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Structure and Pattern of Energy Use in Agriculture and Its Impact on Agricultural Productivity: A Case Study of Bhiwani District of Haryana

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Abstract: Key objective of this research study is to analyze the structure and pattern of energy use, energy input-output ratio, relationship between energy use and agricultural productivity in agriculture of Bhiwani district (Haryana). Data used in this study based on purposive sampling collected from 573 households by using a face to face well-structured questionnaire during 2013. The results revealed that operation of fertilizers application has consumed maximum amount of energy followed by irrigation, sowing, field preparation, harvesting and transportation, threshing and winnowing, and marketing process. Chemical fertilizers have supplied the bulk amount of energy followed by diesel pump set, tractor, human and seeds. Bajra crop has registered as most energy efficient crop whereas wheat recoded as least energy efficient crop. It was also found that there exist a positive correlation between energy use and agricultural productivity in agriculture of the district.
Keywords: Energy; Energy Input-Output Ratio; Agricultural Productivity; coefficient of Correlation; Bhiwani.

INTRODUCTION

Energy is one of the fundamental requirements in different aspects of modern progressive life as well as each sector of economy. Agriculture is the most essential economic and productive activity of human being which has consumed energy as vital input in crop cultivation since primitive age. Agriculture is itself an energy conversion process that converts solar energy into food energy for human and feed for animal through photosynthesis [1].

Energy and agriculture are complementary each other but these are closely associated with each other as agriculture is both consumer and producer of energy in the various form of bio-energy [2−4].

The sources of energy use in agriculture production system can be divided broadly in two groups: direct and indirect. Direct sources of energy use refer to those which liberate energy directly such as animate energy (human labour and animal power), diesel and electricity power. The indirect sources of energy include seeds, bio-fertilizers, chemical fertilizers, pesticides, insecticides, herbicides, water for irrigation and machinery which do not release energy directly [5,6].

Agricultural productivity is a quantitative concept which refers to the ratio of index of total local agricultural output produced to the index of total inputs used in the process of farm production. It measures the efficiency and effectiveness of agriculture in terms of inputs used in the production of crops. It is generally used to articulate the capacity of agriculture to produce crops in a particular agricultural area [7,8]. Agriculture productivity also defined as "yield per unit area" [9] , and "output per unit of input" [10]. Agricultural productivity expresses physical relationship between total output and total inputs used to increase the final output [11].

MATERIAL AND METHODS

The present study has been conducted in Bhiwani district of Haryana during 2013. For this study, five main source of energy (human, diesel pump set, seeds, chemical fertilizers and tractor) and seven main agricultural operations (field preparation, sowing, irrigation, fertilizers application, harvesting and winnowing, threshing and winnowing, and marketing process) and three major crops (wheat, mustard and bajra) have been selected.

The present study is primarily based upon the primary data collection at farm level. So, the district has been divided into 10 development blocks as per government division and from each block three villages have been selected. The selection of 3 villages from each block has been done on the basis of three criteria viz, proximity to canal, nearness to block headquarter and remoteness of the area (Figure 1). Here, remoteness refers to far distance of the village from the block headquarter. On the basis of purposive sampling, from each sample village roughly 10 per cent of the total households have been selected for field survey. Then, one respondent has been selected from each selected household for interview/survey. Therefore, total 573 respondents have been surveyed through a well-structured questionnaire. The collected raw data related to energy input and output of crops was in various forms of unit like kilogram, quintile, minutes, hours, acre etc. So, first of all the collected raw data related to energy use and its output has been converted into k.cal./hectare with the help of energy equivalent conversion table [12] (Table 1). Thereafter, the total energy use and total crop output of each respondent has been calculated. After that, the average energy input and average crop output of each selected sample crop have been calculated at village, block and district level.

Then, the energy input and output ratio has been worked out for each selected sample crop by dividing the total energy used by a sample crop by total crop output of the same crop. Further, total energy use and total agricultural productivity of the district have been calculated by adding of the total average energy used of each sample crop and adding of the total average crop output of each sample crop respectively. Finally, the correlation between total energy use and total agricultural productivity has been calculated by using the Karl Pearson's formula:

Fig–1: Bhiwani district of Haryana

Source: Haryana Space Applications Center (HARSAC), 2013

Karl Pearson's Correlation Coefficient

$$r = \frac{\sum xy}{\sqrt{\sum x^2 \times \sum y^2}}$$

Where,

r = Coefficient of Correlation

$x = (X - \bar{X})$

$y = (Y - \bar{Y})$

Table–1: Energy Equivalents for Different Inputs and Outputs

Category	Energy Equivalents
Man	470 K.Cal./hr
Tractor (30 hp)	19,230 K.Cal./hr
Electric tube well (20 hp)	12,820 K.Cal./hr
Diesel Pump Set (7.5 hp)	4,807.5 K.Cal./hr
Nitrogen (Fertilizer)	14,325 K.Cal./kg
Phosphate (Fertilizer)	2,650 K.Cal./kg
Potash(Fertilizer)	1,600 K.Cal./kg
Seeds and Output: Wheat and Bajra Crop	3,510 K.Cal./kg
Seeds and Output: Mustard Crop	5,970 K.Cal./kg

Source: The Energy and Resources Institute, 1987

RESULTS AND DISCUSSION

Agricultural Operation-wise Energy use

The operation of fertilizer application has consumed the maximum average amount of energy (93,39,887.7 k.cal./hect.) in the district followed by irrigation (27,15,813.3 k.cal./hect.), sowing (7,38,996.6 k.cal./hect.), field preparation (7,29,177.0 k.cal./hect.), harvesting and transportation (3,77,476.7 k.cal./hect.) and threshing and winnowing (2,43,301.5 k.cal./hect.) (Table 2). Fertilizer application has also registered as the maximum energy consuming operation for the production of each selected sample crop. Generally, soil of the district is sandy, loamy and sandy loamy. It is light to medium in texture and low in nitrogen and phosphorus, medium in potash, deficient in sulphur and zinc [13]. Therefore, the soil is not fertile and the farmers use more chemical fertilizers to increase the fertility of soil as well as to get more crop production. The district falls under semi-arid and sub-tropical agro-climatic zone having dry sandy soil with undulating landscape which requires more irrigation water with more frequencies of watering. The operation of marketing process has consumed minimum average amount of energy (2, 19,809.7 k.cal./hect.) because most of the farmers sale their crops production nearby the market. Further, marketing process has consumed equal amount of energy (73,269.9 k.cal./hect.) for each sample crop as the distance between a sample village and their nearby market has taken as same for each sample crop.

Sowing, irrigation, fertilizer application, threshing and winnowing consume more energy in cultivation of wheat crop as compare to mustard and bajra crops. Wheat crop requires more quantity of seed, number of watering, chemical fertilizers and threshing hours than mustard and bajra crops. Field preparation uses higher energy in case of mustard production (3,57,064.2 k.cal./hect.) as compare to wheat (2,47,601.4 k.cal./hect.) and bajra crop (1,24,511.4 k.cal./hect.) because mustard crop requires more number of ploughings than wheat and bajra crops. Harvesting and transportation consumes more energy in case of bajra crop (1,38,494.2 k.cal./hect.) as compare to wheat (1,30,662.7 k.cal./hect.) and mustard crop (1,08,319.8 k.cal./hect.) because it takes more harvesting time than wheat and mustard crops.

Table–2: Agricultural Operation-wise Use of Energy for Production of Selected Crops in Bhiwani District, 2012-2013

Crop	Energy Consumption in Average K.cal./hect.							Total
	Field Preparation	Sowing	Irrigation	Fertilizer Application	Harvesting and Transportation	Threshing and Winnowing	Marketing Process	
Wheat	2,47,601.4 (3.73)	5,50,912.7 (8.30)	13,94,415.4 (21.00)	41,48,933.1 (62.50)	1,30,662.7 (1.97)	93,018.8 (1.40)	73,269.9 (1.10)	66,38,814.0 (100.00)
Mustard	3,57,064.2 (7.35)	99,500.3 (2.05)	8,20,008.2 (16.88)	33,19,698.9 (68.32)	1,08,319.8 (2.22)	81,045.8 (1.67)	73,269.9 (1.51)	48,58,907.1 (100.00)
Bajra	1,24,511.4 (4.34)	88,583.6 (3.09)	5,01,389.7 (17.49)	18,71,255.7 (65.27)	1,38,494.2 (4.83)	69,236.9 (2.42)	73,269.9 (2.56)	28,66,741.4 (100.00)
Total	7,29,177.0 (5.08)	7,38,996.6 (5.14)	27,15,813.3 (18.91)	93,39,887.7 (65.02)	3,77,476.7 (2.63)	2,43,301.5 (1.69)	2,19,809.7 (1.53)	1,43,64,462.5 (100.00)

Note: Figures in bracket are percentage to total.
Source: Primary Survey, 2013

Source-wise Energy use

Chemical fertilizers (NPK) have supplied the bulk amount of energy (93,32,947.4 k.cal./hect.) in agriculture of the district followed by diesel pump set energy (23,57,947.9 k.cal./hect.), tractor energy (13,38,878.6 k.cal./hect.), human energy (8,23,033.2 k.cal./hect.) (Table 3). Seed energy accounted the minimum average amount of energy (5, 11,655.4 k.cal./hect.) as farmers are used less quantity of crop seeds as compare to other selected sources of energy.

Human, Diesel pump set, chemical fertilizers and seeds have supplied more amount of energy for the production of wheat crop as compare to mustard and bajra crop. Under chemical fertilizers, nitrogenous (N) has supplied bulk amount of energy for the production of each selected sample crop followed by phosphatic (P) and Potassic (K). Tractor produced more amount of energy for the production of mustard crop (5,48,960.9 k.cal./hect.) as compare to wheat (4,70,287.0 k.cal./hect.) and bajra crop (3,19,630.7 k.cal./hect.). As mustard crop required more number of ploughing as compare to wheat and bajra crops.

Table−3: Source-wise Use of Energy for Production of Selected Crops in Bhiwani District, 2012-13

Crop	Energy Consumption in Average K.Cal./Hect.								Total
	Human	Diesel Pump Set	Chemical Fertilizers				Seeds	Tractor	
			N	P	K	Total (NPK)			
Wheat	3,50,757.0 (5.28)	12,03,165.9 (18.12)	37,38,349.9 (56.31)	3,87,464.4 (5.84)	21,299.0 (0.32)	41,47,113.3 (62.47)	4,67,490.8 (7.05)	4,70,287.0 (7.08)	66,38,814.0 (100.00)
Mustard	2,47,469.5 (5.09)	7,19,787.8 (14.81)	28,75,260.6 (59.18)	3,51,916.3 (7.24)	89,212.2 (1.84)	33,16,389.1 (68.26)	2,62,99.8 (0.54)	5,48,960.9 (11.30)	48,58,907.1 (100.00)
Bajra	2,24,806.7 (7.84)	4,34,994.2 (15.18)	18,06,944.3 (63.03)	62,500.7 (2.18)	0000 (0.00)	18,69,445.0 (65.21)	1,78,64.8 (0.62)	3,19,630.7 (11.15)	28,66,741.4 (100.00)
Total	8,23,033.2 (5.73)	23,57,947.9 (16.42)	84,20,554.8 (58.62)	8,01,881.4 (5.58)	1,10,511.2 (0.77)	93,32,947.4 (64.97)	5,11,655.4 (3.56)	13,38,878.6 (9.32)	1,43,64,462.5 (100.00)

Note: 1. N- Nitrogenous P- Phosphatic K- Potassic
2. Figures in Brackets are Percentage to Total
Source: Primary Survey, 2013

Crop-wise Energy Input Output Ratio

'Energy input output ratio' described as the ratio of total energy input and total energy output. It generally, reflects the energy efficiency of a particular crop in the agricultural production process or it indicates that how much energy output (agricultural output) produced per unit of energy consumed [14,15,16]. In the present research study, all the selected sample crops i.e. wheat, mustard and bajra were recorded as energy efficient crops in the district as all the same selected sample crops have shown energy input output ratio less than 1.00 (Table 4). If the energy input output ratio less than1.00 then it reflects the energy efficiency of a crop. Though, wheat crop has produced more output than mustard and bajra crop in each block of the district but it has highest average energy input output ratio (0.47) followed by mustard (0.42) and bajra (0.39) crop. Therefore, wheat has recorded as a least energy efficient crop while bajra crop recorded most energy efficient crop among selected sample crops in the district. In other words, bajra crop has consumed minimum average amount of energy to produce one unit of crop production as compared to wheat and mustard crop. Thus, bajra crop is more economical and beneficial than wheat and mustard crop in the district.

Table−4: Crop-wise Energy Input Output Ratio in the Blocks of Bhiwani District, 2012-13 (Average K.Cal./hect.)

Block	Wheat *(Rabi)*			Mustard *(Rabi)*			Bajra *(Kharif)*		
	Input	Output	Input Output Ratio	Input	Output	Input Output Ratio	Input	Output	Input Output Ratio
Bhiwani	63,73,371	1,56,44,034	0.41	36,62,818	1,16,46,720	0.31	28,16,930	75,52,553	0.37
Loharu	77,45,484	1,53,20,754	0.51	50,10,872	1,12,68,599	0.44	38,29,652	85,05,787	0.45
Bawani Khera	65,75,213	1,43,85,632	0.46	47,61,149	1,09,77,689	0.43	27,53,720	72,73,860	0.38
Kairu	65,17,368	1,38,55,930	0.47	48,58,932	1,16,03,922	0.42	26,38,240	72,36,820	0.36
Badhara	67,06,611	1,40,08,368	0.48	50,96,293	1,18,40,619	0.43	29,19,352	71,22,685	0.41
Behal	65,89,763	1,30,97,214	0.50	53,28,093	1,21,91,641	0.44	28,54,137	68,07,148	0.42
Tosham	63,15,643	1,30,63,401	0.48	52,32,571	1,11,32,114	0.47	26,73,383	66,51,541	0.40
Dadri-I	61,01,885	1,34,81,894	0.45	50,31,027	1,11,65,919	0.45	26,60,293	67,62,215	0.39
Siwani	66,06,652	1,31,75,351	0.50	45,17,033	1,03,88,287	0.43	26,55,498	69,96,202	0.38
Dadri –II	68,56,150	1,54,29,846	0.44	50,90,283	1,32,83,293	0.38	28,66,209	78,27,610	0.37
District Average	66,38,814.0	1,41,46,242.4	0.47	48,58,907.1	1,15,49,880.3	0.42	28,66,734.6	72,73,642.1	0.39

Source: Primary Survey, 2013

Correlation between Energy Use and Agricultural productivity

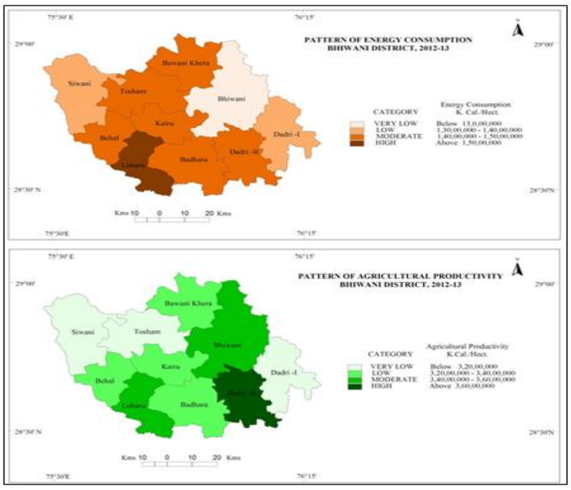
The use of modern energy inputs play an important role in improving the crop productivity and fertilizers are the most important determinants of agricultural productivity [17]. The greater amount of agricultural production and agricultural productivity depends upon various factors but energy inputs are most valuable [18]. Appropriate use of irrigation water, better placement of seeds and balance use of fertilizers resulted into increase in the agricultural productivity [19].

In the present study, correlation has been computed to determine the relationship between energy use and agricultural productivity by applying the Karl Pearson's formula of correlation coefficient. In this study, the energy use has been taken as independent variable (X) and agricultural productivity as dependable variable (Y) (Table 5). The study has found that there exist a positive correlation between energy use and agricultural productivity in agriculture of the district having a correlation value of 0.34. But, this degree of correlation (0.34) is low which indicates that there is a weak positive relationship between energy use and agricultural productivity in agriculture of the district. The Study has also found that there are lots of spatial variations in the level of energy use and agricultural productivity in agriculture of the district due to undulating topography, spatial variations in soil fertility and use of energy inputs (Figure 2).

Table–5: Energy Use and Agricultural Productivity in Selected Sample Crops in Blocks of Bhiwani District, 2012-13 (Average K.cal./hect)

Block	Energy Use (X)	Agricultural Productivity (Y)
Bhiwani	1,28,53,119	3,48,43,307
Loharu	1,65,86,008	3,50,95,140
Bawani Khera	1,40,90,082	3,26,37,181
Kairu	1,40,14,540	3,26,96,672
Badhara	1,47,22,256	3,29,71,672
Behal	1,47,71,993	3,20,96,003
Tosham	1,42,21,597	3,08,47,056
Dadri- I	1,37,93,205	3,14,10,028
Siwani	1,37,79,183	3,05,59,841
Dadri - II	1,48,12,642	3,65,40,749

Source: Primary Survey, 2013



Fig–2: Map

Source: Primary Survey, 2013

CONCLUSION

Thus, based on above information it can be stated that the use of energy inputs play a significant role in agriculture of Bhiwani district. But, the growth and development of agriculture in terms of agricultural production and productivity in the district is still far behind as compare to other districts of the Haryana state. In case of bajra crop, energy use strongly leads to the production and its productivity in the district. But in view of wheat and mustard crop, energy use does not provide more support to increase their production and productivity due to climatic variability, poor quality of soil and ground water, undulating agricultural field, increasing incidence of pests, weeds and diseases, delay and shortage of good quality seeds and fertilizers, erratic and poor supply of canal water in the district. Hence, the agricultural productivity can be improved in the district by promoting sustainable agricultural development process.

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