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ENERGY ANALYSIS OF MAIZE PRODUCTION SYSTEMS IN NAGARKURNOOL DISTRICT, TELANGANA, INDIA

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ABSTRACT

This study analyzed energy inputs and outputs in Maize production systems in Nagarkurnool district. Results showed total energy input of 16806.87 MJ/ha with nitrogen fertilizer accounting for 62.37 % and diesel fuel 15.08 % of energy consumption. Maize yield was 7904 kg/ha with energy use efficiency of 0.89, energy productivity of 0.47 kg MJ^{-1}, and net energy deficit of 1789.28 MJ ha^{-1}. The study recommends integrated nutrient management, appropriate mechanization, and transition to renewable energy sources to achieve energy efficiency above 1.0 and establish sustainable Maize production systems.

***Keywords*:** Energy intensiveness, Energy productivity, Net energy

Introduction

Maize is the third most important cereal crop in India after rice and wheat, which accounts for around 10 percent of total food grain production in the country. It is used for three main purposes as human food, feed for poultry and livestock. Maize being the highest yielding cereal crop in the world is of significant importance for countries like India. Efficient use of these energies helps to achieve increase in production and productivity contributes to the profitability and competitiveness for agriculture sustainability, in rural living (Singh *et al.,* 2002). Energy is one of the most important material bases for the economic growth and social development of a country or region. Energy efficiency in crop production directly influences production costs, making it especially crucial for developing nations where traditional farming methods often result in elevated operational expenses. Agriculture accounts for approximately 18.5 percent of India's total energy consumption (Vijayakumar *et al.*, 2023), encompassing both direct energy sources such as human labor, animal power, fuels, and electricity, as well as indirect energy inputs including machinery, fertilizers, and herbicides derived from renewable and non-renewable sources.

The agricultural sector functions as both a substantial energy consumer and producer, necessitating a comprehensive evaluation of production methods and techniques to optimize energy efficiency. Contemporary agriculture faces mounting pressure from population growth, diminishing arable land availability, and increasing demands for improved living standards, resulting in escalated energy usage patterns (Kizilaslan, 2019). The sector's heavy reliance on electricity, fuels, natural gas, and other energy resources, combined with capital-intensive technologies, reflects the complex energy dynamics within modern agricultural systems.

Nagarkurnool district, is characterized by Red & Sandy soils which are not suitable for cultivation of rainfed crops. Farmers cultivate Cotton, Red gram, castor, Maize, Groundnut in these soils during kharif season which require less water for production.The land suitable for agriculture in Nagarkurnool district is 8,61,478 acres .

Materials and Methods

This research was undertaken within the Nagarkurnool District of Telangana State, focusing on farms cultivating Maize during the year 2023. Data for the study were gathered through face-to-face surveys conducted on sixty Maize-producing farms in Nagarkurnool district. The selection of farms for the survey was determined using a simple random sampling method. The formula for this method is outlined as follows

$$n = \frac{N \times s \times s \times t \times t}{(N-1) \times d^2 + s^2 \times t^2}$$

Where

n = the volume of sample,

s = the standard deviation,

t = the t value of the 95% confidence interval (1.96),

N = the number of farms belonging to the sampling frame and

d = desired margin of error or allowable error

Finally energy use efficiency, specific energy, energy productivity and net energy were determined by applying standard equations (Hatirli *et al.*, 2008 and Mohammad *et al.*, 2010).

$$\text{Energy use efficiency} = \frac{(\text{output energy } [\text{Mjha}^{-1}])}{(\text{input energy } [\text{Mjha}^{-1}])} \quad ...(1)$$

$$\text{Specific energy} = \frac{(\text{input energy } [\text{Mjha}^{-1}])}{(\text{Maize yield } [\text{Kgha}^{-1}])} \quad ...(2)$$

$$\text{Energy productivity} = \frac{(\text{Maize yield}[\text{Kg}ha^{-1}])}{(\text{input energy}[\text{MJ}ha^{-1}])} \quad ...(3)$$

$$\text{Net energy} = \text{output energy } (\text{MJha}^{-1}) - \text{input energy } (\text{MJha}^{-1}) \quad ...(4)$$

$$\text{Energy intensiveness} = \frac{\text{Energy input } (\text{MJ}ha^{-1})}{\text{Cost of cultivation } (\text{Rs } ha^{-1})} \quad ...(5)$$

Agrochemical energy ratio was calculated by applying Equations

$$\text{Agrochemical energy ratio} = \frac{\text{Input energy of agrochemicals}(\text{MJ}ha^{-1})}{\text{Total input energy } (MJ\ ha^{-1})} \quad (6)$$

The following equation was used in the calculation of fuel consumption per hectare for each field operation. (Moerschner and Gerowitt, 2000):

$$ED = h \times AFU \times PEU \times RU$$

where:

ED = Specific direct energy use (fuel) for a field operation, MJ ha^{-1}.

h = Specific working hours per run, h ha^{-1}

AFU = Average fuel use per working hour, L h^{-1}

PEU = Specific energy value per litre of fuel, MJ L^{-1}

RU = Runs, number of applications in the considered field operation

Table 1 : Energy equivalents of input and output in Maize production systems.

Equipment /inputs	Unit	Energy equivalents	Reference
A. Inputs			
1. Human Labor	H	1.96	(Ajay *et al.,* 2025 and Yilmaz *et al*., 2005)
2. Machinery	h	62.50	(Ajay *et al.,* 2025 and Esengun *et al.,* 2007)
3. Diesel fuel	L	51.33	(Gaurang Meher Diljun *et al*., 2022 and Seyed *et al.,* 2013)
4. Chemical Fertilizer	Kg		
(a) Nitrogen		66.14	(Gaurang Meher Diljun *et al*., 2022 Erdal *et al*., 2007)
(b) Phosphate (P_2O_5)		12.44	(Ajay *et al.,* 2025 and Rafiee *et al.*, 2010)
5. FYM		0.3	(Seyed *et al.,*2013)
6. Chemical		120	(Erdal *et al.*,2007 and Ozkan *et al.,* 2007)
7.Seed	Kg	14.7	(Ventkat *et al.,* 2024 and Ozkan *et al.,* 2004)
B. Output			
1. Maize	Kg	14.7	(Ventkat *et al.,* 2024 and Mandal *et al*., 2002)

Table 2: Energy equivalents of input and output in Maize production systems in Nagarkurnool district

Quantity	Quantity per unit area (ha)	Total energy equivalents ($MJha^{-1}$)	Percentage of total energy (%)
A. Inputs			
1. Human Lab our (h)	60	117.6	0.70
2. Machinery (h)	30	1881	11.19
3. Diesel fuel(L)	45	2533.95	15.08
4. Chemical Fertilizer(kg)			
(a) Nitrogen	159	10483.19	62.37
(b) Phosphate (P_2O_5)	57.5	715	4.25
(d) FYM	1500	450	2.68
5. Pesticides(kg)	3	555	3.30

6. Seed(kg)	19.76	71.136	0.42
Total energy input(MJ)		16806.87	100
B. Output			
1. Maize	7904	15017.6	100
Total energy output(MJ)		15017.6	100

Results and Discussion

The study unveiled that the average production cost per hectare of Maize crop amounted to Rs. 44,500/. Table 2 presents a breakdown of inputs utilized and outputs in Maize production systems, along with their energy equivalents and percentages of the total energy input. Results indicated that the total energy input in Maize production systems was 16806.87 MJ/ha. The, Nitrogen fertilizer employed in Maize production systems accounted for the highest share at 62.37% (see Fig. 1). Diesel fuel energy ranked second with 15.08 % contribution to the total energy input. Seed, on the other hand, represented the smallest share of the total energy input at 0.42 %. Additionally, the study observed a Maize grain yield of 7904 kg/ha, equating to a total energy equivalent of 15017.6 MJ/ha. Table 3 presents the energy indicators for Maize production systems.

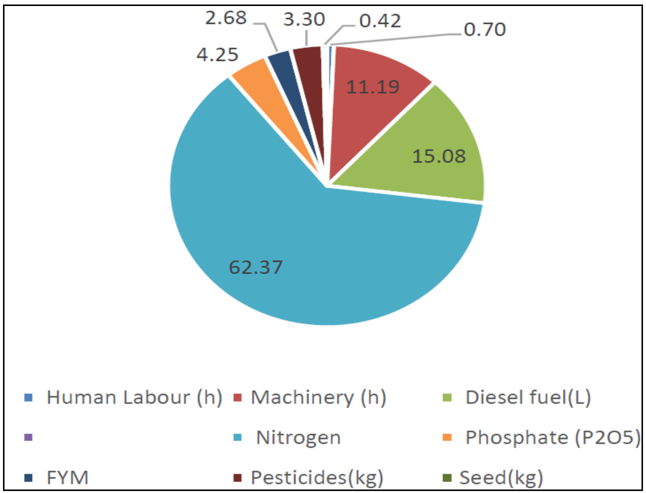

Fig. 1 : Percentage of energy inputs in Maize production system

Table 3 : Indicators of energy use in Maize production systems

Indicators	Unit	Quantity
Inputs energy	$MJha^{-1}$	16806.88
Output energy	$MJha^{-1}$	15017.6
Grain yield	$Kgha^{-1}$	7904
Energy use efficiency		0.89
Specific energy	$MJkg^{-1}$	2.12
Energy productivity	$KgMJ^{-1}$	0.47
Agrochemical Energy Ratio	%	0.69
Net energy	$MJha^{-1}$	-1789.28
Energy intensiveness	$MJRs^{-1}$	0.38

Notably, from table 3 the energy efficiency, represented by the output-input ratio, was 0.89. If energy use efficiency is above 1, the production system generates energy The lower energy use efficiency observed in Maize production systems can be attributed to the elevated energy inputs, particularly the consumption of Nitrogen fertilizer.

From the study it is observed that in Maize production systems, the energy productivity, denoting the grain yield per unit of energy input, was 0.47 kg MJ^{-1}, while the specific energy, indicating the input energy required per unit of grain yield, was 2.12 MJ kg^{-1}. A lower value of specific energy is desirable as it indicates higher energy efficiency in production. Put differently, for every MJ of input energy, 0.47 kg of Maize grain was produced, or conversely, 2.12 MJ of energy was expended to yield one kilogram of grain. Furthermore, the system's net energy, is calculated as the output minus input, which is amounted to 1789.28 MJ ha^{-1}. The net energy is low because of less yield in the study area. A high agrochemical ratio implies a large agrochemical footprint and negative environmental effects such as nitrogen leaching, air and water pollution and GHG emissions (Pishgar-Komleh *et al.,* 2013). In this study, the agrochemical energy ratio was 0.69% of the input energy, which is desirable. Additionally, the energy intensiveness, indicating the amount of energy produced per rupee spent, was computed at 0.38 MJ Rs^{-1}, signifying that for each rupee invested, 0.38 MJ of energy could be generated. The energy consumption of different implements/machinery is shown in table 4 From table it can be concluded that cultivator consumed less fuel energy. Combine harvester consumed highest fuel energy.

Table 4 : Fuel energy of implements/machinery

Machine/Implement	Specific direct energy use (fuel) for a field MJ per ha
Disc plough	760.19
Cultivator	295.63
Rotavator	703.88
Combine harvester	2083.47

Conclusion

This study of maize production in Nagarkurnool district reveals suboptimal energy performance with an energy use efficiency of 0.89, negative net energy of -1789.28 MJ ha^{-1}, and energy productivity of 0.47 kg MJ^{-1}. The system currently depends heavily on fossil fuels with minimal renewable energy utilization. Achieving sustainable maize production requires strategic interventions including integrated nutrient management, appropriate mechanization, crop diversification, and energy-conscious farming practices to achieve energy use efficiency above 1.0 with positive net energy. Transitioning toward renewable energy sources and optimizing input efficiency will enhance economic viability while supporting sustainable agricultural intensification in the region.

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