increasing consumption and demand for animal products in this part of world. In addition, increase in animal population also has other benefits like, provides organic matter, which is wealth for poor farmers etc.

In regarding the Deccan plateau in Southern India, livestock – crop integration system is a principle farming pattern adapted by bulk of the cultivators. India is also one of the leading producers of rice and milk. Wide variety of crops like rice, maize, groundnut, cotton, sorghum, vegetables etc. are grown. More or less all farm families will maintain livestock (either dairy, sheep, poultry etc.).

Highly scarce information is available regarding the impact of different farming systems on energy use and GHG emissions in the Deccan plateau of Southern India. An attempt was made to evaluate the energy sequestered in integrated crop-livestock farming system, the energy sequestration of different crops, livestocks and GHG emission from livestock and crop management in Southern Deccan plateau region of India.

2 Materials and Methods

2.1 Description of study area

The survey was conducted under All India Coordinated Research Project on Integrated Farming System, as part of On Farm Research in Medak district of Telangana State in Southern India. The area of surveyed includes two blocks of Medak district *i.e.* Yeldurthy and Toopran covering three villages in each block. Three representative villages from each block i.e. six villages for each district were selected randomly. From each village six farm households were chosen at a random keeping in mind that at least four households should represent each farming system. Yeldurthy and Toopran blocks were the typical blocks of Medak districts, which are located 100 kms east of capital city Hyderabad (Telangana State). Study area is situated in the central part of Telangana State. Its coordinates are 17^{o} 27' 0" – 18^{o} 19' N latitude, 17^{o} 27' 0" – 18^{o} 19' E longitude 442m. Study area comes under Southern plateau and hill zone agroclimatic zone of India. The mean annual rainfall was 861 mm, the mean temperature of the study area was 26.8°C. Climatic condition of the region is tropical. Before commencement of the study, the strong research methodology was developed to investigate the targeted farmers via. statistical and scientific methods through prepared questionnaire. Overall 36 farmers were surveyed in the year 2017-18 for a period of one year from June, 2017 to May, 2018. Farmers in the study area grow crops like rice, maize, fodder sorghum, tomato, okra, cotton groundnut there acreages are 37.74, 14.04, 0.25, 0.9, 0.3, 1.0, 0.2 ha respectively. With regard to livestock, total of 177 dairy cattle, 466 sheep and 129 poultry were maintained by 36 farm families in total. All the farmers were following integrated livestock and crop farming system in different proportions. Geographic and meteorological features of the surveyed villages were similar to other villages, where the integrated livestock-crop farming systems were practiced in this part of world.

2.2 Collection of data

The data regards to the complete production of crops and live stocks were assessed from the targeted farmers by detail interview with individual farmer with the help of bench mark survey questionnaire in the study area. General information of farmer such as holding size, farm land details, farm machinery and equipment, crop wise input used like seed, fertilizers, human labour, bullock labour, chemical, oils used. Production of various farm out puts (rice, maize, tomato and fodder etc) and disposal of produce livestock details like number of animals, fodder, concentrates, mineral mixture, livestock products were reported in detail to calculate the energy balance and GHG emissions.

2.3 Calculations of energy balance and GHG emissions

Various inputs were used for the production of crops and maintenance of livestock, outputs that were generated by using the inputs and their energy equivalents are presented in table 1 (ubiquitous environmental sources of energy *i.e.* radiation, wind etc. was not taken into account). Energy equivalents present in the table 1 were used to calculate the input and output energy values *i.e*., the input energy which was utilized to produce the output energy. Input energy classified into direct (labour, fuel and electricity) and indirect energy (fertilizers, chemicals, machinery, irrigation, manures and seed), renewable (labour, organic manures and seed) and non renewable energy (fuel, fertilizers, chemicals, machinery and water). Output energy like the energy embodied in the crops, livestock products and byproducts were considered.

Different values generated from the input and output energy were used to calculate the energy use efficiency, energy productivity, specific energy, net energy, land use efficiency, non renewable energy ratio, direct energy, indirect energy, renewable energy and non renewable energy (standard formulas are given in table 2). Land use efficiency is the amount of energy generated in a given unit of land. The ratio between total output and input energy is the energy use efficiency. Net energy is the difference between the total output energy generated minus total input energy supplied to produce the crop. Energy productivity is the quantity of crop produced by the supply of given amount of energy. Non renewable energy ratio is the same as energy use efficiency except it considers only non renewable energy used for the crop production.

GHG emissions were in principle calculated with default emission factors, as cited by many authors. In present study different factors that contribute to the GHG emissions were machinery, diesel, N, P, K chemical fertilizers, FYM, electricity, chemicals, rice under submergence, production of milk, FYM, mutton, eggs and poultry. Default factors per unit for the above said factors were used to calculate the GHG emissions (Table 3). The present study accounts only for farm management (within the farm gate) do not account for outside the farm gate. Calculation was done up to the farm gate only.

3 Results and Discussion

3.1 Energy use analysis

The data collected from the surveyed area covering 36 farmers with total acreage of 54.43 ha under crops (occupied by rice, maize, fodder sorghum, tomato, okra, cotton and groundnut), 177 dairy cattle, 466 sheep and 129 poultry birds; these data helps in characterizing the energy use by 36 farmers of the study area in crops and livestock. Input quantities used for production of crops are presented in table 4, input and output energies for crop production are presented in table 5. In production of crops, input energy per unit area crop production varied considerably among crops. The input energies for the production of rice, maize, fodder sorghum, tomato, okra, cotton, groundnut were 1171215.0, 347730.5, 6096.8, 24959.7, 9561.7, 32629.3, 7247.5 MJ respectively. Total input energy for the crop production in the study area was 1598441.0 MJ. Input energies required to calculate for individual crops per ha to produce the output were 31007.2, 24767.1, 24387.3, 27733.0, 31872.3, 32629.3, 36237.7 MJ for rice, maize, fodder sorghum, tomato, okra, cotton, groundnut respectively. Highest input energy required for the production of groundnut while the least one was observed in the fodder sorghum per ha area.

The output energy *i.e.* economic and byproducts energy varies with crops, presented in table 5 (in lower panal). The variation in yield depends on the genetic potential of crop and management practices. The output energy calculated for both economic and byproducts, the values for rice, maize, fodder sorghum, tomato, okra, cotton, groundnut were 6122882.0, 2702090.0, 59850.0, 58634.8, 23458.0, 75725.0, 21270.0 MJ respectively. Mean values of the output energy in MJ ha^{-1} (table 5) were calculated as rice (162288.5), maize (192456.6), fodder sorghum (239400), Tomato (65149.8), okra (78193.3), cotton (75725.0) and groundnut (106350). Sartori et al. (2005) observed in the maize conservation farming, it requires input energy of 46900 MJ ha^{-1} and it generated 161980.0 MJ ha^{-1} output energy. The overall output energy for the study area for crop enterprise was 9063909.8 MJ. Output energies produced by the crops were higher than the energy consumed for production (Table 5). The crop enterprise has produced a positive energy of 7465468.8 MJ compared to consumed energy in the study area. Similarly, Tsatsarellis (1991) calculated the energy use in cotton and reported that cotton crop in total sequestrated energy of 82600.0 MJ ha^{-1}.

Table 1 Energy coefficients of inputs and outputs in integrated crop-livestock production

Input			
Item	Unit	Energy equivalent	Referance
Human labour	h	1.96	Mobtaker et al., 2012
Bullock labour	h	10.10	Chandrakar et al., 2013
Diesel	L	56.31	Barber, 2004
Machinery	h	62.70	Rafiee et al., 2010
Seeds			
a. Rice	kg	14.70	Mohammadi et al. 2014
b. Maize	kg	14.70	Mohammadi et al. 2014
c. Fodder sorghum	kg	14.70	Mohammadi et al. 2014
d. Tomato	kg	0.96	Gopalan et al., 2012
e. Okra	kg	1.46	Gopalan et al., 2012
f. Cotton	kg	18.00	Larson & Fangmeir, 1978
g. Groundnut	kg	23.73	Gopalan et al., 2012
N	kg	60.60	Akcaoz et al. 2009
P	kg	11.10	Akcaoz et al. 2009
K	kg	6.70	Ozkan et al. 2004
FYM	kg	0.30	Devasenapathy et al., 2009
Electricity	kWh	12.00	Tsatsarellis, 1991
Herbicide	kg	102.00	Chaudhary et al., 2009
Pesticide	kg	120.00	Rahman & Barmon, 2012
Insecticide	kg	58.00	Tabar et al., 2010
Dry fodder	kg	12.50	Mohammadi et al. 2014
Concentrates	kg	11.71	Petal, 2012
Green fodder	kg	8.37	Petal, 2012
Output			
Rice	kg	14.70	Mohammadi et al. 2014
Rice straw	kg	12.50	Mohammadi et al. 2014
Maize	kg	14.70	Mohammadi et al. 2014
Maize stover	kg	12.50	Mohammadi et al. 2014
Fodder Sorghum	kg	13.30	Krishnamoorthy et al.1995
Tomato	kg	0.96	Gopalan et al., 2012
Tomato stover	kg	13.00	Mondal, 2010
Okra	kg	1.46	Gopalan et al., 2012
Okra stover	kg	13.00	Mondal, 2010
Cotton	kg	15.50	Larson & Fangmeir, 1978
Cotton stalk	kg	18.2	Ozturk & Bascetincelik, 2006
Groundnut	kg	23.73	Gopalan et al., 2012
Groundnut stover	kg	17.58	Koopmans & Koppejan, 1997
Milk	L	4.9	Gopalan et al., 2012
FYM	kg	0.3	Devasenapathy et al., 2009
Mutton	kg	4.94	Gopalan et al., 2012
Eggs	kg	7.24	Gopalan et al., 2012
Poultry	kg	21.75	Cao & Adeola, 2015

Table 2 Standard formulas used for calculation of different indices of energy use

Parameter	Formula	Reference
Energy use efficiency	Output energy (MJ ha^{-1}) / Input energy (MJ ha^{-1})	Paramesh et al. (2018)
Energy productivity	Crop yields (kg ha^{-1}) / Input energy (MJ ha^{-1})	Mohammadi et al. (2010)
Specific energy	Input energy (MJ ha^{-1}) / Output (t ha^{-1})	Paramesh et al. (2018)
Net energy gain	Output energy (MJ ha^{-1}) - Input energy (MJ ha^{-1})	Mohammadi et al. (2010)
Land use efficiency	Output energy (MJ) / Total land (ha)	Vanloon et al. (2005)
Non renewable energy ratio	Output energy (MJ ha^{-1}) / Non-renewable energy input (MJ ha^{-1})	Vanloon et al. (2005)
Direct energy	Labour+fuel+electricity (MJ ha^{-1})	Mohammadi et al. (2014)
Indirect energy	Chemical fertilizers+ pesticides+insecticides+herbicides+machinery+manure+seed(MJ ha^{-1})	Mohammadi et al. (2014)
Renewable energy	Labour+FYM+seed (MJ ha^{-1})	Mohammadi et al. (2014)
Non renewable energy	Machinery+diesel+electricity+chemical fertilizers+pesticides+insecticides+herbicides(MJ ha^{-1})	Mohammadi et al. (2014)

Table 3 GHG emission coefficients of integrated crop-livestock system

Item	Unit	GHG emission equivalent	Referance
Machinery	kg CO_{2eq} MJ^{-1}	0.071	Komleh et al., 2013
Diesel	kg CO_{2eq} L^{-1}	2.76	Moghimi et al., 2014
N	kg CO_{2eq} kg^{-1}	1.3	Lal, 2004
P	kg CO_{2eq} kg^{-1}	0.2	Lal, 2004
K	kg CO_{2eq} kg^{-1}	0.15	Lal, 2004
FYM	kg CO_{2eq} kg^{-1}	0.126	Komleh et al., 2013
Electricity	kg CO_{2eq} kWh^{-1}	0.8	Nguyen & Hermansen., 2012
Herbicide	kg CO_{2eq} kg^{-1}	3.9	Soni et al., 2013
Pesticide	kg CO_{2eq} kg^{-1}	5.1	Soni et al., 2013
Insecticide	kg CO_{2eq} kg^{-1}	6.3	Lal, 2004
Paddy	1.1 kg CH_4/ha/day× 25 kg CO_{2eq}	1.1	IPCC, 2006
Milk	kg CO_{2eq} kg^{-1}	3.4	Gerber et al., 2013
Mutton	kg CO_{2eq} kg^{-1}	23.8	Gerber et al., 2013
Eggs	kg CO_{2eq} kg^{-1}	4.2	Gerber et al., 2013
Poultry	kg CO_{2eq} kg^{-1}	6.6	Gerber et al., 2013

Table 4 Rate of inputs applied in Crop production

	Units	Rice	Maize	Sorghum	Tomato	Okra	Cotton	Groundnut
Area	ha.	37.74	14.04	0.25	0.90	0.30	1.0	0.20
Inputs								
Human labour	h	38696.0	12048.0	120.0	2160.0	1200.0	920.0	320.0
Bullock labour	h	1622.4	760.0	0.0	128.0	8.0	160.0	24.0
Diesel	L	3077.5	1035.0	2.5	12.5	20.0	40.0	5.0
Machinery	h	615.5	207.0	0.5	2.5	4.0	8.0	1.0
Seed	kg	2499.0	347.0	30.0	10.0	3.0	3.0	40.0
N	kg	6667.5	2864.0	45.0	220.0	32.0	317.0	64.0
P	kg	4053.0	1582.0	10.0	112.0	23.0	219.0	46.0
K	kg	2683.0	790.0	0.0	12.0	0.0	45.0	0.0
FYM	kg	165500.0	76000.0	1500.0	500.0	3000.0	10000.0	0.0
Electricity	kWh	25000.0	1355.0	100.0	220.0	150.0	50.0	50.0
Herbicide	kg	72.5	20.7	1.5	5.0	4.0	4.5	0.5
Pesticide	kg	30.5	14.0	3.2	3.2	2.5	2.2	0.2
Insecticide	kg	28.2	14.0	3.7	3.7	2.5	2.2	0.2

Table 5 Input and output energies for crop production

	Units	Rice	Maize	Sorghum	Tomato	Okra	Cotton	Groundnut
Area	ha	37.74	14.04	0.25	0.90	0.30	1.00	0.20
Input energy								
Human labour	h	75844.7	23614.1	235.2	4233.6	2352.0	1803.2	627.2
Bullock labour	h	16386.2	7676.0	0.0	1292.8	80.8	1616.0	242.4
Diesel	L	173294.0	58280.8	140.8	703.9	1126.2	2252.4	281.5
Machinery	h	38591.8	12978.9	31.3	94.0	250.8	501.6	62.7
Seed	kg	36735.3	5100.9	441.0	9.6	4.4	54.0	949.2
N	kg	404050.5	173558.4	2727.0	13332.0	1939.2	19210.2	3878.4
P	kg	44988.3	17560.2	111.0	1243.2	255.3	2430.9	510.6
K	kg	17976.1	5293.0	0.0	80.4	0.0	301.5	0.0
FYM	kg	49650.0	22800.0	450.0	150.0	900.0	3000.0	0.0
Electricity	kWh	300000.0	16260.0	1200.0	2640.0	1800.0	600.0	600.0
Herbicide	kg	7400.1	2116.5	153.0	510.0	408.0	459.0	51.0
Pesticide	kg	3660.0	1680.0	390.0	390.0	300.0	270.0	30.0
Insecticide	kg	1638.5	812.0	217.5	217.5	145.0	130.5	14.5
Total		1170215.0	347730.8	6096.8	24959.7	9561.7	32629.3	7247.5
per ha.		31007.3	24767.1	24387.3	27733.0	31872.3	32629.3	36237.7
Output energy								
Economic part	kg	3275557.0	1483965.0		4684.8	4088.0	30225.0	14238.0
Straw/fodder	kg	2847325.0	1218125.0	59850.0	53950.0	19370.0	45500.0	7032.0
Total		6122882.0	2702090.0	59850.0	58634.8	23458.0	75725.0	21270.0
per ha.		162238.5	192456.6	239400.0	65149.8	78193.3	75725.0	106350.0

Table 6 Input energy and output energy of livestock enterprise in integrated crop-livestock system

Input			
Buffalos			
	Units	Quantity	Energy
Dry fodder	kg	289635.0	3620438.0
Concentrates	kg	63879.0	748023.1
Human labour	hr	54900.0	107604.0
Green fodder	kg	102332.0	856314.2
Energy			5332379.0
Sheep			
Dry fodder	kg	57890.0	723625.0
Concentrates	kg	6205.0	72660.5
Human labour	hr	8760.0	17169.6
Green fodder	kg	1000.0	8368.0
Energy			821823.2
Poultry			
Concentrates	kg	987.0	11557.7
Human labour	hr	1302.0	2551.9
Energy			14109.7
Total input energy of livestock			6168311.9
Output			
Milk	lit	57632.0	282396.8
FYM	kg	239800.0	71940.0
Mutton	kg	10252.0	50644.9
Eggs	kg	18.0	130.3
Poultry	kg	148.0	3219.0
Total output energy of livestock			408331.0

Table 7 Energy indices in crop production

	Units	Rice	Maize	Fodder Sorghum	Tomato	Okra	Cotton	Groundnut	Avg. of crops
EUE		5.23	7.77	9.82	2.35	2.45	2.32	2.93	4.70
Energy productivity	kg MJ^{-1}	0.19	0.29	0.74	0.20	0.29	0.06	0.08	0.26
Specific Energy	MJ kg^{-1}	5.25	3.44	1.35	5.11	3.41	16.73	12.08	6.77
Net Energy	MJ ha^{-1}	131231.2	167689.4	215012.7	37416.7	46321.1	43095.7	70112.2	101554.2
Land use efficiency	MJ ha^{-1}	162238.5	192456.5	239400.0	65149.8	78193.3	75725.0	106350.0	131359.0
Non renewable energy ratio		6.17	9.36	12.04	3.04	3.77	2.90	3.92	5.89
Direct energy	MJ ha^{-1}	14984.7	7537.8	6303.9	9855.8	17863.3	6271.6	8755.7	10224.7 (34.3%)
Indirect energy	MJ ha^{-1}	16022.5	17229.3	18083.4	17877.2	14008.9	26357.7	27482.0	19580.2 (65.7%)
Reneweable energy	MJ ha^{-1}	4732.8	4215.9	4504.8	6317.8	11123.9	6473.2	9094.0	6637.5 (22.3%)
Non renewable energy	MJ ha^{-1}	26274.5	20551.3	19882.5	21415.2	20748.3	26156.1	27143.7	23167.4 (77.7%)

Table 8 Energy indices in livestock enterprise

	EUE	Energy productivity	Specific Energy	Net Energy
Buffalos	0.066	0.011	92.52	-4978042.0
Goat	0.061	0.012	80.16	-771178.0
Poultry	0.237	0.012	86.03	-10760.4

Input and output energies for the livestock enterprises are presented in table 6. Input energy required for the maintenance of dairy cattle, sheep, poultry were 5332379.0, 821823.2, 14109.7 MJ respectively. Total amount of energy input required was 6168311.9 MJ for livestock enterprise in the study area. The output energy was very low in livestock enterprise *i.e.* milk (282396.8 MJ), FYM (71940.0 MJ), mutton (50644.9 MJ), eggs (130.3 MJ) and poultry (3219.0 MJ). Total output energy for the livestock enterprise was 408331.0 MJ. The livestock enterprise has produced negative energy use of -5759980.9 MJ compared to consumed energy. The livestock enterprise was the most energy intensive component and was great consumer of the energy due to large use of feed ingredients and it is very labor intensive component compared with the crop enterprise.

Table 7 presents the energy indices for crops. The results of study revealed that energy use efficiency of overall crop enterprise was 4.70. It indicates that output energy 4.70 times to the input energy in crops in the study area. Helander & Delin, (2004) reported that energy efficiency of integrated system is more than conventional system. With regards to individual crops, it was highest in fodder sorghum (9.82) and least in cotton (2.32). Lewandowski & Schmidt (2006) stated that increase in chemical N fertilizer application decreases the energy efficiency. The energy productivity of the crops was calculated to be 0.26 kg MJ^{-1}, which means 0.26 kg output is produced per MJ energy consumption. In the present study energy productivity is highest for fodder sorghum (0.74 kg MJ^{-1}) and least for cotton (0.06 kg MJ^{-1}). Specific energy is the amount of energy in MJ required to produce the 1 kg economic yield. Crop enterprises have the mean specific energy of 6.77 MJ kg^{-1}. It means 6.77 MJ is required to produce 1 kg economic product. Fodder sorghum requires only 1.35 MJ and cotton requires 16.73 MJ to produce a kg of economic produce. Crop enterprise consumes 65.7% indirect energy and 77.7% of non renewable energy these findings are in line with Talukder et al. (2019). They reported that in rice production consumes substantial amount of non renewable energy *i.e.* 68 – 84% of total input energy. Crop enterprise have land use efficiency of 131359.0 MJ ha^{-1}, it means system produces 131359.0 MJ output energy per ha area. Net gain of energy per ha area for crop enterprise was 101554.2 MJ. Deike et al. (2008) reported that high values of output energy results in greater net energy gain. Crop enterprise has the non renewable energy ratio of 5.89.

Table 8 presents the various energy indices of livestock enterprises. The energy use efficiency of dairy cattle, sheep, poultry were 0.066, 0.061, 0.237 respectively in the study area. Energy productivity of the livestock enterprises were dairy cattle (0.011), sheep (0.012) and poultry (0.012). Among the livestock enterprise, dairy cattle requires 92.52 MJ per liter of milk, sheep requires 80.16 MJ to produce one kg of mutton and poultry requires 86.03 MJ to produce one kg of poultry meat. All the three enterprises in the livestock have a negative energy gain. Pahlavan et al. (2011) stated that low energy efficiency in system is due to higher input energy.

Table 5 and 6 presents the results accounts for the energy performance of study area *i.e.* crop production and livestock respectively. Table 6 shows clearly that livestock enterprises consumes substantially higher energy and in return produces the very little output energy, which can potentially cause a serious impact on sustainability in long run. In this regard Moore (2010) stated that, increase the energy productivity of the system to attain the sustainability of production. It was quiet opposite in case of the crop enterprise, it consumes little energy and produces much higher output energy. As the farmers of the study area practices integrated livestock and crops, the total input energy for the study area (all 36 farmers) was 7766752.9 MJ and output energy was 9472240.8 MJ. When the total system is considered, it is environmentally sustainable in long run, as system as positive energy of 1705487.9 MJ. This is made possible by the energy use saving in the crop enterprise; totally offset the livestock negative energy use. Livestock enterprise is a good revenue generation sector to farmers, it is recommended to go for integrated livestock-crops for the energy sustainability. Malcolm et al. (2015), also reported integration helps in lowering the energy use. According to Moraine et al. (2017) integration of crop-livestock farming systems promises a greater sustainability.

3.2 Greenhouse gas emissions

The data collected from the surveyed area, covering 36 farmers, where integrated livestock-crops were followed and converted into kg CO_{2eq} by using the emission coefficients for crops and live stocks. GHG emissions regarding the crop production was presented in table 9. GHG emissions were highest in rice crop (116969.6 kg CO_{2eq}) it occupies an area of 37.74 ha of land, with mean of 3099.4 kg CO_{2eq} ha^{-1}. Mohammadi et al. (2014) also reported that compared to all crops under study rice has produced highest GHG emissions. Maize occupies an area of 14.04 ha and had potential to emit GHG of 17929.9 kg CO_{2eq} with an average of 1277.1 kg CO_{2eq} ha^{-1}, followed by cotton (1916.8 kg CO_{2eq}), okra (643.8 kg CO_{2eq}), tomato (643.6 kg CO_{2eq}), fodder sorghum (382.5 kg CO_{2eq}) and groundnut (151.0 kg CO_{2eq}). Total GHG emissions from the crops were 138637.3 kg CO_{2eq} in total of 54.43 ha. If we consider GHG emissions for specific area of ha it ranges between 715.4 kg CO_{2eq} ha^{-1} (tomato) to 3099.4 kg CO_{2eq} ha^{-1} (rice). Similar study was conducted by Tongwane et al. (2016) noticed that tomato crop management has produced 1650 kg CO_{2eq} ha^{-1}. Bos et al. (2014) reported that GHG emission in crop production ranged from 45 kg CO_{2eq} Mg^{-1} (sugar beet) to 520 kg CO_{2eq} Mg^{-1} (pea).

Figure 1 presents the contribution of different parameters to GHG emissions for 1 ha crop production and figure was quite helpful to

Table 9 Amount of GHG emissions from crop and livestock enterprises

	GHG (kg CO_2eq) in surveyed area	GHG (kg CO_2eq)/ha
Crops		
Rice	116969.6	3099.4
Maize	17929.9	1277.1
Fodder sorghum	382.5	1529.9
Tomato	643.6	715.1
Okra	643.8	2145.9
Cotton	1916.8	1916.8
Groundnut	151.1	755.4
Crops total	138637.3	
Livestock		
Milk	195948.8	
FYM	30214.8	
Mutton	166362.0	
Eggs	75.6	
Poultry	976.8	
Livestock total	393578.0	
Overall total	532215.3	

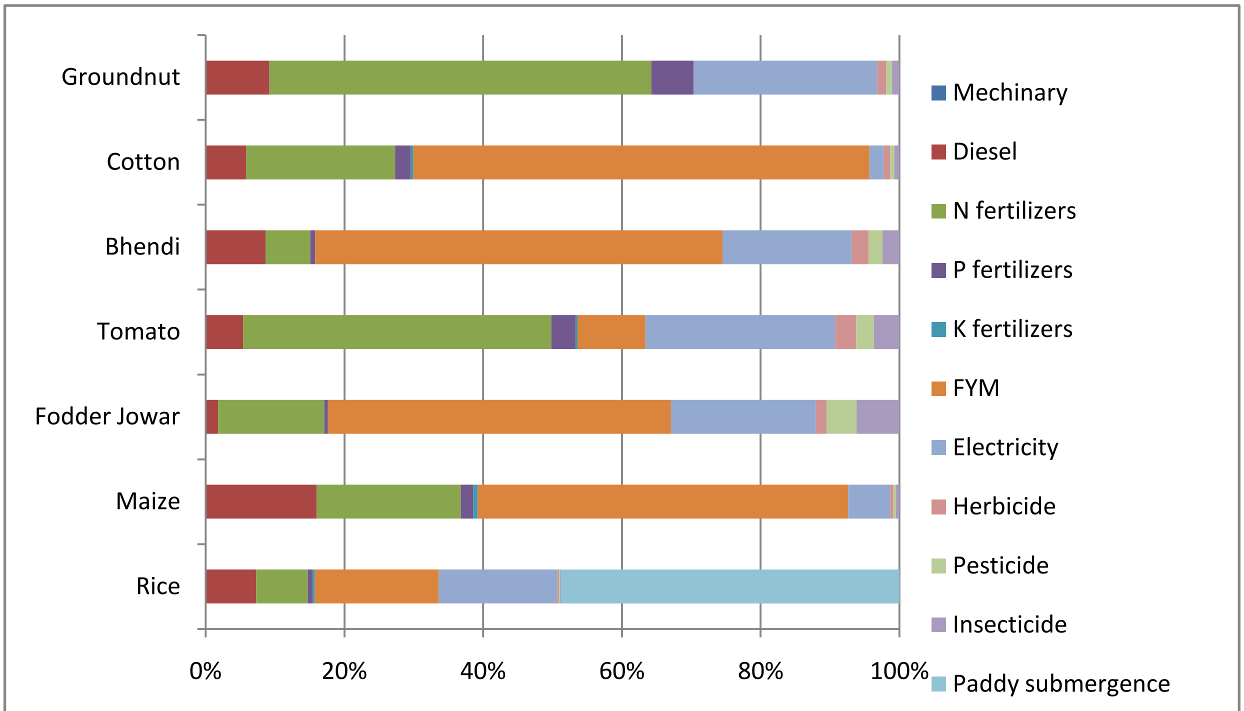

Figure 1 Contribution of different parameters in the GHG emissions of 1 ha crop production in study area

assess the role of different parameters for GHG emissions in crop production. For rice production, submergence of crop was the most important source for GHG emissions followed by electricity and FYM application. Similar findings were summarized by Liu et al. (2010); Nayak et al. (2015) and Xu et al. (2017). Rice crop under submergence (continuous flooding) generates CH_4 emissions because of reduced conditions in soil. While in cotton, okra, fodder sorghum, maize, the application of FYM was among the most important contributor of GHG emission. In the study, after FYM, electricity and N fertilizers play a pivotal role in GHG emissions. Sarauskis et al. (2019) also reported that FYM fertilization resulted in increase in GHG emissions.

As the input energy was very high to produce a specific quantity of livestock products and was expected that GHG emissions from the livestock will be higher than the crop production. The results of the GHG emission was summarized in the table 9 (in lower panal). In the study 177 dairy cattle and bullocks has produced 57637 lit of milk, 6740 kg of meat, 239800 kg of FYM. The CO_2 emission coefficient to produce a liter of milk, kg of meat and FYM were 3.4, 36.8 and 0.126 kg CO_{2eq} respectively. The dairy cattle produces 195948.8, 30214.8 kg CO_{2eq} for production of milk, FYM respectively. In total produces 226163.6 kg CO_{2eq} from the dairy cattle components. Similar findings were reported by Mariantonietla et al. (2017) in Italy, these researchers stated that production of milk was one of the important factors for GHG emissions in agriculture. GHG emissions associated with sheep were presented in table 9. To produce a kg of mutton the CO_2 emission coefficient was 23.8 kg CO_{2eq}. In the study year sheep weight was 10252 kg. The potential GHG emission from sheep components was 166362.0 kg CO_{2eq}. The CO_2 emission coefficient for eggs and poultry meat was 4.2 and 6.6 kg CO_{2eq} kg^{-1}. The production of eggs and poultry meat in study was 18.0 kg and 148.0 kg respectively. So, the poultry component can produce the GHG emissions of 1052.4 kg CO_{2eq}. Total GHG emissions from the livestock enterprises were 641610.0 kg CO_{2eq}. Whole study area GHG emission was 780247.3 kg CO_{2eq}. Vetter et al. (2017) reported that GHG emission was highest for rice and livestock products. The plant protein to animal protein conversion was inefficient in livestock, this was the utmost important point for the high GHG emissions from livestock as reported by Ripple et al. (2014). Li et al. (2017) concluded that integrated livestock-crop systems can reduce the net GHG emissions by 10.15% compared to two separate systems. Saltona et al. (2014) and Buller et al. (2015) conducted a case study in Pantanal savanna highland, Brazil regarding integrated crop-livestock systems and summarized that system can improve soil fertility and mitigate GHG emissions helps towards a more sustainable agriculture in long term for Brazilian cerrado.

Conclusion

The principal aim of the current study was to assess the energy use and GHG emissions from integrated crop-livestock systems in semi arid Deccan plateau of Southern India and their sustainability in long run. Policy makers are very keen at popularizing the integrated crop-livestock system, assessing energy dynamics and environmental impact of the system helps in its sustainability in future. The information regarding inputs and outputs were collected from 36 farmers, integrated crop-livestock was evaluated in terms of energy use and GHG emissions. Among enterprises, crop enterprise in the system was highly efficient in energy while livestock enterprise was very highly inefficient. The results indicate that crop enterprise consumed 1598441.0 MJ of energy and generated 9063909.8 MJ. Crop enterprise has a positive energy balance of 7465468.8 MJ. Energy use efficiency of 4.7 and it consumed indirect (65.7%), non renewable energy (77.7%) greater than direct (34.3%) and renewable energy (22.3%). Regards to livestock enterprise, it consumed 6168311.9 MJ of energy and produced 408331.0 MJ. This enterprise has a negative energy balance of -5759980.9 MJ. Overall, the net energy balance of integrated crop-livestock system was 1705487.9. It implies, negative energy balance in livestock enterprise is neutralized by positive energy balance of the crop enterprises. On a whole integrated crop-livestock system can sustain in long run due to positive energy balance the system. Livestock enterprise alone sustainability is big issue in future.

Comparison between energy input and emitted CO_2 in the study area showed that there was a direct relationship between energy input and CO_2 emissions. In GHG emission analysis in crop enterprise emissions ranged between 3099.4 kg CO_{2eq} ha^{-1} (rice) to 715.4 kg CO_{2eq} ha^{-1} (tomato). Among the crops rice has emitted greater kg CO_{2eq} ha^{-1} per specific area and 50% of emissions were caused by submergence of rice crop. Total GHG emissions form crop enterprise was 138637.3 kg CO_{2eq}. Livestock enterprise production system emitted 641610.0 kg CO_{2eq}, it was much higher compared to crop enterprises in study area. To whole system has produced 780247.3 kg CO_{2eq}. Livestock production represents the one of the prime source of income for small and marginal farmers and was the protein supplement in this part of India. This study clearly insight that integrating livestock with crop production is best possible option to increase the energy use and to reduce GHG emissions that helps in environmental sustainability. Hope, all the farmers will convert to integrated crop-livestock and policy makers should encourage the system, so that farming will be sustained both in energy use and environmental impact.

Conflict of interest

Not have any conflict of interest with any one of co authors and others.

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