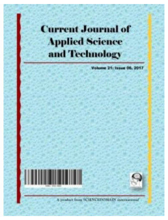

Current Journal of Applied Science and Technology

28(6): 1-12, 2018; Article no.CJAST.43428
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Change in Scenario of Sugarcane Production in Narsinghpur, India, during 2013 to 2016

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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. Authors AKS, MKP and NKK guided the analyses of the study. Authors AKS and NKK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/43428
Editor(s):
(1) Sait Engindeniz, Professor, Department of Agricultural Economics, Faculty of Agriculture, Ege University, Turkey.
Reviewers:
(1) Olutosin A. Otekunrin, Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria.
(2) Preeya Puangsomlee Wangsomnuk, Khon Kaen University, Thailand.
(3) Eririogu Henry, Federal University of Technology, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/25903

Original Research Article

Received 19th May 2018
Accepted 31st July 2018
Published 17th August 2018

ABSTRACT

The aim of this study was to determine the energy inputs and use a pattern per hectare for change in the scenario of sugarcane production in Narsinghpur, India, during the three year cropping pattern from 2013 to 2016.

The data were collected from farmers with the help of pre tested questionnaire or direct interview method. In the selected area of study, all the physical inputs in the form of direct and indirect sources and outputs in the form of yield and by-products are converted into common units of energy (MJ) per unit area (ha).

The result was found during the study, the most energy consuming operation was irrigation, it required maximum energy (66.22%) 311021.7 MJ/ha followed by sowing (10.78%) 43497.6 MJ/ha,

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fertilizer application (9.99%) 61623 MJ/ha, transportation (7.65%) 31215.45 MJ/ha, intercultural (2.25%) 14646.57 MJ/ha, seedbed preparation (1.28%) 5984.33 MJ/ha, harvesting (0.91%) 3528 MJ/ha, FYM application (0.47%) 6213.09 MJ/ha, plant protection (0.23%) 1843.44 MJ/ha and ratooning (0.13%) 588 MJ/ha in the cultivation of sugarcane from seedbed preparation to ratooning during 2013 to 2016.

Keywords: Sugarcane; scenario change in sugarcane; energy use pattern; energy analysis; Narsinghpur.

1. INTRODUCTION

Energy is the key for development and judgment of developed and developing countries can be made on the basis of per capita energy consumption. Energy consumption in developed countries is very high as compared to developing countries [1]. It is the need to use energy carefully and plug all wasteful uses of energy in agricultural production system [2]. The introduction of high yielding varieties of crops in the early seventies and progressive expansion of area under these varieties created an increasing demand for energy inputs [3]. However, worldwide reports from intensive agricultural production system have indicated that there is an increasing trend in production with an increase in energy use up to certain limit [4]. But after that law of diminishing return starts operating at a certain level of energy inputs reducing the energy efficiency of production [2].

Oil energy is being used not only in the form of fuel for operating machinery in production agriculture but also indirectly in the production of a variety of materials, especially fertilizers [5]. Also use of high yielding varieties demanding high energy for irrigation, fertilizer and pesticide have led to negative environmental effects which ultimately would require additional energy and economic inputs for regeneration. The most distributing feature is that agriculture has been proved to be unsustainable in the long run giving lesser yield with time for the same level of inputs due to a variety of reasons including the development of soil salinity, soil erosion etc [6].

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy [7,8]. Energy use in agriculture has developed in response to increasing populations, a limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor intensive practices, or both [9]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production since it provides financial savings, fossil resources preservation and air pollution reduction [10].

The above scenario of the early seventies spurred a number of research groups to consider the energy and environment issues in depth in the light of achieving sustainable agriculture. There is a wide variation in the energy consumption pattern with crops, geo-climatic variations and cultural practices. Due to this, studies have to be location specific [11].

Sugarcane belongs to the bamboo family of plants and is indigenous to India. It is the main source of sugar, gur and khandsari. About two-thirds of the total sugarcane produced in India is consumed for making gur and khandsari and only one-third of it goes to sugar factories. It also provides the raw material for manufacturing alcohol [12].

Sugarcane is known to be much more efficient in photosynthetic efficiency than other crops because more solar energy is harvested as a crop. Sugarcane occupies a very prominent position on the agricultural map of India covering large areas in subtropics and tropics. On an average, white sugar production accounts for nearly 60 per cent of the total cane produced in the country The area under sugarcane is hovering around 4.4 million hectares and with an average productivity of 68 tonnes/ha [12]. Sugarcane is known to be much more efficient in photosynthetic efficiency than other crops because more solar energy is harvested as a crop.

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 in 2015-2016 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 [6]. 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 [11]. India occupies the second rank in the 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 lakh hectare and 31.73 lakh tonnes [6,11].

The purpose of this study was to determine the energy inputs and use a pattern per hectare for change in the scenario of sugarcane production in Narsinghpur, India, from 2013 to 2016.

2. MATERIALS AND METHODS

The study was carried out to investigate or examine energy requirement for sugarcane in the selected area of study Narsinghpur, Madhya Pradesh, India. The study dealt with the selection of villages and farmers, categorization of farmers/farms and data were collected on the pre-tested proforma by a combination of interview method and by taking an actual measurement. The physical data were converted to a common denominator by multiplying them with the appropriate energy equivalent coefficient. Analysis of energy inputs to attain the objective of the study. The information included the quantity of energy inputs in the form of seed, fertilizers, chemicals, irrigation, human, animal, and prime movers etc. The output in the form of yield and by-products were determined from all the farmers of the villages, further cropping pattern and hectare age under crop from farm to farm also were recorded. The operation time, fuel consumption, crop yield, and other parameters needed to be evaluated in a standardized manner in the study area of Nrsinghpur (M.P.).

2.1 Calculation of Energy

To ensure that the maximization of yield per hectare basis gives equal weight to each of the activities. The number of decision variables (or activates) included in the solutions is less than or equal to the number of constraints in the model. Once the solution for X_1's, say X^*_i's is obtained, the value of the objective function (*i.e.* the value of the maximum yield) and usage of various energy sources are obtained using the expressions.

$$\text{Yield} = \sum_{i=1}^{n} YiXi* \quad (1)$$

$$\text{Human energy} = \sum_{i=1}^{n} hi\,X^*i \quad (2)$$

$$\text{Animal energy} = \sum_{i=1}^{n} ani\,X^*i \quad (3)$$

$$\text{Diesel Energy} = \sum_{i=1}^{n} di\,X^*i \quad (4)$$

$$\text{Electrical energy} = \sum_{i=1}^{n} ei\,X^*i \quad (5)$$

$$\text{Seed energy} = \sum_{i=1}^{n} si\,X^*i \quad (6)$$

$$\text{Fertilizer energy} = \sum_{i=1}^{n} fi\,X^*i \quad (7)$$

$$\text{Mechanical energy} = \sum_{i=1}^{n} mi\,X^*i \quad (8)$$

$$\text{Chemical energy} = \sum_{i=1}^{n} ci\,X^*i \quad (9)$$

$$\text{Total energy} = \sum_{i=1}^{n} ti\,X^*i \quad (10)$$

Since $t_i = h_i + an + d_i + e_i + f_i + s_i + m_i + c_i$, the sum of the energy usage from different sources shall be equal to the energy usage [16].

The values of the decision variables were similarly used for calculating the energy used in each operation. The choice of the constraints in the LP model can be need-based. It can be

- All sources of energy being considering
- All sources of energy and all active operations
- All active operations and energy sources not contributing to any operation

The constraints may be appropriately formed in the model.

2.2 Agricultural Scenario of Madhya Pradesh

Madhya Pradesh is located in the central part of India, extending from 17°48' to 26° 52' north latitudes and from 74°02' to 84°25' east longitudes. Its rocks are among the oldest in the world, dating Back to Pre-Cambrian and Paleozoic days. Geologically the central India plateau is part of the Gondwana plate and through it running from west to east, is the only true rift-valleys of the Tapti and Narmada rivers [2]. The Vindhyachal range of mountains meets the Satpura hills in Madhya Pradesh. The State is surrounded by many states like; Uttar Pradesh, Chhattisgarh, Andhra Pradesh, Maharashtra, Gujarat and Rajasthan [13].

Among the rural people of Madhya Pradesh are the tribal Gonds, Kols, Bhils, Muris and Oraons. Some of the tribes are still out of touch with the social and cultural world around them and believe in their traditional cultural practice [2].

The state of Madhya Pradesh occupying 30.74 Mha (44 Mha before the separation of Chhattisgarh) geographical area is the largest state in the country with 45 districts and 313 development blocks. In India, the total area under sugarcane cultivation was reported to be about 49.18 lakh hectare [14]. The country produced about 3414.25 lakh tonnes of cane at a national average of about 69.42 tonnes/ha in the year of 2015-16. India occupies the second rank in the production of sugarcane in the world and contributes nearly 20.4% area and 18.60% production [15].

3. RESULTS AND DISCUSSION

This section deals with the results obtained from the field studies and its interpretation of the sugarcane production in the Narsinghpur, India. Under this study the following aspects were studied such as, energy use pattern through direct and indirect sources, changing energy use scenario in different rounds of survey, effect of operation wise energy requirement, source wise energy utilization, determination of energy coefficients, development of equations on the basis of actual energy use at the farmers field , optimization of energy use and prediction of energy requirement from different sources for required yield level of sugarcane for selected area, Narsinghpur, Madhya Pradesh, India.

3.1 Operation Wise and Source Wise Energy Use Pattern (MJ/ha) in Narsinghpur during 2013-16

Operation wise and source wise energy use pattern for the cultivation of sugarcane in the selected area of Narsinghpur from 2013 to 2016. The detail of operation wise and source wise energy use pattern from 2013 to 2016 are shown in Table 3.1.

3.1.1 Total energy input (MJ/ha) in Narsinghpur from 2013 to 2016

In the study from 2013 to 2016 heavy dependency was put on irrigation. However, in the survey, irrigation is still the major component of energy but there has been a significant improvement in seedbed preparation and sowing resulting in the change in energy use pattern. In order to distinguished between the energy use patterns used by selected area of study. Table 3.1 gives the details of energy requirement for different operations under different categories of farmers for the year from 2013 to 2016.

3.1.2 Operation wise energy use pattern

The operation wise energy requirement varied between 263455.01 MJ/ha to 480161.18 MJ/ha with a mean value of 357949.20 MJ/ha. Fig. 3.1 shows that irrigation required maximum energy (66.22%) followed by sowing (10.78%), fertilizer application (9.99%), transportation (7.65%), intercultural (2.25%), seedbed preparation (1.28%), harvesting (0.91%), FYM application (0.47%), plant protection (0.23%), ratooning (0.13%). 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 the 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 a neighbour.

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

Fig. 3.2 showed that the first highest energy contributing source was electricity. Electricity required the minimum energy of 166870.8 MJ/ha and maximum of 300367.5 MJ/ha from 2013 to

2016. Irrigation consumed maximum energy but fertilizer use was minimum. This means that there exists no direct relation between irrigation and fertilizer use. The fertilizer contributed 9.92% of total energy [16]. The use of farmyard manure was not enough in selected area Narsinghpur during the survey. Total average energy use by all sources was 357949.2 MJ/ha from 2013 to 2016 and a minimum of 263455.01 MJ/ha during the year of 2013 to 2016. In most years' energy used varied between 104908.45 to 357785.72 MJ/ha.

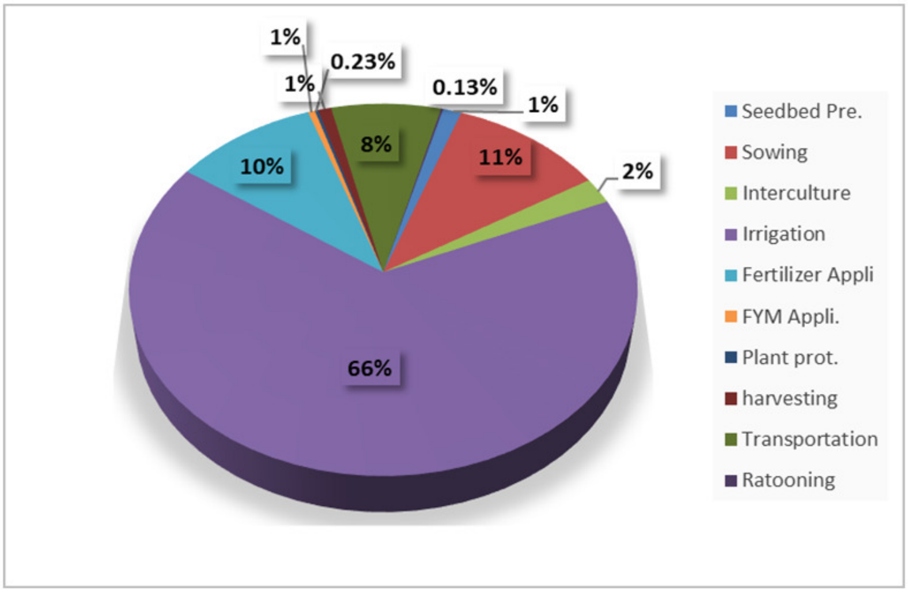

Fig. 3.1. Operation wise energy use pattern for sugarcane (percentage) in Narsinghpur from 2013 to 2016

Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

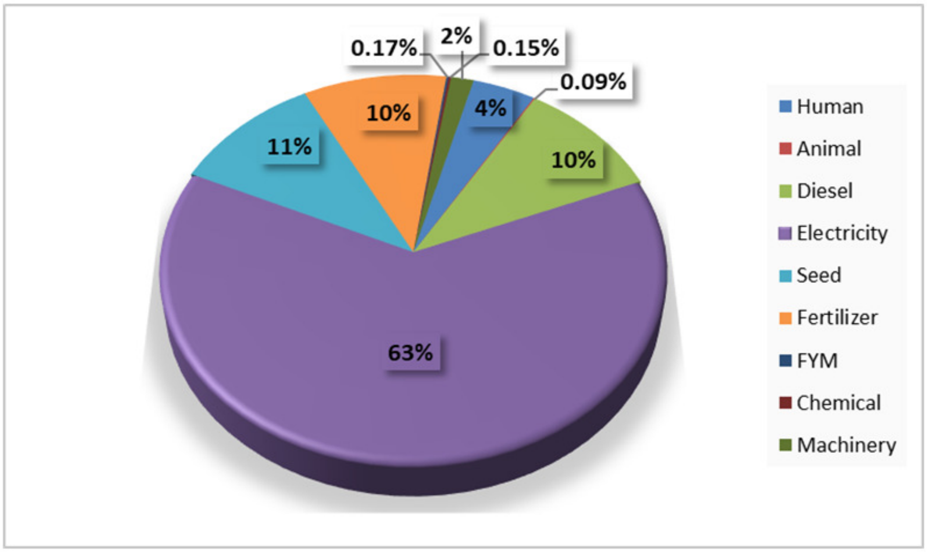

Fig. 3.2. Source wise energy use pattern for sugarcane (percentage) in Narsinghpur from 2013 to 2016

Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

Table 3.1. Operation wise or source wise energy (MJ/ha) used in Narsinghpur (M.P.) from 2013 to 2016

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 Pre	5984.33	4818.04	4420.33	3233.72	4420.33	5953.09	3957.49	5396.2	4280.1	3571.09
Sowing	43497.6	38153.6	38153.14	38080	40534	40926	38080	40730	33909	34105
Interculture	14646.57	8962.17	4811.52	7217.28	8889.69	9725.88	2616	9725.88	7871.61	6381.09
Irrigation	311021.7	262170.9	246048.9	246048.9	228472.1	256338.9	210899.1	259184.4	175749.3	175749.3
Fertilizer Appli.	61623	25482	30282	29595	30633	61623	34995	36141	23697	23697
FYM Appli.	6213.09	-	-	3016.29	-	4279.38	-	3560.37	-	-
Plant protection	1843.44	-	928.14	782.91	944.28	1538.4	692.7	1538.4	-	-
Harvesting	3528	3528	3291	2940	3528	3528	2940	3528	2940	2940
Transportation	31215.45	31215.45	25034.85	16570.5	12556.74	12556.74	22296.51	68749.83	37160.82	16570.5
Ratooning	588	588	470.4	441	470.4	470.4	588	470.4	468	441
Total	480161.2	374918.2	353440.9	347925.6	330448.5	396939.8	317064.8	429024.5	286075.9	263455
Source wise energy (MJ/ha)										
Human	15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64
Animal	-	1212	-	-	-	-	1818	-	453	-
Diesel	49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49
Electricity	300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8
Seed	42400	36437.5	36437.5	37100	39750	39750	37100	39750	33125	33125
Fertilizer	61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5
FYM	1800	-	-	900	-	1350	-	1350	-	-
Chemical	1614	-	450	540	909	1080	450	1080	-	-
Machinery	9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77
Total	482157.6	374723.4	353285.2	347778.8	330292.3	396810.4	316870.8	428895.7	285921	263308.2
Grand total	962318.8	749641.6	706726	695704.5	660740.9	793750.2	633935.6	857920.1	571996.8	526763.2
Yield q/ha 2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175
Energy ratio	1.96	1.9	1.68	1.82	1.9	2	1.94	1.89	1.73	2.18
Specific energy MJ/kg	2.69	2.77	3.14	2.89	2.78	2.64	2.72	2.78	3.05	2.42
Productivity kg/MJ	0.37	0.36	0.31	0.34	0.35	0.37	0.36	0.35	0.32	0.41

Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

The author was investigated that the seed is another energy contributing source in rabi season and sugarcane seed contributed between 33125 to 42400 MJ/ha during the survey. It contributed approximately 10.48% of the total energy. The contribution of diesel was about 10.18% of total energy input. Initially during 2013 to 2016 when bullock farming was common then 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 2013 to 2016 (49885.02 MJ/ha) [17].

Uses of machinery vary between 20748.9 MJ/ha to 55971.10 MJ/ha. As the use of tractor drawn implements increased being heavier the energy contribution by machinery increased. Total energy contribution by various sources varies between 20748.9 MJ/ha (2013-14) to 55971.10 MJ/ha (2013-16). The variation occurs mainly due to variation in energy contribution by electricity and fertilizer. The percentage change in energy supplies for sugarcane production through different sources [18].

The difference in total energy use is not significant. Use of electricity produced in last 3 years 2013-14 or 2015-16 may be due to the intense use of comparatively efficient methods of irrigation (sprinkler). In Narsinghpur also the use of agrochemical for weeding and insects control was not found popular for sugarcane production. One of the reasons of fewer yields in the Narsinghpur region during the early survey was the production of another crop during Kharif season which resulted into a comparatively poor yield of sugarcane in rabi season. Consumption of machinery energy has not increased significantly since seedbed preparation and sowing mainly done by traditional bullock drawn dufan or tractor drawn light cultivator/bund former. Tilth level was not considered as an important factor affecting the yield of sugarcane [16].

3.2 Energy Inputs

Table 3.2 revealed that the ratio of total direct to indirect energy sources from 2013 to 2016 was 3.62. It means the use of physical energy input increased in every next survey as well use of diesel and electricity remains almost the same. The commercial or non-commercial energy source and its ratio were 18.35 from 2013 to 2016. The main reason is the increased use of diesel and fertilizers with time. The ratio of renewable energy to non-renewable energy use was 0.16. The variations in the energy use pattern have been found encouraging. The productivity increased from 0.30 kg/MJ in 2013 and 0.35 kg/MJ in 2016.

Table 3.2. Energy from different classified sources and determination of energy coefficients in Narsinghpur (2013 to 2016)

Energy (MJ/ha)	Survey years (2013 to 2016)
Direct energy	278029.61
Indirect energy	76756.11
Renewable energy	51044.05
Non-renewable energy	303741.67
Direct renewable energy	16006.65
Direct non-renewable energy	262023.06
Indirect renewable energy	35037.5
Indirect non-renewable energy	41718.61
Commercial energy	303741.67
Non-commercial energy	16546.55
Direct-indirect energy ratio	3.62
Renewable – non-renewable energy ratio	0.16
Direct renewable-direct non-renewable energy ratio	0.06
Indirect renewable-indirect non-renewable energy ratio	0.89
commercial –non-commercial energy ratio	18.35
Productivity (kg/MJ)	0.35
Yield (q/ha)	2575
Specific energy (MJ/kg)	2.77
Output-input energy ratio (MJ/unit)	6.86

Source; Indian Institute of sugarcane research, Lucknow

The yield increased from 895 q/ha (2013) to a maximum of 2575 q/ha (2016) the increment of 34.75%. The requirement of energy for the unit yield of sugarcane has been found in increasing order and its minimum value was 148130.6 MJ/ha and increase to 357949.2 MJ/ha during 2013-16, the increment of 41.38% of energy. The energy use efficiency can be evaluated by energy ratio and the significant increase in output-input energy ratio was observed. Its value was 6.86 from 2013 to 2016. These ratios are comparatively higher than other agricultural allied business the reason is the inclusion of energy of leaf and residues which used to be equal. In weight thus, it can be concluded that sugarcane production in Narsinghpur has become highly energy efficient during the recent years as compared to early 10-15 years back.

3.3 Commercial and Non-commercial Energy Ratio to Productivity

Over the years of study, shown in Table 3.3 there is an increased dependency on a commercial source of energy and reduction in the non-commercial source of energy resulting in increased productivity. This correlation is evidenced from the following table for selected area of Narsinghpur the commercial and non-commercial energy ratio to the productivity from 0.81, 0.79, 0.71, 0.77, 0.81, 0.84, 0.83, 0.79, 0.74 and 0.94 from 2013 to 2016.

3.3.1 Commercial energy sources (MJ/ha)

During the study of commercial energy sources shown in Fig. 3.3 it was found that the farmers used the diesel energy (36449.10 MJ/ha), electricity energy (225573.96 MJ/ha), chemical energy (612.30 MJ/ha), fertilizer energy (35509.2 MJ/ha) and machinery energy (5597.11 MJ/ha). The percentage of commercial energy sources like; diesel, electricity, chemical, fertilizer and machinery varied as diesel (12.00%), electricity (74.26%), chemical (0.20%), fertilizer (11.69%) and machinery (1.84%) in the sugarcane cropping year from 2013 to 2016.

3.3.2 Non-commercial energy sources (MJ/ha)

During the study of non-commercial energy sources shown in Fig. 3.4, it was found that the farmers used non-commercial energy sources like; human, animal and FYM energy sources. For human energy (15658.25 MJ/ha), animal energy (348.3 MJ/ha) and FYM energy (540.00 MJ/ha). The percentage of non-commercial energy sources like; human, animal and FYM varied as human (94.63%), animal (2.10%) and FYM (3.26%) in the sugarcane cropping year from 2013 to 2016.

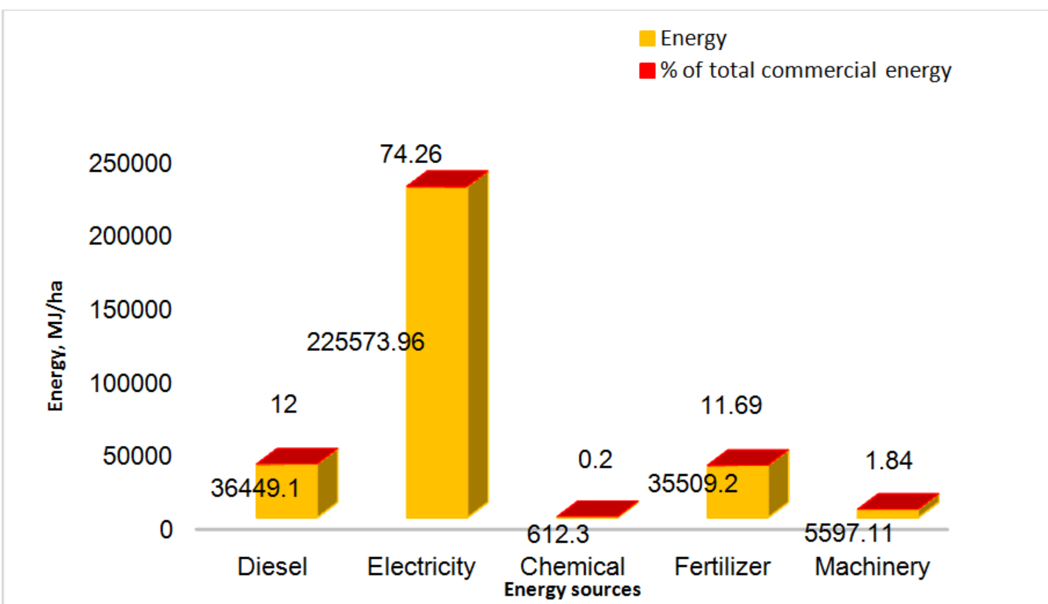

Fig. 3.3. Commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016
Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

Table 3.3. Commercial and non-commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016

Item		Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10
Commercial energy sources (MJ/ha)											
Diesel		49885.02	39440.65	32379.36	26163.86	23153.53	27975.36	22447.41	77413.29	41810.16	23822.49
Electricity		300367.5	253292.4	233619	233619	216930	233619	200244.9	250306.2	166870.8	166870.8
Chemical		1614	-	450	540	909	1080	450	1080	-	-
Fertilizer		61200	25245	30045	29454	30369	61200	34731	35877	23485.5	23485.5
Machinery		9048.64	6088.32	5268.51	4540.5	4205.91	4615.08	5016.87	8485.8	7150.53	3736.77
Total		422115.16	324066.37	301761.87	294317.36	275567.44	328489.44	262890.18	373162.29	239316.99	217915.56
Non- Commercial energy sources (MJ/ha)											
Human		15842.46	13007.54	15085.79	15461.46	14974.89	27220.97	15062.6	14633.36	13025.98	12267.64
Animal		-	1212	-	-	-	-	1818	-	453	-
FYM		1800	-	-	900	-	1350	-	1350	-	-
Total		17642.46	14219.54	15085.79	16361.46	14974.89	28570.97	16880.6	15983.36	13478.98	12267.64
Grand total		439757.62	338285.91	316847.66	310678.82	290542.33	357060.41	279770.78	389145.65	252795.97	230183.2
Yield q/ha	2013-16	3575	2700	2250	2400	2375	3000	2325	3075	1875	2175
Productivity kg/MJ		0.81	0.79	0.71	0.77	0.81	0.84	0.83	0.79	0.74	0.94

Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

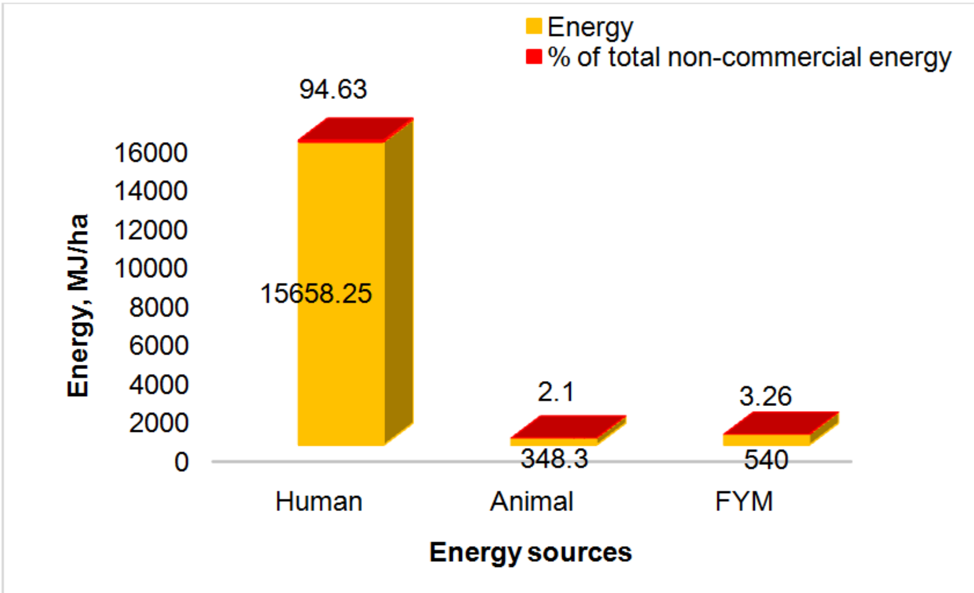

Fig. 3.4. Non-commercial energy sources (MJ/ha) in Narsinghpur from 2013 to 2016
Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur

3.4 Effect of Irrigation on the Yield of Sugarcane

The relationship between yield and irrigation energy is mainly considered for the year of 2013 to 2016. 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 the rainy season. In this system land used to be sloppy at the centre like ponds so water does not a loss by runoff. In the Narsinghpur most of the farmers possessed tube well and the farmers, who did not have a water source, hired the irrigation water from neighbouring farms. The relation between irrigation energy and yield is shown in Fig. 3.5 for the selected area Narsinghpur. By considering irrigation energy as predictor and yield as a response they can be correlated with the following equation.

$$y = 0.010x - 5.589 \quad (11)$$

$(r^2 = 0.780)$

Higher irrigation energy means either a higher number of irrigation or more hours of water supply in each irrigation. In these years the water reached the plants by the free flow. Most of the farms had a 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 the un-irrigated fields average yield were only 1875 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 the availability of assured irrigation. The farmers without assured irrigation did not incline to select sugarcane crop rather they selected another crop like; wheat, urid, black gram, green gram etc. These relations were found stronger when the data of farmer's survey of the years from 2013 to 2016 was considered.

Fig. 3.5 shows the irrigation level is one of the most effective factors to enhance the yield of sugarcane in the Narsinghpur. The data of the year 2013-16 of the selected area Narsinghpur shows that there exists strong and positive co-relation between energy consumption for irrigation and productivity of sugarcane. They are significantly co-related at 1 per cent level of significance. The value of $(r^2 = 0.780)$. It means irrigation had a direct effect on yield throughout the survey years and still there is a scope to enhance the yield of sugarcane in Narsinghpur. On an average, the annual rainfall is about 1300 mm which is quite high as compared to another region of the state. The soil is vertisole so the water retention capability of the soil is also high. winter rain is also common for the Narsinghpur region.

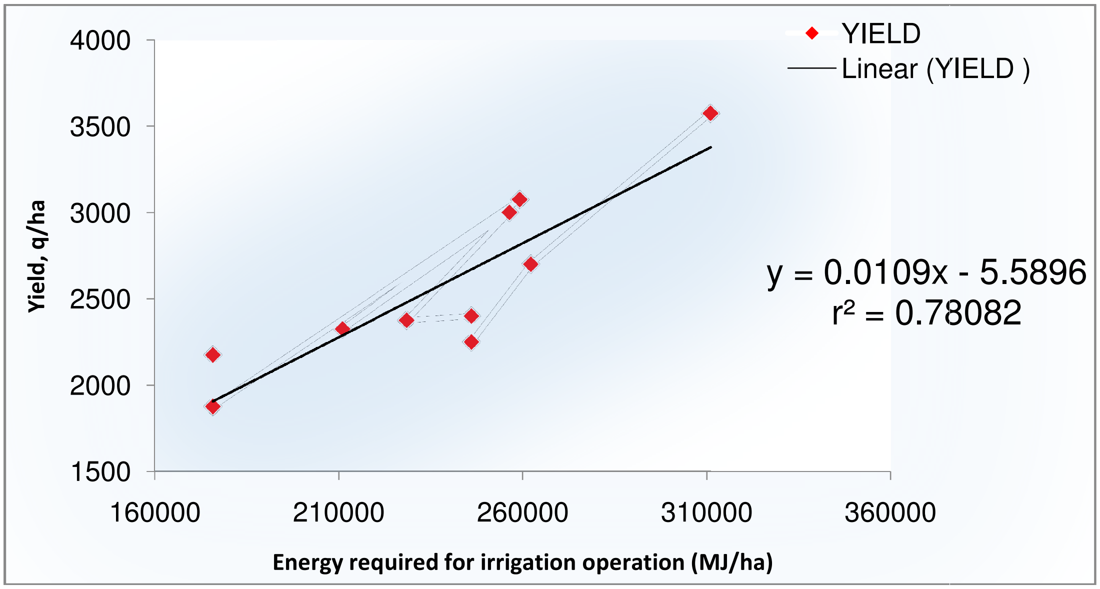

Fig. 3.5. Effect of irrigation on the yield of sugarcane (Narsinghpur, 2013-16)
Source; Avinash Kumar. 2017. Energetics of sugarcane in the District of Narsinghpur, Madhya Pradesh. Unpublished thesis, COAE, JNKVV, Jabalpur [19]

4. CONCLUSION

The aim of the study was to optimize the energy sources and use a pattern for change in the scenario of sugarcane production in the selected area of study Narsinghpur, India. The contribution of seed energy was found 42400 MJ/ha in the three years cropping and harvesting session of sugarcane due to one-time sowing of sugarcane during 2013 to 2016 for sugarcane crop production in the selected area Narsinghpur, India. The fertilizer was an energy consuming source for sugarcane which consumed about 10% of total source wise energy input. Irrigation was found to be the highest energy consuming operation across the selected area under study. Specifically, it consumed about 79056.13 MJ/ha in 2013 and 237168.39 MJ/ha in 2016 and the use of direct energy was comparatively very high as compared to the indirect energy in earlier surveys. The percentage area under irrigation showed an increasing trend in Narsinghpur and it reached from 35% to 85% respectively. The direct-indirect energy ratio was 3.62 from the total energy input from 2013 to 2016 in Narsinghpur for sugarcane.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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