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Energy Utilization Pattern in Maize Production under Dryland Systems

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ABSTRACT

The study examined the energy use pattern in maize crop production under dryland systems. The study revealed that fertilizer was found to be the dominant source of energy contributing 6841 to 10415 MJ ha^{-1} which accounted for 47.8 to 61.3% of the total energy utilized in maize production in both clusters. The total energy utilized for maize production by medium farmers 16973 and 16455 MJ ha^{-1} in MC1 and MC2, respectively was higher than that of large and small farmers. The operation wise energy use pattern in maize production showed that among all the operations, land preparation consumed highest amount of energy across all category of farmers. The output-input energy ratio was highest in large farmers 5.12 and 4.53 for MC1 and MC2, respectively. Small farmers observed as lowest in machinery energy ratio (MER) and mechanization index (MI) values were found at value of 0.19 and 0.22, respectively for MC1 and 0.17 and 0.23, respectively for MC2. The lowest total cost of energy was observed in medium farmers Rs. 2.10 and 2.06 per MJ in MC1 and MC2 respectively.

Key words : Garland chrysanthemum, Gibberellic acid, Paclobutrazol and Salicylic acid.

India is a predominantly agricultural country; where in nearly 50% of the population still relies on agriculture as its principal source of income. In development of agricultural process over a period of time, energy played a key role in Indian agriculture during which, farm power availability increased from about 0.293 kW ha^{-1} in 1960-61 to 1.841 kW ha^{-1} in 2012 -13 (Mehta *et al,* 2014a). Agriculture plays a two-sided role as energy user as well as producer, because it uses different types of commercial and non-commercial energies in direct and indirect forms. The energy use pattern for unit production of crop varies under different agro climatic zones. The use of energy in crop production depends on the availability of energy sources in particular region and also on the capacity of the farmers (Kalbande and More, 2008). Energy use patterns of crops differ with the type of machines available and extent of farm operations, irrigation modalities and inputs uses. The structure of energy use pattern in Indian agriculture has experienced a marked shift from animate to mechanical sources since four decades due to introduction of various types of machines. Any such changes need to be studied periodically and in structured manner to quantify the mechanization pattern under different cropping systems to identify the gaps and suggest remedial measures. Many such studies were carried out in various crops under irrigated systems, but no such recent studies were found in rainfed conditions pertinent to Telangana State. Hence, this study was undertaken with the objective of determine the energy use pattern in selected crop production operations for maize crop.

Energy is one of the most valuable inputs in crop production. It is invested in various farms such as inputs, mechanical power, human power and animal power. The amount of energy used in agricultural production, processing and distribution should be significantly higher in order to feed the expanding population and to meet other social and economic goals. Human and animal energy is predominately being used in majority of the farm production operations starting from land preparation to harvesting of the crops in Indian agriculture.

Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It is the third most important cereal crop in India after rice and wheat. The area under maize cultivation is increased from 7.5 M ha in the year 2004-05 to 9.4 M ha in 2013-2014 with a productivity of 2.5 MT ha^{-1} (Anon, 2014). The area under maize cultivation in Telangana state is 0.51 M ha, which occupies 8.7% of gross cropped area in 2014 and the productivity of crop is around

4197 kg/ha (Directorate of Economics and Statistics, 2014).

MATERIAL AND METHODS

A field survey was carried out to collect the relevant data and analyze energy utilization pattern for various field operations in maize crop. The field survey was carried with a predefined survey schedule in two selected clusters and with three categories of farmers. The farmers were classified into 3 categories *viz.* 1) small (1 to 2 ha), 2) medium (4 to 10 ha) and 3) large farmers category (10 ha and above) as described by Sanjeeva Reddy *et al.,* (2009). Under each category 10 sample farmers were selected to collect the data which is needed for the study. The pre-prepared questionnaire consisted of relevant questions to get appropriate data from individual farmers. Data on energy used from three different direct sources of energy (human, animal and mechanical) and their use pattern in different operations of maize cultivation from land preparation to harvesting were collected from all the selected farmers. Similarly, the data on input sources like seed, fertilizer and plant protection chemicals used were also collected for determining total energy consumption in maize production in respective category of farmers. For converting collected data of different power sources and inputs into energy units, different energy conversion coefficients were used (Table 1).

Knowing the total energy expenditure in each category of farmers, the following performance indicators were worked out for maize crop.

Energy use efficiency:

The comparison of how efficiently different crops convert input energy into output energy is called energy use efficiency and defined as the ratio of output energy to input energy.

Energy productivity (kg/MJ) =

$$\frac{\text{Crop yield (kg)}}{\text{Input energy (MJ)}}$$

$$\text{Energy ratio} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

Net energy = Energy output – Energy input

Machinery energy ratio

The machinery energy ratio and mechanization index are internationally accepted indicators of mechanization status in a particular crop. The machinery energy ratio is an index which represents the fraction of the total energy inputs through the various tools and implements used in different operations for cultivation practices of a particular crop. The machinery energy ratio was determined using equation described by Adrian *et al.,* (2007).

$$MER = \frac{M_{e(a,i)}}{T_{e(a,i)}}$$

Where, MER is the ratio of the machinery energy to the total energy input

$M_{e(a,i)}$ is the energy input through the various machines/implements

$T_{e(a,i)}$ is the total energy input (from human labour, animals, machine/hand tools, seed, and farm yard manures) for the production of crop 'i' in the production unit 'a'.

Mechanization index

Mechanization index is an index based on the ratio of the cost of use of machinery to the total animate and machinery cost for the estimation of the mechanization. A mechanization index based on the matrix of use of animate and machinery energy inputs was determined as is suggested by Singh (2006) and as given below.

$$I_{mi} = \frac{C_{EMi}}{C_{EHi} + C_{EAi} + C_{EMi}}$$

Where,

I_{mi} = Mechanization index of the i^{th} crop,

C_{EMi} = Cost of use of machinery i^{th} crop,

C_{EHi} = Cost of use of Human labour i^{th} crop

C_{EAi} = Cost of use of bullock pair i^{th} crop

In order to determine the mechanization index in the present case, the cost of machinery, human labour and animal is taken as the amount of input energy and the unit cost of input energy is assumed as constant irrespective of their input source. Assumption is that, higher productivity requires more power and farmers using sophisticated

Table 1. Equivalent coefficients for various sources of energy (Singh., 2013).

Energy source	Units	Equivalent energy (MJ)
Adult man	Man-h	1.96
Adult woman	Woman-h	1.57
Large bullocks	Pair-h	14.05
Medium bullocks	Pair-h	10.10
Diesel	Liter	56.31
Prime movers other than electric motor including self-propelled machines	Kg	68.40
Nitrogen	Kg	60.60
P_2O_5	Kg	11.1
K_2O	Kg	6.7
FYM	Kg	0.3
Chemicals	Kg	120
Maize Seed	Kg	14.7
Maize Produce	Kg	14.7

Table 2. Basic profile of project clusters.

	Information	Maize	
		MC1 (Gudur clusters)	MC2 (Machavaram clusters)
I. a	Total geographical area, ha	687.96	750
	Total cultivable area, ha	526	600
	Major soil type	Black cotton soils	Sandy loam soils
	Mean annual rainfall, mm	800	700
	No. of house hold	250	300
I. b	Major crops		
	Cotton, ha	50	175
	Maize, ha	150	190
	Paddy, ha	100	95
	Vegetables, ha	50	75
	pigeon pea	25	65
II	Agril. workers, No.	600	425
	Draught animal pair	20	85
	Tractor, No.	14	8
	Tractor drawn implements/ machinery	33 (2.3 No./tractor)	14(1.75 No./tractor)
	Power thresher, No.	2	0
	Diesel engines, No.	0	0
	Electric pump sets, No.	200	130
	Hand compression sprayer, No.	20	40
	Power sprayer, No.	22	10
III	Power availability, kW/ha	2.54	1.37

self-propelled machines like threshers, combine may require higher farm power per unit area.

RESULTS AND DISCUSSIONS

Baseline information of the selected clusters

The selected clusters namely, Gudur clusters (MC1) from Ranga Reddy and Machavaram (MC2) clusters from Nalgonda district fall under dryland zone of Telangana state and maize being grown completely under rainfed conditions as k*harif* season crop. The basic profiles of the selected clusters were presented in Table 2. These clusters fall under semi-arid region with varied soil types and long term mean annual rainfall ranges from 700 to 800 mm. The number of water pumping systems reported in the clusters also indicates that, the clusters are under rainfed conditions without any major irrigation canal facilities.

These MC1 and MC2 clusters had 20 and 85 draught animal pairs and 14 and 8 numbers of tractors, respectively. However, no tractor matching other machinery was seen in any of these two clusters except primary and secondary tillage implements. The power availability of clusters was found to be 2.46 and 1.37 kW ha^{-1} in MC1 and MC2, respectively. In MC1 two tractors operated medium range multi crop threshers were in use, major job being maize cobs threshing.

Operation-wise and source-wise energy utilization pattern (MJ ha^{-1}) for MC1

The operations and source wise energy utilization pattern for maize in MC1 was presented in Table 3 and 4. In the field operational activities, land preparation consumed maximum total operational energy across all farm categories, in which large farmers spent 1919 MJ ha^{-1} followed by medium farmers 1590 MJ ha^{-1} and small farmers 1179 MJ ha^{-1} lowest, which include mainly of machinery and animate power sources. After land preparation, the next highest energy consumed operation was threshing, whose quantity ranged from 19.3 to 26.6% of the total operational energy. Farm yard manure (FYM) application was observed as lowest energy consumed operation in all categories of farmers; large, medium and small farmers were recorded 650, 588 and 392 MJ ha^{-1}, respectively. In maize crop, major dominant input source reported was fertilizers irrespective of different categories of farmers and its contribution in total energy in selected categories of farmers ranged from 49.1 to 61.3% followed by the next highest was mechanical energy in the range of 19.2 to 25.9%. As the sources wise energy uses were concerned, medium farmers used highest chemical fertilizers 10415 MJ ha^{-1} and large farmers highest mechanical energy 3805 MJ ha^{-1} and farm yard manure (FYM) 1720 MJ ha^{-1}. The two lowest energy expended operations reported were input seed and chemicals to control pest and weed growth in maize crop across all the categories of farmers.

The total operational, inputs and overall total energy used by different categories of farmers for MC1cluster was shown in Figure 1. In cluster MC1, the large farmers utilized maximum total over all energy for various field operations 5203 MJ ha^{-1} and medium farmers utilized inputs use energy 12211 MJ ha^{-1}. The total maximum energy utilized in maize production was observed with medium farmers (16973 MJ ha^{-1}), when compared with large (14683 MJ ha^{-1}) and lowest 13144 MJ ha^{-1} with small category farmers due to low operational and inputs energy use.

Operation-wise and source-wise energy utilization pattern (MJ ha^{-1}) for MC2

Table 3 and 4 also presents information on operation wise and different inputs use energy in maize production cluster MC2. In the second cluster also, it was observed that maximum energy was used in land preparation by all three categories of farmers, where large farmers spent high amount of energy 1428 MJ ha^{-1} followed by small (1248 MJ ha^{-1}) and medium farmers (1167 MJ ha^{-1}) the lower. Similarly, like cluster MC1, threshing operation consumed next highest energy among field operations. The maize harvesting occupies fifth position in the order of energy requirement, though the physical numbers seems to be low. This particular operation completely dependent on human labours for cobs removal from standing stalk in both the clusters.

As the source wise energy utilization pattern is concerned, the fertilizer input energy once again recorded higher than other inputs in cluster MC2, ranging from 9133 MJ ha^{-1} in case of medium farmers and lowest being 7297 MJ ha^{-1} with large

Table 3. Operation wise energy input coefficient (MJ ha^{-1}) for maize crop.

Cluster	Farm category	Farm operations					
		Land preparation	Sowing	Intercultural & weeding	Harvesting	Threshing	FYM application
MC1	Large	1919	366	680	561	1028	650
	Medium	1590	505	671	485	922	588
	Small	1179	326	889	536	1204	392
MC2	Large	1428	347	897	569	1101	822
	Medium	1167	514	1115	505	722	786
	Small	1248	267	1038	514	1186	348

Table 4. Source wise energy input coefficient (MJ ha^{-1}) for maize crop.

Cluster	Farm category	Source wise energy						
		Human	Bullock	Mechanical	FYM	Seed	Fertilizers	Chemicals
MC1	Large	1213	186	3805	1720	254	7220	286
	Medium	1080	226	3456	1264	254	10415	277
	Small	1374	625	2527	1235	254	6841	288
MC2	Large	1113	468	3583	2117	290	7297	371
	Medium	1023	610	3176	1853	290	9133	371
	Small	1352	729	2521	970	290	8427	309

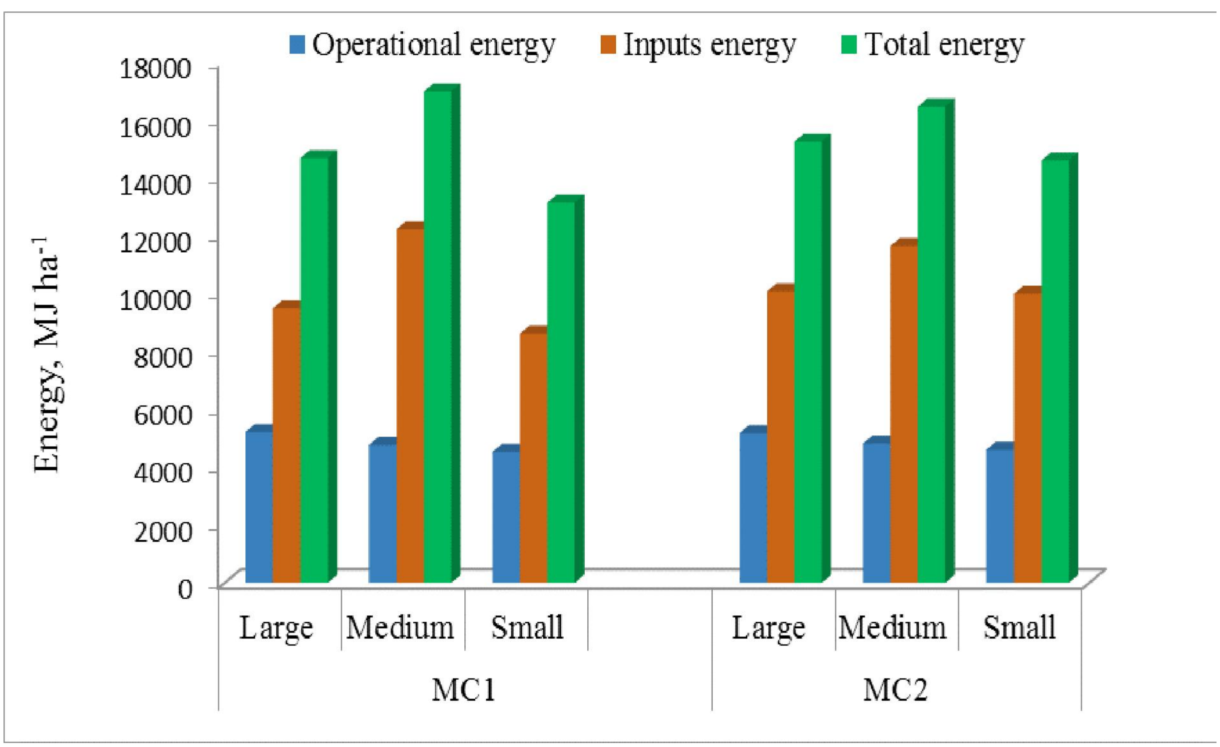

Figure 1 Operational, input and total energy expenditure in maize crop production

Table 5. Energy use efficiency in maize production system.

Parameters	MC1			MC2		
	Large	Medium	Small	Large	Medium	Small
Input energy MJ ha^{-1}	14683	16973	13143	15240	16455	14598
Output energy MJ ha^{-1}	75212	80191	60859	68987	73967	63791
Yield, kg ha^{-1}	5116	5455	4140	4693	5032	4352
Energy ratio	5.12	4.72	4.63	4.53	4.50	4.37
Energy productivity kg MJ^{-1}	0.35	0.32	0.32	0.31	0.31	0.30
Net energy return, MJ ha^{-1}	60529	63218	47716	53747	57512	49193

Table 6. Machinery energy ratio (MER) and mechanization index (MI).

Parameters		Large	Medium	Small
Machine Energy ratio	MC1	0.26	0.20	0.19
	MC2	0.24	0.19	0.17
Mechanization index	MC1	0.36	0.40	0.22
	MC2	0.39	0.37	0.23

farmers. However, this fertilizer input energy constituted highest share 57.7% of the total energy under small category and lowest 47.8% in large category of farmers. The input seed and chemicals accounted the lowest and second lowest input energies respectively among all inputs used operations. In source wise energy utilization aspects, the mechanical sources contributed more in case of large and medium farmers to an extent of 3583 and 3176 MJ ha^{-1} respectively and human energy (1352 MJ ha^{-1}) in case of small category of farmers indicating that, small farmers dependent on their own family labour for majority of operations.

Figure 1 shows operational, inputs and total energies. Highest operational energy has been used by large farmers (5165 MJ ha^{-1}) followed by medium (4809 MJ ha^{-1}) and small farmers (4602 MJ ha^{-1}) in MC2, where input energy was highest in medium category farmers (11647 MJ ha^{-1}) and did not shown much variability between large and small category farmers. The total energy utilized for maize production by large, medium and small category of farmers was 15240, 16455 and 14598 MJ ha^{-1}, respectively.

Comparative of energy utilization in maize crop production

In both the maize growing clusters either the operation wise energy use or inputs energy use showed similar trends in majority of the aspects, except few sparsely distributed deviations. The high energy consumed by land preparation was due to use of tractors with matching implements by medium and large category of farmers. Threshing operation recorded second highest energy after land preparation, which was due to use of maize shellers in irrespective of categories and few of farmers informed that, they used combine harvesters on hired basis, which avoids the threshing operation. Farmers are applying pre-emergence herbicides to control the weed growth and no machinery was found to intercultural operations. The machinery used in maize production was limited to two or three operations, remain which are carried out using animate power sources.

The two clusters showed similar trends of energy utilization for operations, but there was variation in inputs energy, due to difference in amount of inputs application for crop production. The small category farmers were mostly dependent on human labour and draught animals for various operations, due to high cost of machinery. Farm

Table 7. Costs of various operations in maize crop production.

Category of farmer	Particularies	Land preparation	Sowing	Intercultural & weeding	Harvesting	Threshing	FYM application	Seed	FYM	Fertili zers	Chemicals	Total
MAIZE CLUSTER 1												
Large	Cost of operation, Rs/ha	7057	1641	7516	5928	1318	1129	1235	3529	6277	953	36582
	Energy cost, Rs/MJ	3.68	4.49	11.04	10.58	1.28	1.74	4.86	2.05	0.87	3.33	2.49
Medium	Cost of operation, Rs/ha	6351	2170	6563	5028	1665	1012	1235	2646	7980	924	35575
	Energy cost, Rs/MJ	4.00	4.30	9.77	10.36	2.83	1.10	4.86	2.09	0.77	3.33	2.10
Small	Cost of operation, Rs/ha	3740	1551	8433	6404	1733	847	1235	2470	5233	960	32606
	Energy cost, Rs/MJ	3.17	4.76	9.49	11.94	4.42	0.70	4.86	2.00	0.76	3.33	2.48
MAIZE CLUSTER 2												
Large	Cost of operation, Rs/ha	5610	1323	6466	5240	1604	1623	988	4058	4940	1030	32883
	Energy cost, Rs/MJ	3.93	3.82	7.21	9.20	1.46	1.97	3.41	1.92	0.68	2.78	2.16
Medium	Cost of operation, Rs/ha	4517	1588	7287	3970	1152	1611	988	3705	7807	1235	33859
	Energy cost, Rs/MJ	3.87	3.09	6.54	7.86	1.59	2.05	3.41	2.00	0.85	3.33	2.06
Small	Cost of operation, Rs/ha	3881	1711	7392	6616	1314	835	988	1941	6263	1235	32177
	Energy cost, Rs/MJ	3.11	6.41	7.12	12.87	1.11	2.40	3.41	2.00	0.74	4.00	2.20

yard manure application increased with increase in farm size. This is mainly because of large and few medium farmers applied FYM more in the form of poultry litter and had capacity to purchase the same, where as other farmers applying from their own animals.

In these clusters, the energy utilization from mechanical sources was increased with increase in farm size and small farms were also depend some extent on mechanical sources for some operations and fertilizer was the predominant source of input energy in all farms. Inadequate soil moisture regime in rainfed farms demanded higher tillage energy consumption even for low productivity level and nitrogenous and phosphoric fertilizers usage was higher in rainfed farms. Singh (2013) made similar observations in rainfed gram crop production.

Energy use efficiency

Among these two clusters, the highest output energy was found in medium farmers 80191 MJ ha^{-1} of MC1 (Table 5) and similar trend as that of cotton was observed in maize also. Not much variation was found in the energy ratio among the farmers which ranged from 4.37 to 5.12 and negligible variation in input and output ratios. The net energy was highest for medium farmers 63218 MJ ha^{-1} and lowest with small category farmers (47716 MJ ha^{-1}) in MC1.

In all these clusters, the reason for low energy ratio for medium farmers than small and large farmers was due to less output energy, more input energy and fewer yields per unit area. The farmers of these clusters are completely depends on the rainfall and inputs, it indicated that the yield depends upon the climatic characteristics and inputs use pattern for the crop. From the study, the yield was increased with increase in input energy and energy ratio was increased with increase in farm size and the similar observations were reported by Singh (2013) and Shahin *et al.,* (2008).

Machinery energy ratio and mechanization index

The machinery energy ratio (MER) trends observed were more or less similar in case of large and medium farmers in MC1 and MC2 Clusters. On overall, machinery energy ratio values decreased with decrease in land holding size, indicating that, the large and medium farmers are able to use machinery energy in the range of 19 to 26% in MC1 and MC2 clusters. There was not much deviation in mechanization index (MI) of large and medium farmers in clusters MC1 and MC2 whose values ranged from 0.36 to 0.40. Like machinery energy ratio, in MI also there was observable difference between small farmers and other category of farmers. MI was 0.22 and 0.23, respectively in MC1 and MC2.

In these clusters, small farmers were the lowest machinery energy utilized category for crop production. It indicated that, small category of farmers was observed as hindrance for use of machinery in the clusters in comparison to large and medium farmers. In these clusters, no appropriate implement/self-propelled machinery was observed for various field operations except land preparation and transport of FYM, inputs, agricultural produce etc. For all other operations like sowing, intercultural & weeding and harvesting were carried out by human labour, which also affected mechanization index. Mechanization index values indicated that, these clusters were poorly mechanized, which causes stagnation in crop productivity.

Cost of energy

Cost of various operations, inputs and unit cost of energy for large, medium and small categories of farmers of maize clusters were reported in Table 7. It was observed that, the total productions costs ranged from Rs. 36580 to 35600/- per hectare in MC1 and Rs. 32900 to 33850/- per hectare in MC2 and low cost by small farmers Rs. 32200/- and 32600/- per hectare in MC1 and MC2 clusters, respectively. In the field operational activities intercultural and weeding followed by land preparation occupied first and second highest cost constituted activities in the order and fertilizer use among the inputs. Of all the input sources, the highest input cost was spent on fertilizers irrespective of different categories of farmers and its cost ranged from 15 to 23% in maize crop production. The results of this study clearly pointed out that, the operations in which farmers were completely dependent on human energy costs more price per unit energy spent i.e. in harvesting Rs. 7.86 to 12.87 per MJ and intercultural in the range of Rs. 6.54 to 11.04 per MJ. On the other hand, higher range horse power source like tractor used operation of land preparation in the range of Rs. 3.11 to 4.00 per MJ. Among all inputs, less cost per unit energy was required for fertilizers, which ranged from Rs. 0.70 to 0.90 per MJ for maize, because of very handy in nature.

CONCLUSIONS

The analysis of the study reveals that approximately 60% of input energy utilized from the fertilizers for crop production and land preparation consumed maximum energy among operations. The energy utilized for maize crop was highest in medium farmers and lowest in case of small farmers. In these clusters, there is no special machinery was found for field operations except tillage operations and human labour and animals were majorly involving for sowing, intercultural and harvesting operations. Hence there is need to introduce the machinery for human involved operations. The energy utilization from draft animals decreased with increase in farm size.

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