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Energy Use Pattern and Scenario Change in Sugarcane (ratoon) Cultivation for Bhabar Region of Uttarakhand, India

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ABSTRACT

The production and productivity are directly related with use in unit operation of agricultural production. The variation in yield of crop occurs in India due to wide variation in energy inputs, agro-climatic conditions and resources used. Keeping this in view, a study has been carried out to find the energy scenario of sugarcane (ratoon) crop for sugarcane production in Bhabar region of Uttarakhand, India. The scenario shows, energy consumption was highest in tractor farm followed by animal farm and mixed farm in this region and total operational energy ranged from 3576 to 6222 MJ/ha for sugarcane (ratoon) crop cultivation. Irrigation was the highest energy consuming operation in sugarcane (ratoon) crop cultivation operations. The energy productivity ranged from 2.712 to 3.944 kg/MJ for sugarcane (ratoon) crop cultivation.

Key words: Energy scenario, Energy inputs, Energy productivity, Uttrakhand, sugarcane

INTRODUCTION

Sugarcane occupies a very prominent position on the agricultural map of India covering large areas in sub-tropics 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 (Rana *et al*., 2003a). Ratoons occupy a sizable proportion of the total area under cane cultivation, upto 50% of cane area in sub-tropical states like Uttar Pradesh. The major advantage of ratoons lies in its early maturity, lower cost of cultivation and high sugar recovery during early period of crushing (Rana et *al*., 2003b).

Advance technology has created an energy intensive life style. Modern agriculture is not exception of it. India has become self sufficient in food production by adopting improved technologies in agriculture. The present level of production is an outcome of use of high yielding varieties of seeds, chemicals, fertilizers, pesticides, improved irrigation facilities, more area under irrigation, more area under crop, higher level of mechanization, better marketing facilities, well defined credit policies and support price of sugarcane and food grains. In agriculture sector, sugarcane share is about 7% of the total value of agriculture output and occupied about 2.6% of India's gross cropped area during 2006-07(Anonymous, 2012). Sugarcane provides raw material for the second largest agro-based industry after textile (Rana *et al*., 2003b) About 527 working sugar factories with total installed annual sugar production capacity of about 242 lakh tonnes are located in the country during 2010-11. The average cane yield of India has increased from 40.5 tonnes/ha (1950-51) to 70 tonnes/ha (2009-10) (Anonymous, 2013). The production and productivity is directly related with energy availability. This availability of power in Punjab is 3.5 kW/ha, which is highest in the country while average power availability in agriculture for whole country is 1.5 kW/ha. To obtain still more production and productivity, higher energy inputs and better management of food production is required. Energy is an essential input for economic development and improving the quality of life.

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The development of conventional as well as non-conventional forms of energy is necessary for meeting the growing demand of energy needs of society. The power generation in India has increased from 1400 MW in 1947 to 2.00 Lakhs MW at the end of 2010-11, which is comprised of power from hydroelectric, thermal, wind and nuclear power stations. The power availability for production agriculture in India is 1.5 kW/ha and lies higher its requirement in Punjab which is about 3.5 kW/ha (Singh, 2002). In comparison of above Japan is the highest energy consuming country, where the energy input to agriculture production is 14.0 kW/ha. To obtain still more production and productivity, higher energy inputs and better management of crop production system will be needed. The process of crop production collects and converts solar energy in the form of food energy. To complete this conversion efficiency a variety of energy inputs in the form of energy required in physical operations, chemicals (fertilizers, pesticides etc.) and biochemical (seeds) are required.

Mishra (1986) conducted an experimental study for energy analysis of major crops of Tarai region of Uttarakh and (earlier Uttar Pradesh) by considering different sources of energy and operations in crop production. He reported that irrigation, seed bed preparation and transplanting consumed 66-72 per cent of total energy input in paddy crop production whereas irrigation, seed bed preparation and threshing consumed 70-88 per cent of total energy in wheat crop. Energy output - input ratio was highest for sugarcanes crop followed by maize, paddy and wheat. Mittal and Dhawan (1989) examined energy parameters for irrigation treatment in Indian agriculture and reported that irrigation consumed upto 60 per cent 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.

Dhawan and Mittal (1994) analyzed the contribution of various factors of production, such as fertilizer, diesel, electricity, seeds and machinery etc. Analysis of all factors of crop production revealed that water (with the help of electricity and diesel) and fertilizers were key factors affecting the yield of major crops in India, except the sugarcane where seed supplied a large amount of energy. Singh and Singh (1996) studied the energy consumption pattern in Punjab agriculture by taking data from the cost of cultivation scheme for the year 1989-90. They found that the use of commercial energy varied directly while the use of non-commercial energy varied inversely with the farm size. The second zone of principal crops emerged as the highest use of commercial energy on per hectare basis. Valentin (1997) studied ecobalance of production and energy cycles. He has given modern possibilities of generating energy from sugar beet and reported that beet pulp is vastly inferior to sugarcane bagasse as an energy source.

Singh *et al.* (1994) analyzed energy inputs to the Indian agriculture during last 40 years to identify trends in energy use in agriculture on farms, categorized into 3 groups viz. bullock operated (Animal farm), bullock + tractor operated (Mixed farm) and tractor operated (tractor farms) farms. Energy input resources used on each type of farm was categorized into three groups: (i) Physical energy resources *i.e.* human, animal and mechanical, electrical prime movers. (ii) Chemical energy resources i.e. fertilizers and agro-chemicals and (iii) Biochemical energy resources *i.e.* seeds and hormones. Total energy input in Indian agriculture increased 5.5 times during 1951 to 1991 while the production for the same period increased by only 3.5 times. The increased energy inputs in the Indian agriculture have contributed significantly towards the increase in food grain production.

Keeping in view of the above there was lack in study of energy use pattern and change in its scenario, therefore, the study was carried out for sugarcane (ratoon) crops in Bhabar region of Uttarakhand and presented here in this article.

MATERIALS AND METHODS

Study has been carried out to find the energy use pattern and change in its scenario of sugarcane (ratoon) crop cultivation in terms of energy inputs for Bhabar region of Uttarakhand. The data were collected on prescribed proforma using multistage sampling technique by individual interviewing method including all categories of farmers. The selected villages were Jaipur Bisa, Jaipur Padali and Tejpur Negi in Bhabar region of Uttarakhand. Data were collected from the selected villages of Bhabar region of Uttarakhand. The first, second and third survey in different years were termed as first, second and third round of survey respectively for sugarcane (ratoon) crop in Bhabar region. 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 scenario was prepared for sugarcane (ratoon) 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 change in its energy scenario was prepared for sugarcane (ratoon) crop.

Energy calculation:

$$\text{Yield} = \sum_{i=1}^{n} Y_i X_i^*$$

$$\text{Human energy} = \sum_{i=1}^{n} h_i X_i^*$$

$$\text{Animal energy} = \sum_{i=1}^{n} a_i X_i^* \quad ,$$

$$\text{Diesel energy} = \sum_{i=1}^{n} d_i X_i^*$$

$$\text{Electrical energy} = \sum_{i=1}^{n} e_i X_i^* \quad ,$$

$$\text{Seed energy} = \sum_{i=1}^{n} s_i X_i^*$$

$$\text{Fertilizer energy} = \sum_{i=1}^{n} f_i X_i^*$$

$$\text{Machine energy} = \sum_{i=1}^{n} m_i X_i^*$$

$$\text{Chemical energy} = \sum_{i=1}^{n} c_i X_i^*$$

$$\text{Total energy} = \sum_{i=1}^{n} t_i X_i^*$$

where, $t_i = h_i + an_i + d_i + e_i + f_i + s_i + m_i + c_i$

Yi = yield level per activity, kg/ha Xi=Farmarea per activity, ha

hi = Human energy level for activity i, MJ/ha
ani = Animal energy level per activity i, MJ/ha
di = Diesel energy level for activity i, MJ/ha
ei = Electrical energy level for activity i, MJ/ha
si = Seed energy level for activity i, MJ/ha
fi = Fertilizer energy level for activity i, MJ/ha
m i = Machine energy level for activity i, MJ/ha
ci = Agro Chemical energy level for activity i, MJ/ha
ti = Total energy level consumed by activity i, MJ/ha

Total energy is the sum of the energy usage from different sources.

RESULTS AND DISCUSSION

The data collected from selected villages of Bhabar region for three rounds of survey were analyzed and compared for sugarcane (ratoon) crop with the first round and second round of survey. The energy use pattern and change in its scenario in terms of source wise and operation wise due to use of different implements/ equipment and significance of different sources on sugarcane (ratoon) crop production is discussed for animal farms and tractor farms. The significance of different sources of energy inputs has been tested at 1%, 5% and 10% level of significance (LOS). The discussion on sugarcane (ratoon) crop and farm wise energy scenario is as follows:

Animal Farm

Source wise energy use pattern in sugarcane (ratoon) cultivation for animal farm with three rounds of survey results is presented in Table 1. It is clear from the table that animal farms were present in each round of survey under the study area. The source wise total energy use in sugarcane (ratoon) cultivation has increased by 12.17% and 1.63% in second and third round of survey with respect to first round whereas it has decreased by 9.40% in third round with respect to second round of survey. It was due to use of less fertilizer energy and other resources. The use of human energy has increased by 11.78% and decreased by 13.23% in second and third round with respect to first round of survey while it has decreased by 22.38% in third round with respect to second round of survey. The use of animal energy has decreased by 70.90% and 37.08% in second and third round of survey with respect to first round but it has increased by 116.22% in third round with respect to second round of survey. It was due to use of appropriate implements with the animals. The use of electric energy has increased by 79.05% and 90.39% in second and third round with respect to first round of survey whereas it has increased by 6.33% in third round with respect to second round of survey. It was due to use of electricity in irrigation. The use of fertilizer energy has increased

Table 1: Source wise energy use pattern in sugarcane (ratoon) cultivation on irrigated animal farm in Bhabar region of Uttaranchal

(MJ/ha)

Source	I Round	II Round	III Round	% Change in II round w.r.t. I round	% Change in III round w.r.t. I round	% Change in III round w.r.t. II round
	(1)	(2)	(3)	(4)	(5)	(6)
Human	1385	1548	1202	11.78	-13.23	-22.38
Animal	851	248	536	-70.90	-37.08	116.22
Diesel	0	0	0	0.00	0.00	0.00
Electric	1524	2728	2901	79.05	90.39	6.33
Seeds	0	0	0	0.00	0.00	0.00
FYM	0	0	0	0.00	0.00	0.00
Fertilizer	4993	5863	4861	17.43	-2.65	-17.10
Chemical	0	0	0	0.00	0.00	0.00
Machinery	446	192	260	-57.02	-41.66	35.72
Canal	1789	1746	1408	-2.40	-21.31	-19.38
Total (MJ/ha)	10988	12326	11168	12.17	1.63	-9.40
Direct	3760	4524	4638	20.33	23.37	2.52
Indirect	7229	7802	6529	7.93	-9.68	-16.31
Renewable	2236	1796	1737	-19.68	-22.31	-3.27
Non-renewable	8752	10530	9430	20.31	7.75	-10.44
Commercial	8752	10530	9430	20.31	7.75	-10.44
Noncommercial	2236	1796	1737	-19.68	-22.31	-3.27
Energy productivity	3.234	3.421	3.346	5.78	3.45	-2.21
Yield (kg/ha)	35540	42171	37364	18.66	5.13	-11.40

by 17.43% and decreased by 2.65% in second and third round with respect to first round of survey whereas it has decreased by 17.10% in third round with respect to second round of survey. Due to variation in use of fertilizer, yield of sugarcane (ratoon) has been affected. The use of machinery energy has decreased by 57.02% and 41.66% in second and third round with respect to first round of survey but it has increased by 35.72% in third round with respect to second round of survey. It was due to variation in farming operations. The use of canal energy has decreased by 2.40% and 21.31% in second and third round with respect to first round of survey whereas it has decreased by 19.38% in third round with respect to second round of survey. It was due to use of more electric energy and less availability of canal water at the time of peak demand. The use of direct energy has increased by 20.33% and 23.37% in second and third round of survey with respect to first round whereas indirect energy has increased by 7.93% and decreased by 9.68% in second and third round with respect to first round of survey. It was due to requirement of direct energy in farm operations. The use of renewable energy has decreased by 19.68% and 22.31% in second and third round of survey with respect to first round whereas non-renewable energy has increased by 20.31% and 7.75% in second and third round of survey with respect to first round. It was due to more dependence on non-renewable energy. Similar pattern was for commercial and noncommercial energy in respective rounds. The energy productivity has increased by 5.78% and 3.45% in second and third round of survey with respect to first round but it has decreased by 2.21% in third round with respect to second round of survey due to increase and decrease in yield of sugarcane (ratoon) in respective rounds.

The operation wise energy used in sugarcane (ratoon) cultivation for animal farm with three rounds of survey results is presented in Table 2. It is clear from the Table that irrigation has consumed highest energy in farm operations. It has increased by 27.72% and 60.78% in second and third round of survey with respect to first round of survey whereas it has increased by 25.89% in third round with respect to second round of survey. It was due to increase in the use of high yielding varieties of sugarcane. The use of weeding energy has increased by 3.57% and decreased by 14.87% in second and third

Table 2: Operation wise energy use pattern in sugarcane (ratoon) cultivation on irrigated animal farm in Bhabar region of Uttaranchal

(MJ/ha)

Operation	I Round	II Round	III Round	% Change in II round w.r.t. I round	% Change in III round w.r.t. I round	% Change in III round w.r.t. II round
	(1)	(2)	(3)	(4)	(5)	(6)
Irrigation	1855	2369	2982	27.72	60.78	25.89
Weeding	554	574	471	3.57	-14.87	-17.80
F.A.	20	35	9	77.58	-54.21	-74.21
Spray	0	0	0	0.00	0.00	0.00
Harvesting	605	806	733	33.29	21.20	-9.07
Threshing	0	0	0	0.00	0.00	0.00
Transportation	1353	496	724	-63.33	-46.50	45.91
Total (MJ/ha)	4386	4280	4919	-2.43	12.16	14.95

round with respect to first round of survey whereas it has decreased by 17.80% in third round with respect to second round of survey. The use of harvesting energy has increased by 33.29% and 21.20% in second and third round with respect to first round of survey due to increase in yield of sugarcane (ratoon) crop. The transportation energy use has decreased by 63.33% and 46.50% in second and third round of survey with respect to first round because it depends on traveling distance of freight or yield also.

Tractor Farm

Source wise energy use pattern in sugarcane (ratoon) cultivation for tractor farm with three rounds of survey results is presented in table 3. It is clear from the table that tractor farms were present in each round of survey. These farms are 3, 6 and 3 in first, second and third round of survey respectively. The sugarcane (ratoon) farms depend on sugarcane planted farms in previous years. It is evident from Table 3 that the total energy used in sugarcane (ratoon) cultivation has decreased by 71.76% and 37.45% in second and third round with respect to first round of survey whereas it has decreased by 19.98% in third round with respect to second round of survey. The use of total energy has affected the yield of sugarcane (ratoon) in respective rounds. The use of human energy has increased by 28.72% and 4.81% in second and third round with respect to first round of survey whereas it has decreased by 18.58% in third round with respect to second round of survey due to increase and decrease of sugarcane (ratoon) yield in respective rounds. The use of diesel energy has decreased by 14.22% and increased by 50.17% in second and third round with respect to first round of survey whereas it has increased by 75.06% in third round with respect to second round of survey. It was due to increase in use of tractor for sugarcane farming operations. The use of electric energy has increased by 16.06% in third round with respect to second round of survey. It was due to increase in use of electric motors for irrigation purpose. The use of FYM energy has been found only in second round of survey because it depends on availability of farm yard manure. The use of fertilizer energy has increased by 32.24% and 14.02% in second and third round of survey with respect to first round to increase the yield of sugarcane (ratoon) whereas it has decreased by 13.78% in third round with respect to second round of survey. The use of chemical energy has mentioned only in second round because it depends on requirement of pesticide in sugarcane (ratoon). The use of machinery has increased by 29.34% in third round with respect to first round of survey due to increase in use duration of implements/equipment. The use of canal energy has decreased by 14.42% in second round with respect to first round of survey due to less availability of canal water at the time of sugarcane (ratoon) peak demand. The use of direct energy has increased by 147.07% and 191.91% in second and third round of survey with respect to first round whereas it has increased by 18.12% in third round with respect to second round of survey due to more dependence on direct energy in farming operations. The use of indirect energy has increased by 47.34% and decreased by 12.65% in second and third round of survey with respect to first round whereas it has decreased by 40.71% in third round with respect to second round of survey. It was due to increased and decreased use of fertilizer energy in sugarcane production. The use of renewable energy has increased by 211.83% and 4.81% in second and third round with respect to first round of survey whereas it has decreased by 66.39% in third

Table 3: Source wise energy use pattern in sugarcane (ratoon) cultivation on irrigated tractor farm in Bhabar region of Uttaranchal

(MJ/ha)

Source	I Round	II Round	III Round	% Change in II round w.r.t. I round	% Change in III round w.r.t. I round	% Change in III round w.r.t. II round
	(1)	(2)	(3)	(4)	(5)	(6)
Human	964	1241	1010	28.72	4.81	-18.58
Diesel	1052	902	1579	-14.22	50.17	75.06
Electric	0	2838	3294	0.00	0.00	16.06
FYM	0	1765	0	0.00	0.00	-100.00
Fertilizer	4465	5905	5091	32.24	14.02	-13.78
Chemical	0	212	0	0.00	0.00	-100.00
Machinery	261	0	338	-100.00	29.34	0.00
Canal	1489	1274	0	-14.42	-100.00	-100.00
Total (MJ/ha)	8231	14138	11313	71.76	37.45	-19.98
Direct	2016	4981	5884	147.07	191.91	18.12
Indirect	6215	9157	5429	47.34	-12.65	-40.71
Renewable	964	3006	1010	211.83	4.81	-66.39
Non-renewable	7267	11132	10303	53.19	41.78	-7.45
Commercial	7267	11132	10303	53.19	41.78	-7.45
Noncommercial	964	3006	1010	211.83	4.81	-66.39
Energy productivity	3.620	2.712	2.843	-25.08	-21.44	4.86
Yield (kg/ha)	29793	38338	32169	28.68	7.98	-16.09

round with respect to second round of survey. It was due to increase in use of human energy. The use of non-renewable energy has increased by 53.19% and 41.78% in second and third round with respect to first round of survey whereas it has decreased by 7.45% in third round with respect to second round of survey. It was due to more dependence on non-renewable energy. The table 3 shows similar pattern for commercial energy and noncommercial energy as non-renewable and renewable energy, respectively. The energy productivity has increased by 25.08% and decreased by 21.44% in second and third around with respect to first round of survey whereas it has increased by 4.86% in third round with respect to second round of survey. It was due to increase in yield of sugarcane (ratoon) and efficient use of energy in respective rounds of survey.

The operation wise energy use in sugarcane (ratoon) cultivation for tractor farm with three rounds of survey results is presented in table 4. It is clear from the table that the use of total operational energy has increased by 30.96% and 65.18% in second and third round of survey with respect to first round whereas it has increased by 26.13% in third round with respect to second round of survey. It was due to use of more irrigation and transportation energy in respective rounds. The use of irrigation energy has increased by 62.04% and 105.72% in second and third round of survey with respect to first round of survey whereas it has increased by 26.96% in third round with respect to second round of survey. It was due to demand of more water by high yielding varieties of sugarcane and use of electric motors. The use of harvesting energy has increased by 119.91% and 109.98% in second and third round with respect to first round of survey due to increase in yield of sugarcane (ratoon). The transportation energy has decreased by 14.79% and increased by 49.67% in second and third round of survey with respect to first round whereas it has increased by 75.76% in third round of survey with respect to second round of survey. Transportation energy depends on traveling distance and yield of sugarcane (ratoon).

Energy use pattern for animal and tractor farms in Bhabar region of Uttarakhand for sugarcane (ratoon) crop cultivation at last round of survey

A comparison was made to represent the overall energy use pattern on animal, and tractor farms for sugarcane (ratoon) cultivation in Bhabar region of Uttarakhand. It is clear that out of total energy consumption in sugarcane

Table 4: Operation wise energy use pattern in sugarcane (ratoon) cultivation on irrigated tractor farm in Bhabar region of Uttaranchal

(MJ/ha)

Operation	I Round	II Round	III Round	% Change in II round w.r.t. I round	% Change in III round w.r.t. I round	% Change in III round w.r.t. II round
	(1)	(2)	(3)	(4)	(5)	(6)
Irrigation	1627.0	2636.3	3347.0	62.04	105.72	26.96
Weeding	507.7	409.2	231.0	-19.40	-54.50	-43.54
F.A.	10.3	37.7	7.0	264.52	-32.26	-81.42
Harvesting	347.3	763.8	729.3	119.91	109.98	-4.52
Transportation	1274.3	1085.8	1907.3	-14.79	49.67	75.66
Total (MJ/ha)	3766.7	4932.8	6221.7	30.96	65.18	26.13

(ratoon) crop cultivation the most energy consuming source was fertilizer (43.53% to 45.00%) followed by electricity (25.98% to 29.12%), diesel (0.00% to 13.96%), canal (0.00% to 12.61%), human (8.93% to 10.76%), animal (0.00% to 4.80%) and machinery (2.33% to 3.43%).

A comparison was also made to represent the operational energy use pattern on animal and tractor farms for sugarcane (ratoon) cultivation in Bhabar region of Uttarakhand. It is clear that the out of total operational energy use in sugarcane (ratoon) cultivation the highest energy consuming operation was irrigation (53.80% to 60.62%) followed by transportation (14.72% to 30.65%), harvesting (11.72% to 14.90%), weeding (3.71 to 9.58%) and fertilizer application energy (0.11% to 0.18%).

CONCLUSION

The use of total energy was highest in sugarcane (ratoon) crops cultivation on tractor farms followed by animal farms and the energy productivity ranged from 2.712 to 3.620 kg/MJ for sugarcane (ratoon) crop cultivation. The yield of sugarcane (ratoon) ranged from 29793 to 42171 kg/ha. The diesel energy was used only on tractor farms which accounted for energy consumption of 1579 MJ/ha for sugarcane (ratoon) crop cultivation. The use of electric energy accounted from 1524 to 3294 MJ/ha in sugarcane (ratoon) crop cultivation. The use of total operational energy ranged from 3767 to 6222 MJ/ha for sugarcane (ratoon) crop cultivation. Irrigation was the highest energy consuming operation which consumed energy from 53.80 to 60.62% of total operational energy for sugarcane (ratoon) crop, respectively. The transportation is other important operations which consumed energy from 11.72 to 14.90% of total operational energy in sugarcane (ratoon) crop production.

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