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Energy Audit of Maize Production System of Selected Villages of North Karnataka, India

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Maize (*Zea mays* L.) is one of the important crops in India like any other cereal. The energy audit of various resources in the agriculture production plays a key role in management of resources. The study was conducted to work out the contribution of various energy sources in production of maize in Kharif season in Haveri district, Karnataka, India. The data was collected randomly from 40 farmers. The energy ratio, energy productivity, specific energy and net energy gain were computed. The maize production consumed 16701.61 MJ ha^{-1} of energy with grain productivity of 5766.50 kg ha^{-1}, out of which the fertilizer consumption was 55 per cent followed by FYM (17.48 per cent) and diesel fuel (14.33 per cent). The contribution of direct and indirect energy sources was about 22.63 per cent and 77.37 per cent. The renewable and non-renewable energy sources contributed about 27.58 per cent and 72.42 per cent, respectively. The grain and straw ratio was 1.3:1. The energy produced from the straw was 55447.08 MJ ha^{-1} with productivity of 4435.76 kg per hectare.

Introduction

Since last decade, area under maize cultivation is continuously increasing to meet the raising demand for the food production in the world. Maize ranks first in the worlds' cereal production, which accounts 38% of the total grain production with 868 million tonnes from 168 million hectare whereas 30% of wheat (691 million tonnes) and 20 per cent of rice (461 million tonnes). In India, the information about the local energy sources and their utilization pattern plays important role in making appropriate energy policies to develop efficient crop production systems. The importance of energy audit is to ensure the resources are placed accurately where they deliver most. Identifying such key areas is one of the major goals of energy audit. Vural and Efecan (2012) determined the energy of inputs and output in maize production in Bursa province. It was observed that, the fertilizers had the highest rate of energy equivalency of all the inputs used in maize production at 51.47 per cent. The output/input ratio was 0.76 in maize production. The energy consumption in wheat-maize crop production was analysed (Mani *et al.*, 2007) and observed that the average energy consumption for wheat in low and high hills were 41.68 MJha^{-1} and 110.8 MJha^{-1} and those for maize were 43.43 MJha^{-1} and 81.33

$MJha^{-1}$, respectively. Moraditochaee (2012) investigated the energy indices under rain fed corn in north of Iran. The average yield of corn was 2375 kg ha^{-1} and its energy equivalent was 37050 MJ ha^{-1}. Energy efficiency for seed was 2.25 with non-renewable energy of 94.88 per cent. The present study aims to investigate the energy use from different sources in maize cultivation and economic investigation of maize cultivation.

Materials and Methods

The data was collected through face to face questionnaire method from the 40 randomly selected farmers in 8 villages (*viz.,* Hosahalli, Ingalagondi, Hiremoraba, Jogihalli, Veerapura, Siragambi, Halabikonda and Rattihalli) of Haveri district of Karnataka, India. The study was conducted for maize crop under Kharif season of 2016. The data collection involved the various operational energy input and output in production system. The data relevant to input sources for one hectare maize cultivation were collected. In order to know the approximate energy input from each sources, number of units of energy sources used were multiplied by respective energy equivalents. The energy equivalents for different sources are shown in the Table 1. The various input energy resources are separated into direct and indirect and renewable and non-renewable forms. The direct energy sources *viz.,* diesel, human, bullocks. Similarly chemical fertilizer, farm yard manure, seeds and farm machinery (tractor, mould board plough, cultivator, blade harrow, indigenous plough, and threshers) are the indirect energy sources. The renewable energy consists of human labour, FYM and seeds. The diesel fuel, farm machinery and chemical fertilizers separated under non-renewable energy.

The operation wise energy requirement was computed based on the different sources used in particular operation. The seed bed preparation involved ploughing land with tractor drawn mouldboard plough followed by cultivation (tractor drown rigid 9 tyne cultivator) or harrowing (animal drawn blade harrow) to generate favourable seedbed. The manure was transported to field by tractor and bullock drown cart from pit and spread over the field manually. The sowing operation consisted of indigenous ploughing to make the furrows and placing seeds in furrow. After emergence and 30DAS, the both inter and intra-row weeding was carried out manually. The intercultural operations were carried out by 2-4 blade bullock drawn harrows in single run for 2-3 times per crop period. Since, rainfall distribution was uneven over the entire district during the crop period, only few farmers irrigated their fields during moisture scarcity in the field. While, remaining farmers couldn't irrigate their fields for entire crop period. The inorganic fertilizer (UAN) was applied twice in the crop duration manually during sowing stage and development stage. Maize crop was harvested manually and transported to convenient place suitable for threshing using tractors and bullock carts. Threshing was done using locally available maize crop threshers. To assess the different energy measures, energy parameters such as energy use efficiency, energy productivity, specific energy and net energy gain were computed using following equations (Avval Mousavi *et al*., 2011; Naveenkumar, 2011):

$$Specific\,energy, MJ\,kg^{-1} = \frac{Energy\,input(MJ\,ha^{-1})}{Yield(kg\,ha^{-1})}$$

$$\text{Energy productivity, kg}\,\text{MJ}^{-1} = \frac{\text{Yield (kg ha}^{-1})}{\text{Energy input (MJ ha}^{-1})}$$

$$Energy\,use\,efficiency = \frac{Energy\,output(MJ\,ha^{-1})}{Energy\,input(MJ\,ha^{-1})}$$

Net energy gain, MJ ha^{-1} = *Energy output (MJ* ha^{-1}*) – Energy input (MJ* ha^{-1}*)*

Cost economics

The capital input was separated into variable cost and fixed cost (Sandigodmath, 2007). Variable cost involved the various input sources such as labour, seeds, organic manure, and inorganic fertilizer. On the other hand, the fixed cost consisted of rental value of owned land and interest on the fixed cost. The labour cost involved the human labour, bullock labour and machine labour in different activities from seed bed preparation to threshing and cleaning. The labours consisted of total men and women as the woman working of 8 hour per day is equivalent to 80% of man working day of 8 hour (Sandigodmath, 2007). For calculation of the cost, an average of pattern labour usage was considered for the different farm activities in maize production (Table 5).

Results and Discussion

The average operation-wise energy spent by the farmers for maize production in the selected villages is given in the Table 2. It was observed that, the major energy consuming operations for maize production were seedbed preparation (3048.46 MJ ha^{-1}), weeding and inter-cultivation (638.15 MJ ha^{-1}) and threshing (579.50 MJ ha^{-1}). The seedbed preparation consumed 62 per cent of total operation-wise energy spent for maize production followed by weeding and inter-cultivation (13%) and threshing and others (12 per cent). Sowing and harvesting operations consumed around 7 and 6 per cent of total operational energy respectively. The similar results were obtained by the (Moraditochaee, 2012).

The different forms of energy used for maize production are shown in the Table 3. The direct energy spent for maize crop production in terms of the diesel fuel usage was 42.51 litres per hectare followed by the human (178 man-h ha^{-1}and 305 man-h ha^{-1} for men and women, respectively). Bullocks were used for 55 h ha^{-1} in different activities of farm operation. The farmers applied chemical fertilizers and FYM without knowledge of nutritional demand to the field. The energy contribution from chemical fertilizer was maximum (55.09%) as compared to other inputs *viz.*, farm yard manure (23%), farm machinery (4%) and seeds (2%) in case of indirect energy. This was due to application of the nitrogen, which accounts about 135 kg ha^{-1} followed by the potash (62 kg ha^{-1}) and phosphorus (54 kg ha^{-1}) by straight and compost fertilizers available locally. Fertilizing was done by human labour (36 h ha^{-1} for all the times).

The fertilizers were applied at the rate of 250 kg per hectare. The farm yard manure (63%) was the major renewable energy source followed by the human, bullocks and seeds. The average of 9730 kg ha^{-1} of manure was applied during seed bed preparation or prior to sowing operation. Most of the non-renewable energy was met by the chemical fertilizer (76%) and 20 per cent of diesel fuel followed by 4 per cent of the farm machinery. The results are in accordance with Vural Hasan (2012), hence justified.

The details of different energy forms and output structure are shown in the Table 4. The share of renewable and non-renewable energy in total energy spent for crop production was 27.58 per cent and 72.42 per cent, respectively. The highest energy ratio of 5.07 was obtained, which was due to higher yield in the region and. The 350 g of maize grains were grown per unit of MJ of energy input (Vural Hasan, 2012). The specific energy requirement was 2.90 MJ per kilogram. The net energy gain from the main product was 68065.28 MJ per hectare. The grain to straw ratio was about 1.3:1 in study area.

Table.1 Equivalents for various sources of energy

Input	Units	Energy equivalent (MJ/unit)
1. Human labour		
a) Men	Man-hour	1.96
b) Woman	Woman-hour	1.57
2. Bullocks	Pair-hour	10.10
3. Diesel fuel	litre	56.31
4. Farm machinery	Kg	62.7
5. Chemical Fertilizers		
a) Nitrogen	kg	60.60
b) Phosphorus	kg	11.10
c) Potassium	kg	6.70
6. FYM	Kg	0.30
7. Seeds (or seed yield)	Kg	14.7
8. Biomass from grain	Kg	12.5

Table.2 Operation-wise energy requirement in maize production

Operation	Energy requirement, MJ ha^{-1}
Seed bed preparation	3048.46
Sowing operation	340.21
Weeding and intercultural operation	638.15
Fertilizer Application	24.94
Harvesting and transportation	274.54
Threshing and others	579.50
Total	**4905.80**

Table.3 Contribution of different energy sources

Input sources	$MJha^{-1}$
Direct energy sources:	
Human labour**	828.05
Men**	349.34
Women**	478.71
Bullocks**	558.14
Diesel fuel*	2393.69
Indirect energy sources:	
Seeds**	300.43
FYM**	2919.48
Chemical fertilizer*	9201.69
Farm Machinery:	
Plough*	44.92
Indigenous plough*	16.90
Tractor*	251.48
Cultivator(rigid 9 tines)*	16.69
Blade harrow (tractor drawn)*	9.29
Blade harrow (animal drawn)*	11.00
Thresher*	146.81
Total	**16701.61**

Note: * Non-renewable energy sources ** Renewable energy sources

Table.4 Status of use of different energy sources and output of the maize production

Particulars	Energy for sunflower
Direct energy use	3779.88 MJ ha^{-1} (22.63%)
Indirect energy use	12921.33MJ ha^{-1} (77.37%)
Renewable energy use	4606.10 MJ ha^{-1} (27.58%)
Non-renewable energy use	12096.12 MJ ha^{-1} (72.42%)
Total input energy	16701.61MJ ha^{-1}
Main product (grain yield)	5766.50 kg ha^{-1}
By-product Yield (material other than grain)	4435.76 kg ha^{-1}
Total output energy:	
Main product (grain yield)	84767.50 MJ ha^{-1}
By-product Yield (material other than grain)	55447.08 MJ ha^{-1}
Energy ratio or Energy use efficiency*	5.07
Energy productivity*	0.35 kg MJ^{-1}
Specific energy*	2.90 MJ kg^{-1}
Net energy gain*	68065.28 MJ ha^{-1}

Note: *with respect to main product output. The values in the parenthesis indicate the percentage of the total input energy

Table.5 Pattern of labour use in maize production per hectare

Sl. No.	Operations	Male, man-hour	Female, female-hour	Total human labour,(%)*	Bullock Labour, pair-hour,	Machine labour, machine-hour	Total (%)*
1	Land preparation	28.15	0	28.15 (6.22)	8.40	11.54	48.09 (9.11)
2	FYM transportation and spreading	17.04	0	17.04 (3.76)	6.11	6.32	29.47 (5.58)
3	Sowing	22.48	41.79	64.27 (14.19)	10.35	0	74.62 (14.14)
4	Application of inorganic fertilizers	7.64	14.41	22.05 (4.87)	0	0	22.05 (4.18)
5	Weeding and intercultural operation	43.49	114.59	158.08 (34.91)	26.60	0	184.68 (34.99)
8	Harvesting	32.73	81.08	113.81 (25.13)	0	0	113.81 (21.56)
9	Threshing and cleaning	22.80	26.66	49.46 (10.92)	0	5.58	55.04 (10.04)
	Total	**174.33 (33.03)**	**278.53 (52.78)**	**452.86 (85.81)**	**51.46 (9.75)**	**23.44 (4.44)**	**527.76 (100)**

*The values in the bracket showing the per cent values of respective total labour.

Table.6 Cost of cultivation for maize production per hectare in the year 2011-12

Sl. No.	Particulars	Amount (Rs./ha)	Percentage (%)
A	**Variable cost**		
1	Labour	20382.34	39.16
a	Human labour	7446.59	14.31
	Female	4177.91	8.03
	Male	3268.69	6.28
c	Bullock labour	7075.75	13.60
d	Machine labour	5860.00	11.26
2	Seeds	1038.75	2.00
3	Organic manure,	3222.45	6.19
4	Inorganic fertilizer	12193.52	23.43
5	Other material charges	1424.50	2.74
6	Interest on working capital	4208.77	8.09
	Total variable cost	42470.34	81.60
B	**Fixed cost**		
1	Rental value of the owned land	8625.00	16.57
2	Interest on Fixed cost	948.75	1.82
	Total fixed cost	9573.75	18.40
	Total cost of cultivation	**52044.09**	100.00

Table.7 Return structure in maize seed production

Particulars	Unit	Quantity/Amount	Percentage
COSTS			
a) Variable cost	Rs.	42470.34	81.60
b) Fixed cost	Rs.	9573.75	18.40
Total cost	Rs.	52044.09	100.00
RETURNS			
a) Yield	Kg	6296.03	-
Price	Rs./kg	15.00	-
Gross returns	Rs.	94440.38	100.00
Net returns over variable cost	Rs.	51970.04	55.03
Net returns over total cost	Rs.	42396.29	44.89
Cost of production	Rs./kg	8.27	-
Benefit Cost Ratio	-	1.81	-

The by-product of 4435.76 kg ha^{-1} was obtained, which accounted about 55447.08 MJ ha^{-1} of energy. The farmers used the crop residues for feeding the animals, making the manure and very few of the farmers burned residues in order to avoid the delay in seed bed preparation for next crop. The pattern of labour use in maize production per hectare is shown in Table 5. From the results we found that, weeding and intercultural operation was the most labour intensive operation consuming 184.68 h (34.99 %), which could be minimised using selective herbicides and by on time weeding.

Harvesting was the second most labour intensive operation consuming 113.81 h (21.56 %), which could be minimised using combines. So that, one can save the cost involved in the threshing and cleaning operation. Similar findings were observed by the Singh and Mittal, 1992. From Table 6, the total cost involved in maize cultivation was Rs.52044.09 per hectare, out of which the variable cost is about 81.60per cent. Under the variable cost, share of inorganic fertilizer was about 23.43% (Rs. 12193.52) at application rate of 2286 kg per hectare. The different fertilizers (*viz.*, Straight (Urea) and complex (DAP, 20: 20: 20, *etc.*) fertilizers) were used 2-3 times (sowing, growing and maturity stage). The second most share in the variable cost was bullock labour (Rs. 7075.75) followed by machine labour (Rs. 5860.00 per hectare) due to predominant usage of bullock in the seed bed preparation, different tillage operations such as ploughing followed by smoothing with a 9 or 5 tyne cultivator and finally with blade harrows for sowing.

The remaining variable costs consisted of outlay in seeds for sowing, other material charges (involves cost of kurpi, sickle, spade, plastic sheet for weeding and covering the harvested ear heads or threshing work) and interest on working capital (8.09%). Whereas, fixed cost involved the rental value of the land was major cost (average Rs. 8625 per hectare as per locality) followed by interest on fixed capital (Rs. 948.75). The costs incurred and return structure of the maize cultivation is shown in the Table 7. The total cost of production was Rs. 52044.09 per hectare, out of which Rs. 42470.34 was variable cost (81.60%) and fixed cost was Rs. 9573.75 (18.40%). The average yield obtained from all the fields was 6296.03kg per hectare. The price per kg of yield of maize seeds was Rs. 15.00. The average gross return was Rs. 94440.38 per hectare. Net return over variable cost was Rs. 51970.04 (55.03%) and net returns over total cost were Rs. 242396.29 (44.89%) per hectare. The cost of production per kg of maize seeds was Rs. 8.27. The benefit cost ratio was 1.81 in maize production.

In conclusion the average energy spent per hectare for the production of maize in different villages of Haveri district was about 16701.61 MJ per hectare. The direct and indirect source of energy contribution was 3779.88 MJ ha^{-1} (22.63%) and 12921.33 MJ ha^{-1} (77.37%) and the renewable and non-renewable source of energy contribution was 4606.10 MJ ha^{-1} (27.58%) and 12096.12 MJ ha^{-1} (72.42%), respectively. Major energy consuming operation was the seed bed preparation followed by weeding and intercultural operation, threshing, sowing and harvesting. Chemical fertilizer, farm yard manure and diesel were the major inputs in the maize production system under rain-fed condition. These inputs contributed to the total energy used at more than 80 per cent. The fertilizer application was by means of manual broadcasting method and without knowledge of nutritional demand to the field. This needs to be managed properly by providing on need basis. In the present case, the fuel energy can be saved by right combination of tillage practices such as rotavator cum seed drill or zero-till-drill. The by-product produced was not used effectively for commercial purpose. In all the operations, the labour intensive operation was weeding and intercultural operation followed by harvesting and sowing. The women labour sharing about 50% of the total working hour in maize production and 85.81 % shared by human labour. The net return over total cost in maize production was Rs. 51970.04 (55.03 % of the gross return) with 1.81 cost benefit ratio.

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