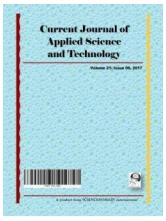

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Assessment of Energy Use Pattern in Different Operations from Various Sources for Cultivation of Sugarcane in the District of Narsinghpur, Madhya Pradesh, India

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AK and AP designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author AKS guided the analyses of the study. Author AKS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The production and productivity are directly related use in unit operation of agricultural production. The variation in yield of crop occurs in Narsinghpur District of Madhya Pradesh due to in wide variation in energy inputs, agro-climatic conditions and resources used. Keeping this in view, the present study deals with energetics of sugarcane in the district of Narsinghpur, Madhya Pradesh, for getting higher energy input. In the selected area, all the physical inputs in the form of direct and indirect sources and output in the form yield of grain and by-product are converted into common units of energy (MJ) per unit area (ha). The trend of use of direct energy (human,

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mechanical, electrical etc. and indirect energy seed, fertilizer, chemical etc. was studied for performing different field operations from tillage to transport operations). The most energy consuming operation was irrigation, it consumed about 79056.13 MJ/ha and it consumed 51% of total energy. Among physical input the fertilizer contributed maximum energy and its maximum energy value was 61200 MJ/ha where as some farmers were found using less than 23485.5 MJ/ha of the total energy input.

Keywords: Sugarcane; Narsinghpur; energy; energy sources; production; productivity; energy input.

1. INTRODUCTION

The state of Madhya Pradesh is situated in the heart of India between latitude 21^{o} to 26^{o} N and longitude 74^{o} and 81^{-o} E. The mean temperature varies from less than 10^{o} Celsius to more than 46^{o} Celsius during winter and summer respectively. The annual rainfall varies from below 800 mm in the western part of the state, to be above 1600 mm in the eastern region [1].

The estimated population of the state is 79.9-millions with a density of 236 persons/km^2. There is a variety of soil type ranging from lateritic through mixed red and black-to-black soils of different depths. The net-cropped area of the state is 19.89 million ha, of which only 5.6-million-ha land is irrigated. The cropping intensity of the state is 132%, which is below national average of 135% [2,3].

Energy plays a major role in national development process and in providing major vital service that improve human condition – fuel for cooking, light for living, and motive power for transport and electricity for modern communication. In agricultural sector energy is used in every form of inputs – human and animal power, seed, fertilizer, agro chemical for plant protection, machinery use for various operations being operated by electricity and fossil fuels, biomass and coal for living, and is directly linked with technological process [4].

Sugarcane *(Saccharum officinarum L.)* an old energy source for human beings and more recently, a replacement of fossil fuel for motor vehicles was first grown in South East Asia. It was introduced to Egypt around 647 (Anno Domini) and about one century later to Spain (755 A.D.) [5]. Sugarcane is a major crop grown in both subtropical and tropical belts of the world for production of sugar. The sucrose synthesised in the leaves is transported to the culm or cane for storage. In general, the vegetative growth rate of sugarcane slows down and sucrose content in cane increases approximately by 180 days after planting. Genotype, plant maturity and environment play a significant role in the rate of sucrose accumulation [3,6].

Sugarcane production is expected to be lower at 309 million tonnes (2016-17), compared to 348 million tonnes the year before. Production of cotton is set to increase from 30 million bales last year to 32.5 million bales in 2016-17 (one bale equals 170 kg). However, this is lower than the past record of 35.9 million bales produced in 2013-14 [7].

In India, the total area under sugarcane cultivation was reported to be about 4.918 million hectares. The country produced about 341.425 million tonnes of cane at a national average of about 69.42 t/ha in the year of 2015-16 [8]. India occupies the second rank in production of sugarcane in the world and contributes nearly 20.4% area and 18.60% production. The major sugarcane growing states are Uttar Pradesh, Maharashtra, Tamil Nadu, Karnataka and Madhya Pradesh etc. The area and production of sugarcane in Madhya Pradesh is about 0.73 lac hectare and 31.73 lac tonnes [7].

At global level, total 121 countries are producing the sugarcane. Out of them some of important countries like Brazil, India, China, Thailand, Pakistan, Mexico, Cuba, Columbia, Australia, USA, Philippines, South Africa, Argentina, Myanmar and Bangladesh are producing approximately 80% of total world production of sugarcane [8]. Worldwide, sugarcane occupies an area of 20.42 million hectares with a total production of 1333 million metric tonnes. Sugarcane area and productivity differ widely from country to country. Brazil has the highest area i.e. 5.343 million ha, while Australia has the highest productivity i.e. 85.1 t/ha [5].

The energy consumption in production of sugarcane is highest as compared to many other crops such as potato, maize, wheat, rice, sorghum etc. Sugarcane is labour intensive requiring about 3300 man-hrs per hectare for

Table 1. List of sugarcane varieties used for the study on sugarcane energy used pattern

Tropical early	Tropical mid- late	Subtropical early	Subtropical mid-late
Co 449	Co 419	BO 43	BO 34
Co 527	Co 740	BO 99	BO 91
Co 775	Co 785	Co 395	Co 312
Co 997	Co 62175	CoJ 64	Co 453
Co 8231	Co 6806	CoP 2	Co 1148
Co 6415	Co 6304	CoP 1	Co 975

different operations. Considering the present trend of availability of labour for sugarcane production, it has been experienced that the use of modern machinery is inevitable. Use of machinery helps in labour saving and timelines of operations, reduces drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources [9,4].

The energy consumption for seed bed preparation and transplanting consumed 66-72% of total energy input in paddy crop production whereas irrigation, seed bed preparation and threshing consumed 70-88% of total energy in wheat crop. Energy output - input ratio was highest for sugarcanes crop followed by maize, paddy and wheat [10]. Energy parameters for irrigation treatment in Indian agriculture and reported that irrigation consumed up to 60% of the total energy requirements for crop production under different methods of irrigation. Energy requirements per unit area were highest for sugarcane, cotton, paddy and wheat crops and lowest for maize. Fossil energy is used to a great extent by most of the crops [11].

The objective of this study is to calculate the direct and in-direct energy used in various operations for cultivation of sugarcane crop.

2. MATERIALS AND METHODS

The study has been carried to find out the energy requirement for sugarcane crop in the selected area of study Narsinghpur, Madhya Pradesh. The study deals with the selection of villages and farmers, categorization of farmers/farms and the data were collected from farmers through face to face questionnaire/survey, analysis and optimization of energy inputs to attain the objectives of the study. There were 10 farmers selected as randomly from the study area of Nrsinghpur. The information collected from the farmers was transformed into computer data sheet as per requirement of energy calculation and results were obtained from energy FORTRAN-77 computer software programmes. The analysis carried out in MS Excel and energy assessment was prepared for sugarcane crop. The statistical analysis was performed with SPSS 7.5 computer software programme using linear regression model. The outlier points were removed. After removal of outlier points the energy use pattern and assessment of energy was prepared for sugarcane crop in the Selected area of study Narsinghpur, Madhya Pradesh. The calculation of energy has been done with following objectives.

1- Selection of villages.
2- Selection of farmers.
3- Collection of data.
4- Classification of energy.
5- Calculation of energy-

   5.1- Direct sources of energy: Human, Animal, Diesel and Electricity etc.
   5.2- Indirect sources of energy: Seed, Fertilizer, Chemical and Machinery etc.

2.1 Energy from Direct Sources

$$DE = HLH \times 1.96 + BPH \times 10.01 + FC \times 56.31 + EC \times 11.93 \quad (1)$$

Where,

DE = Direct Energy, (MJ)
HLH = Human labour hours use
BP = Bullock pair hours used, (h/ha)
FC = Fuel consumption, (l/ha)
EC = Electricity consumption, (kWh/ha).

2.2 Energy from Indirect Sources

$$IE = (C \times WM \times HUM \times OA) + FYM \times 0.3\ MJ/kg + S \times 14.7\ MJ/kg + Ch \times 120\ MJ/l + \text{fertilizer } (N \times 60.0 + P \times 11.1 + K \times 6.7) \quad (2)$$

Where,

IE = indirect energy input from machinery, (MJ)
C = energy coefficient, (MJ/kg)
WM = weight of machinery used per hour, (kg/h)

HUM = hours of use of machinery per hectare, (h/ha)
OA = operational area, (ha)
FYM = Farm Yard Manure, (kg/ha)
S = seed, (kg/ha)
Ch = chemicals, (l/ha)
N = nitrogen (kg)
P = phosphorus (kg)
K = potash (kg).

2.3 Total Energy

$$TE = DE + IE \quad (3)$$

Where,
DE = Direct Energy, MJ
IE = Indirect Energy, MJ

2.4 Mechanical Power

Fuel consumption of tractor and diesel/petrol engines used for different farm operations wise calculated by the following equation:

$$F = \frac{LCF \times RHP \times SFC}{1000} \quad (4)$$

Where,

F = Fuel consumption (l/h)
LCF = Load coefficient factor for different farm operations (LCF=0.6)
RHP = Rated horsepower of power source in hp or kW
SFC= Specific fuel consumption (l/hph) or (l/kWh).

3. RESULTS AND DISCUSSION

This study deals with the results obtained from the field studies and its interpretation of the sugarcane cultivation in the Narsinghpur district of Madhya Pradesh. This includes the demographic details. Under this study the following aspects were studied such as, energy use pattern through direct and indirect sources, farm machinery and power availability, optimization of energy use and prediction of energy requirement from different sources for required yield level of sugarcane for selected area, Narsinghpur district of Madhya Pradesh.

3.1 Operation Wise and Source Wise Energy Use Pattern for Cultivation of Sugarcane

Operation wise and source wise energy use pattern for cultivation of sugarcane in the selected area. The irrigation is the main aspect it has found through survey that for the requirement of the total input energy (MJ/ha) cultivation of sugarcane.

3.2 Energy Input (MJ/ha)

In this study heavy dependency was put on irrigation. However, in the survey, irrigation is till the major component to energy but there has been significant improvement in seed bed preparation and sowing resulting in the change in energy used pattern. In order to distinguished between the energy use patterns used by selected area surveys. The details of energy requirement for different operations under different categories of farmers.

3.3 Operation Wise Energy Use Pattern

The operation wise energy requirement for sugarcane cultivation varied between 112935.73 MJ/ha to 193041.69 MJ/ha with mean value of 148130.6 MJ/ha. Fig. 1 shows that irrigation required maximum energy (53.36%) followed by sowing (26.06%), fertilizer application (8.05%), transportation (6.16%), seed bed preparation (3.11%), interculture (1.81%), harvesting (0.73%), FYM application (0.38%), plant protection (0.18%), ratooning (0.11%) respectively the maximum operation wise energy was consumed by medium land holding farmers and it was lowest by small farms. The trend was not normal and it may be due to absence of winter rain for which farmers required maximum energy per unit area for irrigation due to smaller farm area and also hiring of water from neighbour.

3.4 Source Wise Energy Use Pattern

The main source of energy for production can be direct or indirect in nature the direct sources are those that release energy directly to the system as human and electrical energy etc. These are the most energy supplying sources. Among the indirect sources like seed, fertilizer and chemical supply energy to the system through conversion process. These are useful for plant growth, but work done by the sources can be seen only after completion of conversion process. Machinery is also indirect source as they perform their work, but they are powered by direct sources like diesel and electricity etc. Total energy includes both direct and indirect sources.

Fig. 2 conducted that the highest energy contributing source was electricity. Electricity provided maximum energy i.e. 100122.5 MJ/ha. Irrigation consumed maximum energy but fertilizer used was minimum. This means that there exists no direct relation between irrigation and fertilizer used. The fertilizer contributed only 8.0% of total energy. The survey revealed that, the use of manure was not sufficient in the selected area of Narsinghpur. Total average energy use by all sources were calculated and found to be 148130.6 MJ/ha and minimum of 104908.45 MJ/ha. In most years' energy used varied between 104908.45 to 148130.6 MJ/ha.

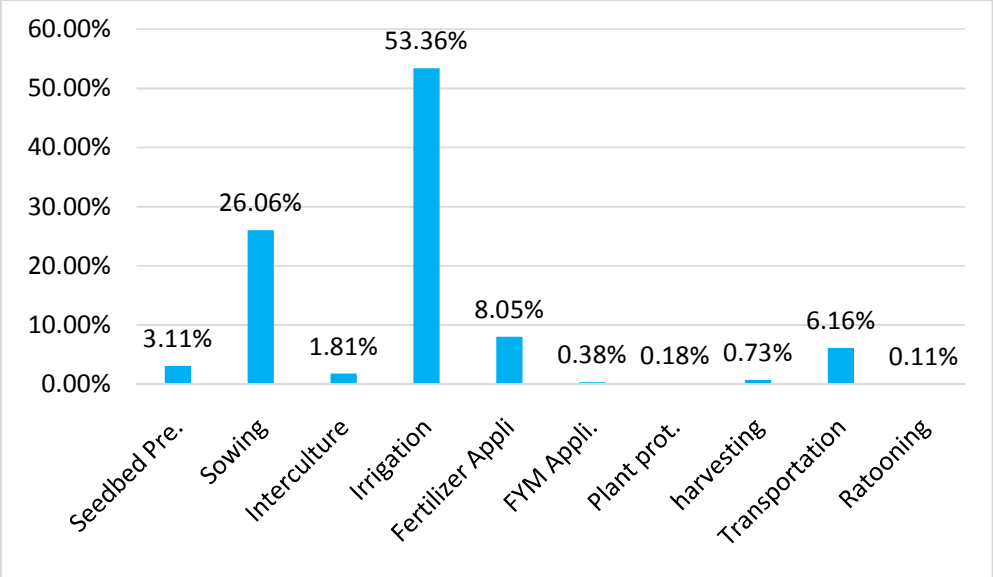

Fig. 1. Operation wise energy use pattern for sugarcane crop

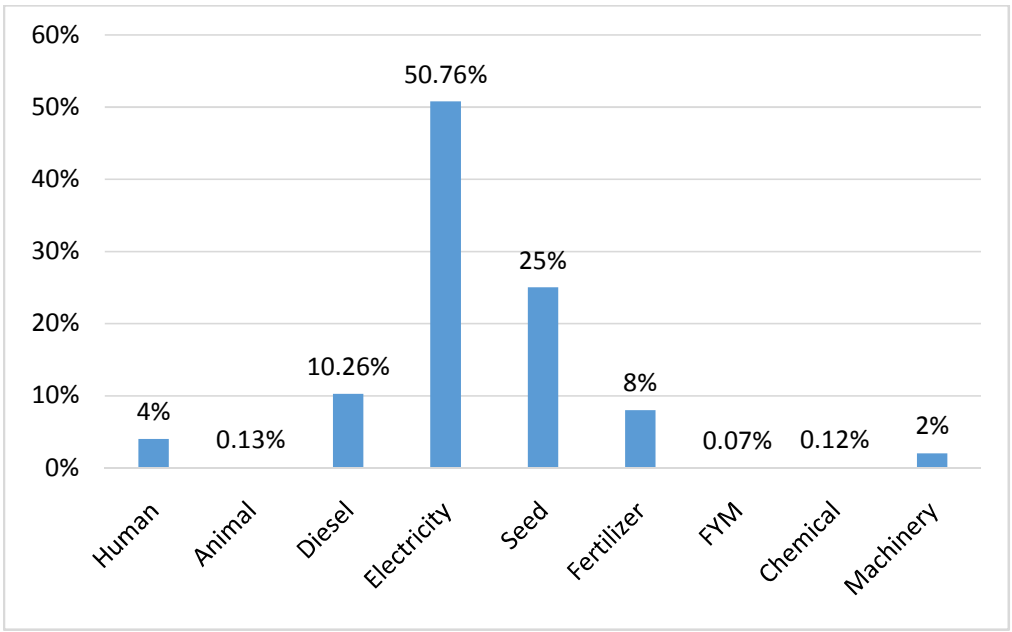

Fig. 2. Source wise energy use pattern for sugarcane crop

Table 2. Operation wise or source wise energy (MJ/ha) used in Narsinghpur district of Madhya Pradesh

Item	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10
Operation wise energy (MJ/ha)										
Seedbed Preparation	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.10	3571.09
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105
Interculture	4882.19	2987.39	1603.84	2405.76	2963.23	3241.96	872.45	3241.96	2623.87	2127.03
Irrigation	103673.9	87390.31	82016.31	82016.31	76157.36	85446.31	70299.71	86394.8	58583.11	58583.11
Fertilizer Application	20541	8494	10094	9865	10211	20541	11665	12047	7899	7899
FYM Application	2071.03	-	-	1005.43	-	1426.46	-	1186.79	-	-
Plant protection	614.48	-	309.38	260.98	314.76	512.8	230.9	512.8	-	-
Harvesting	1176	1176	1097	980	1176	1176	980	1176	980	980
Transportation	10405.15	10405.15	8344.95	5523.50	4185.58	4185.58	7432.17	22916.61	12386.94	5523.50
Ratooning	196	196	156.80	147	156.80	156.80	196	156.80	156	147
Total	193041.69	153620.93	146195.75	143517.7	140119.26	163575	133713.72	173768	120818	112935.73
Source wise energy (MJ/ha)										
Human	6096.4	4469.78	5147.83	5869.22	5584.53	9927.89	5752.6	5599.72	4936.26	4807.88
Animal	-	404	-	-	-	-	606	-	151	-
Diesel	20395.48	17141.89	14540.36	10703.4	10443.25	13072.36	9960.11	29210.81	16538.24	10108.77
Electricity	100122.5	84430.8	77873	77873	72310	77873	66748.3	83435.4	55623.6	55623.6
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125
Fertilizer	20400	8415	10015	9818	10123	20400	11577	11959	7828.5	7828.5
FYM	600	-	-	300	-	450	-	450	-	-
Chemical	538	-	150	180	303	360	150	360	-	-
Machinery	2491.45	2321.96	2032.95	1674.14	1605.49	1741.88	1819.91	3003.36	2615.79	1442.05
Total	193041.69	153620.93	146195.64	143517.7	140119.26	163575.11	133713.72	173768	120818	112935.73
Grand total	386083.38	307241.86	292391.39	287035.4	280238.52	327150.11	267427.44	347536	241636	225871.46
Yield q/ha	1375	950	750	750	875	1125	750	1000	625	750
Energy ratio	1.88	1.63	1.35	1.38	1.65	1.82	1.48	1.52	1.37	1.75
Specific energy MJ/kg	2.80	3.23	3.89	3.82	3.20	2.90	3.56	3.47	3.86	3.01
Productivity ratio	0.35	0.30	0.25	0.26	0.31	0.34	0.28	0.28	0.25	0.33

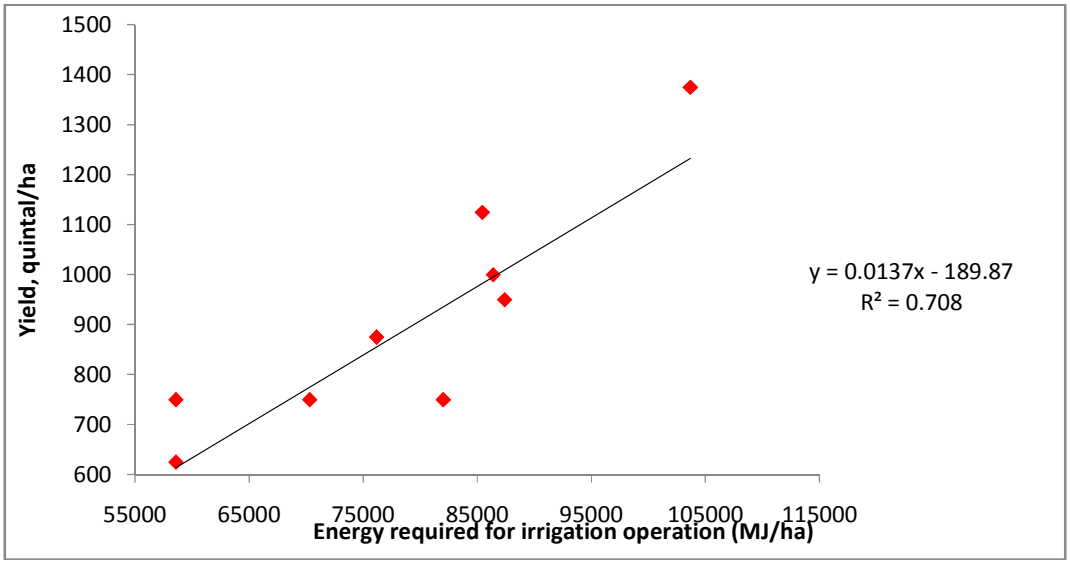

Fig. 3. Effect of irrigation on the yield of sugarcane

Seed is another energy contributing source in rabi season and sugarcane seed contributed between 33125 to 42400 MJ/ha. It contributed approximately 25% of the total energy. The contribution of diesel was about 10.26% of total. Initially during before nineteenth when bullock farming was common the contribution of diesel was only 2023 MJ/ha. Later years the use of diesel increased to a greater extent. The maximum contribution of diesel was observed during the year i.e 20395.48 MJ/ha, in the present study.

Use of animal was inversely proportional to use of diesel. During the survey it was revealed that, animal contributed 1161 MJ/ha. Human contributed 58192.10 MJ/ha to 48362.6 MJ/ha. As the use of bullocks reduced the use of human labour also reduced. This does not mean that utility of human being reduced, only it can be said that now it is used for more quality work than for laborious work. Its contribution was 3.92%. Overall it contributed 4.37% of the total energy.

Use of machinery varied between 17611.1 MJ/ha to 20748.9 MJ/ha. As use of tractor drawn heavier implements increased the energy contribution by machinery increased. Total energy contribution by various sources varied between 20748.9 MJ/ha to 17611.10 MJ/ha. The variation occurs mainly due to variation in energy contribution by electricity and fertilizer. The per cent change in energy supplies for sugarcane production through different sources.

The total energy input from different sources was 148130.6 MJ/ha. The variation among the total energy input on the different farmers was 104741.88 to 148130.6 MJ/ha. The total energy consumed by large farmers (148130.6 MJ/ha) was found to be higher than that of small (104741.88 MJ/ha). Electricity and diesel contributed 50.76% and 10.26% of total energy. Electricity operation was used for irrigation whereas diesel was used mainly for tillage or transportation. The energy inflow through electricity was 75191.32 MJ/ha followed by diesel 15211.46 MJ/ha. Among the indirect source of energy, the fertilizers supplied maximum (20400 MJ/ha). The policy on electric traffic for agricultural use has been varying. The past trend being provision of free electricity. Such policy defines to a great extent the pattern of use of electricity.

3.5 Effect of Irrigation on the Yield of Sugarcane

The relationship between yield and irrigation energy is also considered. The effect of irrigation for the selected area Narsinghpur can be detailed as below:

3.5.1 Narsinghpur

The crop sugarcane was grown by the farmers after paddy crop. It is also cultivated by the farmers had fellow land during kharif. In Narsinghpur “Havelli” system was used in which rainfall water is stored during rainy season. In

this system land used to be sloppy at the centre like ponds so, water do not loss by runoff. In the Narsinghpur most of the farmers possessed tube well and the farmers, who did not have water source, hired the irrigation water from neighbouring farms. The relation between irrigation energy and yield is shown in Fig. 3 for the selected area Narsinghpur.

By considering irrigation energy as predictor and yield as response they can be co-related with the following equation.

$$y = 0.0137x - 189.87 \quad (5)$$

$$(R^2 = 0.7086)$$

Higher irrigation energy means either higher number of irrigation or more hours of water supply in each irrigation. In these years the water reached to the plants by free flow. Most of the farms had slope for movement of the water. The variation in irrigation energy was too much and there were few farmers who did not apply any irrigation and totally dependent on winter or summer rains. The results revealed that un-irrigated fields average yield was only 625 q/ha which was less than half of the average yield in the selected area of Narsinghpur. The choice of sugarcane crop by the farmers has been based on availability of assured irrigation. The farmers without assured irrigation did not inclined to select sugarcane crop rather they selected other crop like; wheat, black gram, green gram etc. These relations were found stronger when the data of farmer's survey of the study was considered.

4. CONCLUSION

The use of direct energy was comparatively very high as compared to indirect energy in early surveys. The direct-indirect energy ratio was 3.62 from the total energy input. Better management of physical inputs, timeliness of operations, saving in unnecessary tillage, quality seed, use of superior chemicals for plant protection, uniformity of water use resulted into a great positive effect which can be seen by output-input energy ratio and yield for the production of sugarcane in Narsinghpur. The energy productivity ranged from 0.25 kg/MJ to 0.35 kg/MJ, for sugarcane crop. Irrigation was found to be the highest energy consuming operation across selected area under study. Specifically, it consumed about 79056.13 MJ/ha and 237168.39 MJ/ha. Among various operations, irrigation, consumed maximum energy ranged between 51% to 63% while considering the reference of the survey.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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