Journal of Agricultural Development and Policy, 2022
Volume 32, No. 1, 7-15

Trends in Energy Use in Punjab Agriculture

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Abstract

The composition of energy use in Punjab agriculture has changed substantially, with a significant shift from the animal and human power towards machines, electricity and diesel. Energy use efficiency is in a continuously declining phase as the energy ratio has declined from 11.8 in 1980-81 to 8.9 in 2018-19. For paddy and wheat occupying about 80 per cent of gross cropped area in Punjab, though the energy use efficiency is approximately the same i.e. 5.12 and 5.32, respectively and the respective energy productivity values are 0.15 Kg/MJ and 0.23 Kg/MJ, but the Specific energy of 6.8 MJ/Kg for paddy compared to wheat i.e. 4.4 MJ/Kg stresses the need for the adoption of energy saving technologies especially in paddy cultivation. The share of commercial energy sources in the input energy has been on the rise and forms about 97 per cent of it. Use of direct energy is higher (i.e. 53 per cent) than the indirect energy use. Amongst the direct energy sources, electricity, while fertilizers amongst the indirect energy sources form the major share of the input energy. The overwhelming significance of irrigation water, chemical fertilizers and electricity consumption in the energy input indicates that there exists an opportunity for improving energy productivity of crop cultivation in the state and this can be achieved primarily through the use of proven energy conservation/ management practices and technologies. There is need for proper management of inputs at farm level and this can be achieved by educating the farmers regarding proper utilization of the scarce farm inputs along with creating awareness about the harmful effect of excessive use of energy inputs. In addition to these, Government policies aimed at improved energy efficiency must also be coherent and regard the synergies and trade-offs with the policies addressing issues of productivity, water use and food safety.

Keywords: Commercial, Direct, Energy, Efficiency, Inputs

JEL Classification: A10, Q10, Q20, Q30, Q40, Q47

Introduction

Agriculture, basically an energy conversion industry, requires energy as an essential input to production, enhancing food security, adding value and contributing to rural economic development. Efficient use of energy by the agriculture sector seems as one of the conditions for sustainable agriculture because it allows financial savings, fossil resources preservation and air pollution reduction (Pervanchon *et al,* 2002). Improvement in the energy efficiency of the agricultural sector has attracted global attention as the key driver for sustainable development and has become one of the best strategies to reduce commercial energy demand and combat climate change (Cardozo *et al,*2018). Energy efficiency improvement and energy saving are conducive to achieve environmentally friendly economic development (Bayar *et al,* 2019).

Energy Analysis provides a relevant view of the specificity of agriculture as a user and a producer of energy simultaneously. Energy Analysis also results into significant approach to explore the causes of variations in energy results. It helps to view efficiency of farming process through the production of various criteria. Energy analysis can therefore play a significant role in the evaluation of sustainability of agricultural process. In this backdrop the present study was carried out to study energy input use pattern and its efficiency in Punjab agriculture.

Data Sources and Methodology

The present study is based on secondary data collected from different sources like published research papers, reports, manuals and thesis were used. Also, data were extracted from the website of Directorate of Economics and Statistics for the year 2018-19 regarding the input use i.e. human labour, fertilizers, Farm yard manure (FYM), machine use, chemicals, main product and by product for paddy and wheat cultivation in Punjab. The data on inputs and output were converted to energy units using embodied energy equivalents

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for each input and output energy type, and expressed in Mega Jules (MJ) using specific energy coefficients (Table 1). Data on crop grain yield was used for the estimation of straw yield using grain to residue ratio method (Chauhan, 2012).

Table 1. Energy coefficients used in energy calculation for crop cultivation

Energy source	Energy coefficient (MJ/unit)
Human labour (h)	1.96
Animal labour (h)	14.05
Fertilizer(kg)	
N	60.6
P_2O_5	11.1
K_2O	6.7
Farmyard manure (FYM)	0.3
Chemicals (kg)	
Granular chemicals (Kg)	120
Liquid chemicals (litre)	102
Machinery (h)	62.7
Diesel (litre)	56.31
Main product or Seed/Grain (Kg)	
Paddy and wheat	14.7
By product (Kg)	
Paddy and wheat straw (kg)	12.5
Electricity (kWh)	11.93

Source: Singh and Singh, 2002

Classification of Farm energy Resources

Further, each agricultural input was categorized as direct and indirect energy source. Direct energy sources (DE) are those which bring out the intended energy directly viz. diesel fuel, human labor, electricity and irrigation, while the indirect energy sources (IDE) comprise energy sources i.e. seed, agri-machinery, fertilizers and chemicals used in crop cultivation. The energy sources were also classified into renewable energy (RE) and non-renewable sources (NRE). RE includes seed, human labor and irrigation, while NRE comprises diesel fuel, agri-machinery, electricity, chemical fertilizers and biocides (Ozkan *et al*., 2007 and Hatirli *et al*., 2006).

Results and Discussion

Scenario of energy use

In a world level study for trends of input energy, crop production and energy use efficiency for the period 1961–2014, it was observed that the spread of intensification was noticeable across Latin America, MICs, and Asia, while it had already happened in North America and Europe (reaching a maximum there around 1990) and had not reached Africa. It was observed that for Asia in comparison to other regions, the energy input level and crop production level showed a continuously rising trend during 1961 to 2011(Figure 1) while the Energy Use Efficiency (EUE) indicated a constant downward trend.

In case of Indian agriculture, the structure of energy use has changed substantially, with a significant shift from the animal and human power towards machines, electricity and diesel (Jha *et al.,* 2012). The total energy use in the agricultural operations has increased from 425.49×10^9 MJ in 1980–81 to 3219.56×10^9 MJ in 2016–17. The share of direct energy in Indian agriculture is also increasing in a time period of 1980-81 to 2016-17 from the 42.2% to 65.5% while share of indirect energy is decreased from 57.8% to 34.5% in this time period (Figure 2). The energy input per hectare of gross cropped area between 1980–81 and 2000–01 increased drastically from 2.46×10^3 to 12.04×10^3 MJ/ha due to a rapid expansion of tube-well irrigation in the Indo-Gangetic Plains (Jha *et al.,* 2012). During 2016–17, the per hectare energy consumption was 16.23×10^3 MJ/ha. Among the direct sources, the share of electricity in total energy use increased from 40 to 64 per cent while among the indirect sources, nitrogen fertilizers contributed the most, with a share of 31 per cent in 2016–17. The energy values of fertilizers applied to crops have increased from about 245×10^9 to 1100×10^9MJ while the share of indirect energy from pesticides reduced to 0.20 per cent in 2016–17 from 1.27 per cent in 1980–81.

It has also been observed that the level of diffusion of technologies and the use of energy-intensive inputs across crops determines the share of energy in the cost of. In a national level study, the energy share of major crops in India ranged from 55 per cent for rapeseed & mustard to 74 per cent for soybean in triennium ending 2015–16 (Figure 3). Though wheat cultivation in India is highly mechanized, still the share of energy in the total cost for wheat cultivation (56%) is less than that for rice (63%). This is because, traditional energy sources like human labour are used more in rice in comparison to wheat.

Groundnut, potato, maize and cotton crops have higher energy share in the cost of cultivation in contrast to those by pulses, oilseeds and sugarcane. The share of direct energy in form of human & machine labour and machine use varied from 30 per cent in potato to 56 per cent in bajra. In case of rice, it was 48 and was 40 per cent for wheat.

Further, analysis of energy consumption pattern in major states of India during 2015–16 indicated that Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra lead in energy consumption with energy use being more than 3 lakh MJ per hectare (Figure 4). Very high level of electricity consumption for irrigation contributed the

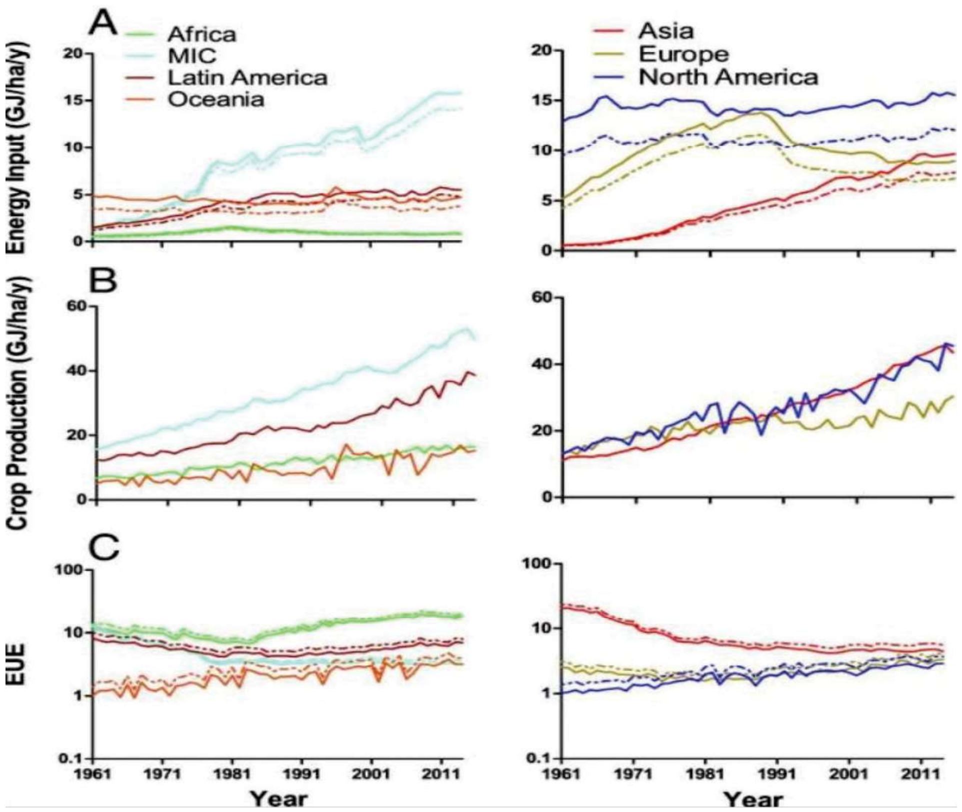


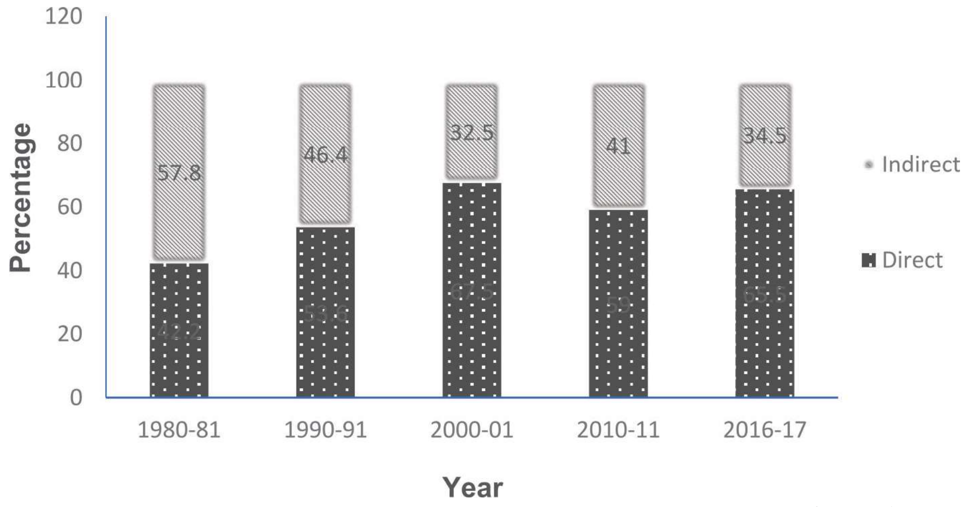
Figure 1. World Level Energy Scenario

(A) Annual energy input (GJ·ha−1 ·y−1) as the sum of fertilizers (N, P, and K), machinery (construction and maintenance), and fuel.

(B) Total annual energy production from all crops (output; GJ·ha−1 ·y−1).

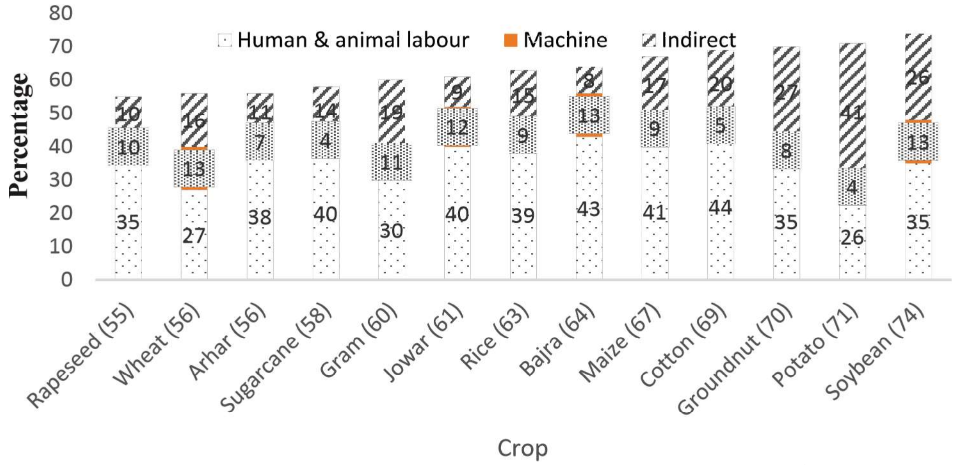
(C) Annual EUE for each continent estimated as the ratio of crop production (GJ) to energy input (GJ). Solid and dashed lines in A and C are for 10- and 30-y machinery lifespans, respectively.

Source: Pellegrini et al., 2018 in which data for input, production, and land are from FAOSTAT, 2017



Source: Jha *et al,* 2021

Fig. 2. Energy use in Indian agriculture (% share in total energy)



Source: Jha *et al.,* 2021

Fig 3. Crop wise shares of direct and indirect energy inputs in total energy cost in India

Note:(i) Figures in parentheses indicate per cent share of energy cost in total cost of cultivation of respective crop

(ii) Human& animal labour and machine are part of direct energy

maximum per hectare energy consumption in these states since the groundwater tables in these regions are deep. Energy consumption in Punjab (2.25 lakh MJ/Ha) and Haryana (96 thousand MJ/Ha) is also high as agriculture has become energy-input intensive in these two states since the green revolution. Assam, Jharkhand, Bihar and Odisha consume very less energy in crop cultivation, hence these eastern states are now identified for the second green revolution in the country through improvement in input use.

Energy consumption in relation to food grain yields indicated that Gujarat, Andhra Pradesh, Tamil Nadu and Punjab use more energy and also produce higher yields, while on the other extreme, Assam, Odisha, Uttarakhand and Jharkhand consume less energy in farming and also have lower yield levels. Haryana, Bihar and Uttar Pradesh have achieved higher yield levels despite lower energy consumption per hectare gross cropped area.

Energy input output balance in agriculture

Analysis of energy balance in Punjab agriculture sector revealed that energy use efficiency is in a continuously declining phase. The energy ratio has declined from 11.8 in 1980-81 to 8.9 in 2018-19(Figure 5). The steady decline in the energy-use efficiency in the state agriculture is a matter of great concern and calls for optimal and proper utilization of energy inputs involved in various farm operations. Therefore, energy analysis becomes the basis for sound management and policy decisions for conservation and efficient management of scarce resources for improved agricultural production.

Punjab agriculture is dominated by paddy-wheat monoculture with these crops together occupying more than 80 per cent of the gross cropped area in the state. Energy analysis for paddy and wheat in Punjab depicts that energy use efficiency is approximately the same for both the crops i.e. 5.12 and 5.32 respectively during 2018-19 (Table 2).

Table 2. Energy input-output analysis for major crops in Punjab, 2018-19

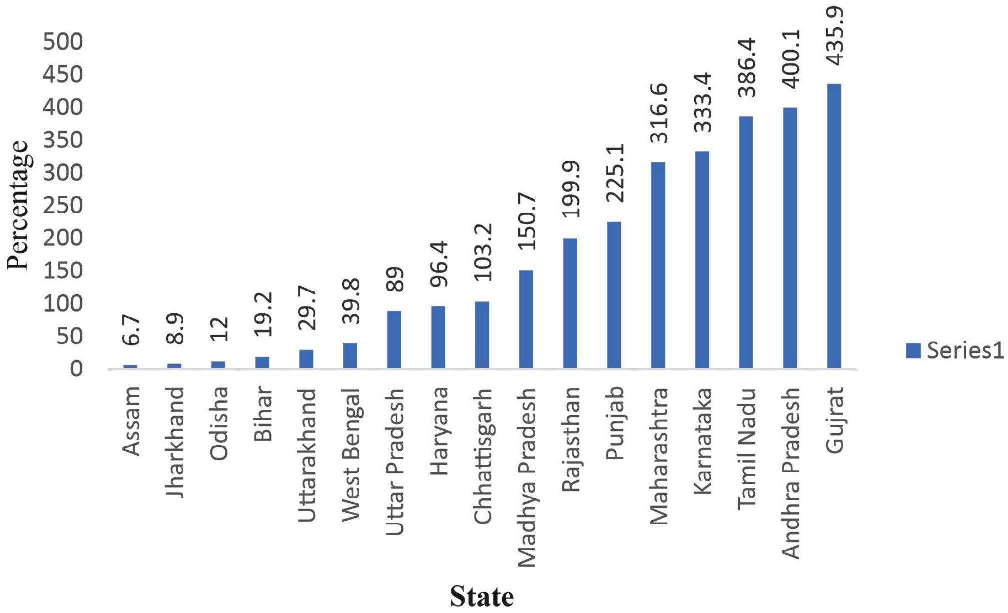
Particulars	Paddy	Wheat
EUE	5.12	5.32
Net energy gain (lakh MJ/Ha)	1.94	0.95
Specific energy (MJ/Kg)	6.8	4.4
Energy productivity (Kg/MJ)	0.15	0.23

Source: Author's calculations

The energy productivity values were 0.15 Kg/MJ and 0.23 Kg/MJ for paddy and wheat respectively. However, in terms of Specific energy i.e total energy used to produce one kg of grains, paddy has a higher requirement i.e. 6.8 MJ/Kg compared to wheat i.e. 4.4 MJ/Kg which again stresses the need for adoption of energy saving technologies in paddy cultivation in the state.

Component wise analysis of energy use for paddy cultivation in South Western Punjab revealed that among different inputs due to high water requirements of paddy crop major share of energy (40.01%) comes from irrigation water followed by fertilizers (24.7%), electricity for pumping water (17 %), diesel fuel (8.8%), chemicals (7.7%), machinery use (0.8%) and seeds (0.3%) as shown in Figure 6.

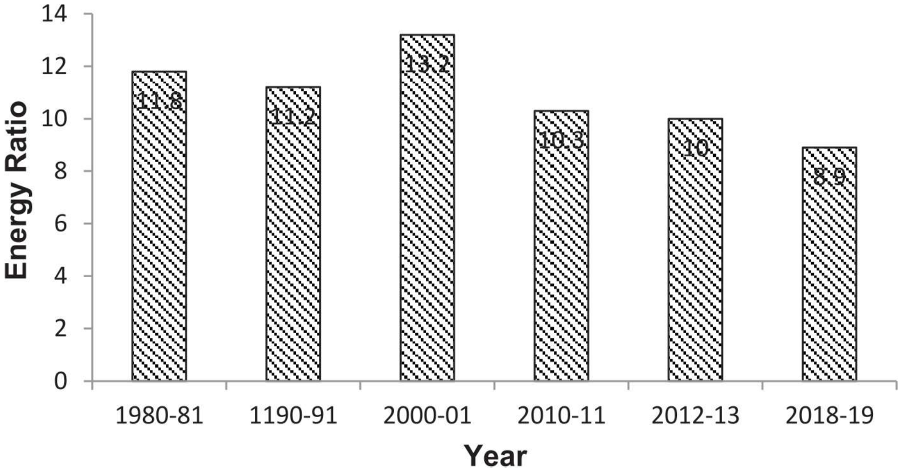
Besides depleting the ground water, the consumption of energy in pumping underground water for paddy cultivation is increasing overtime. Electricity being free for agriculture sector, is again putting a great burden on the state exchequer. The farmers were found to be using more than recommended doses of the fertilizers especially urea in excess because of lack of awareness, low price and easy availability. The study



Source: Jha *et al.,* 2021

Fig. 4. State wise energy consumption in India (000MJ/ha GCA, 2015-16)

Note: Energy consumption per GCA at national level was 178.5 000MJ/ha



Source: Kumar H, 2017 and Author's calculations from data extracted from DES for the year 2018-19

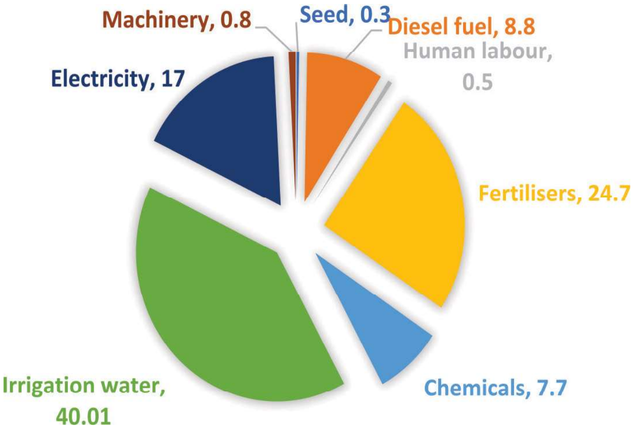
Fig. 5. Energy Balance in Punjab Agriculture

pointed towards rational use of irrigation water, electricity and fertilizers with efficient strategies to increase EUE of paddy cultivation in the state. Similarly, a study for Karnataka highlighted the indiscriminate use of nitrogen fertilizers and irrigation water accounting for 36 per cent and 39 per cent of total energy input in the transplanted paddy (Basavalingaiah *et al*., 2020).Another study on the rice production in India revealed that irrigation and fertilizers accounts for the largest share of total energy input (Chaudhary *et al.,* 2017). Thus, there is need to take suitable steps to increase the EUE in paddy cultivation either by minimizing input use or by using them judiciously.

Similarly, in a study for wheat crop cultivation in Punjab, fertilizers took away the major share i.e. (44.5%) and irrigation (15%), electricity for pumping irrigation water and diesel fuel (14.7%) together constituted the major key input energy use sources (Figure 7).

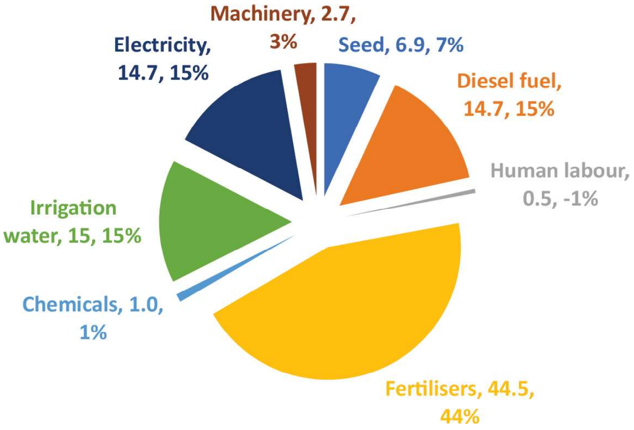
Again, this points towards an urgent need to manage the use of fertilizers in wheat crop to improve the EUE in wheat cultivation of Punjab.

It was also observed that the use of direct energy in



Source: Singh et al., 2019b

Fig. 6. Input energy in paddy cultivation in Punjab (% share)



Source: Singh et al., 2019a

Fig. 7. Input energy in wheat cultivation in Punjab (% share)

agriculture is higher i.e.,53 per cent than indirect energy use (47%) in Punjab agriculture (Figure 8). Amongst the direct energy sources, electricity and fertilizers amongst the indirect energy sources form the major share of input energy.

Categorization of energy as commercial and non commercial energy sources indicated that the use of non-commercial energy in Punjab agriculture had a share of about 35.5 per cent in the total input energy use during 1980-71 but with time it has declined to merely 2.3 per cent during 2018-19 (Figure 9).

The use of commercial energy in the state agriculture forms about 97.7 per cent share in the total input energy during 2018-19 though it was about 87.1 per cent during 1980-81of the total input energy needs. All this point out towards judicious use of commercial energy sources along with exploration of the possibilities which can help to raise the share non-commercial energy in the state agriculture.

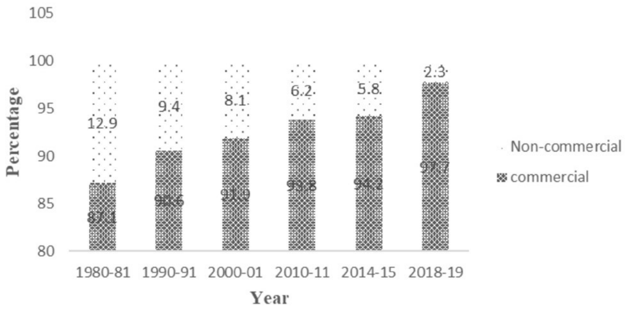
Energy saving technologies/methods

Different studies indicate that by using the scarce farm inputs in a rational manner, the energy can be saved on farm. In a study for Punjab, it was observed that about 47 per cent of input energy can be saved by using electricity judiciously (Table 3) in paddy cultivation. This can be achieved by adjusting the schedule of irrigation and sowing time of rice. Also, about 26 per cent energy savings is possible in terms of irrigation water, diesel fuel (9.7%), chemical fertilizers (9.4%), biocides (5.4%). The results revealed that the overwhelming significance of irrigation water, chemical fertilizers and electricity consumption in the energy input in rice cultivation underpin the opportunities for energy saving.

The real crop water productivity (marketable yield/ Evapotranspiration) was more by 17 per cent in 25th June transplanted rice than 25th May, 23 per cent in short duration than long duration varieties (Jalota *et al.,* 2009). It may be mentioned here that during 2020-21, paddy area under short duration varieties was only 64.1 per cent in the state. In another study on discerning sustainable interaction between agriculture and energy in India, indicated that irrigation, use of machinery and energy–intensive inputs like fertilizers

Source: Singh et al 2019b

Fig. 8. Input energy in Punjab Agriculture Direct and Indirect (% share in total energy)



Source: Kumar H et al., 2017 and Author's calculations from data extracted from DES for the year 2018-19

Fig. 9. Input energy use in Punjab Agriculture Commercial and Non-commercial (% share in total energy)

Table 3. Energy saving from different inputs on following the recommended amounts in rice cultivation in south-western Punjab, India

Input item	Percent share of total input energy saved
Seed	0.2
Diesel Fuel	9.7
Human Labour	0.2
Chemical Fertilizers	9.4
Biocides	5.4
Irrigation Water	27.5
Electricity	46.9
Machinery	0.7

Source: Singh et al 2019b

account for the bulk of energy use in agriculture. Since the fast depletion of non-renewable energy sources is widely acknowledged, and Sustainable Development Goal 7 also indicates the need for transition to clean, green and sustainable energy sources, there is need to increase the use of renewable and bioenergy sources. Agriculture plays an important role as a producer of feedstock in the production of biofuels. Given the untapped potential and nascent market for biofuels in the country, promotional policies that can foster the production of this sector without compromising on food security need to be crafted and implemented (Jha *et al.,* 2021).

Adoption of energy saving technologies like direct seeding of rice (DSR) can also be one of the steps to increase farm EUE in agriculture. In a study for Kerala, energy use efficiency for paddy cultivation under transplanting and Direct Seeded (DSR) methods was estimated at 4.4 and 7.3 respectively (Table 4). The reason for higher EUE under DSR was mainly attributed to the large decrease in energy inputs and study also highlighted the scope for saving energy in transplanting method by 6 per cent.

Total energy input is higher in transplanted paddy production while energy efficiency level is higher in DSR indicating the need to decrease dependency on energy which can be achieved either through efficient use of energy or utilizing organic input (Baharudin and Arshad, 2014). Yuan and Peng (2017) reported that in China, in comparison to commonly followed paddy cultivation practices, the adoption of simplified and reduced input practices resulted in increased EUE and energy productivity by about 19 and 25 per cent, respectively.

Similarly in state level study for wheat crop cultivation, use of energy saving treatments by using conservation method of plantings like Happy Seeder, Zero Tillage and Rotavator were observed to be having higher EUE and less specific energy as compared to conventional tillage (Table 5). Higher

Table 4. Energy Comparison of Transplanted Rice and Direct Seeded Rice in Kerala

Parameter	Puddled Transplanted rice	Direct Seeded Rice
EUE	4.4	7.3
Net energy gain (MJ/Ha)	120171	45403
Specific energy (MJ/Kg)	6.4	4.1
Energy productivity (Kg/MJ)	0.2	0.3

Source: Basavalingaiah et al., 2020

Table 5. Energy use efficiency, Energy production, Energy specific under different treatments for wheat in Punjab

Treatment	Energy use efficiency	Energy specific (MJkg^{-1})
Happy seeder	9.44	3.31
Zero tillage	10.48	2.88
Rotavator	9.11	3.65
Conventional tillage	8.90	3.96

Source: Singh and Kaur , 2017

output input ratio and lower specific energy were recorded under direct drilling methods compared to traditional method for wheat.

Another study for rice-based production systems in Indo-Gangetic Plain region indicated that conservation tillage treatments reduced the energy requirements over conventional tillage treatments and the savings of energy were attributed to reduced energy use in land preparation (69–100%) and irrigation (23–27%), which consumed a large amount of fuel energy (Nandan *et al.,* 2021). Conservation-tillage treatments increased grain and straw yields of crops, eventually increased the output energy (6–16%), net energy (14–26%), energy ratio (25–33%), eventually increased the output energy (6–16%), net energy (14–26%), energy ratio (25–33%), and energy productivity (23–34%) indicating that the zero tillage-based crop establishments in rice-based production systems could be the sustainable alternative to conventional tillage-based agriculture as they conserved non-renewable energy sources, reduced water requirement, and increased crop productivity.

Conclusion and Policy Implications

There exists an opportunity for improving energy productivity of crop cultivation in the state. Improved energy efficiency can be achieved primarily through the use of proven energy conservation management practices and technologies. These measures include resorting to decreased plough, replacing natural fertilizers (manure and organic fertilizers) with chemicals, returning remains and resorting to precise agriculture based on the judicious use of inputs, utilizing alternate sources of energy like inclusion of legume crops into the crop rotation. There is need for proper management of inputs at farm level and this can be achieved by educating the farmers regarding proper utilization of the scarce farm inputs along with creating awareness about the harmful effect of excessive use of energy inputs.

Though, feeding the increasing population is difficult and perhaps not possible without NRE, but due consideration must be given to the environmental impacts of the use of chemicals and fossil fuels. There is a strong need to achieve a sustainable food production system by increasing the share of RE. In addition to these, Government policies aimed at improved energy efficiency must also be coherent and regard the synergies and trade-offs with the policies addressing issues of productivity, water use and food safety. Improving the energy use efficiency by using less energy to provide the same level of output and service is an important instrument that policy makers can use to ensure a number of positive outcomes that can deliver several government priorities, from economic growth to reduced GHG emissions to energy and food security. In agricultural production the input energy determines the farm profitability which heavily depends upon the farmers' investment in improved farming systems. Thus, there is need for cost-effective energy measures from an economic as well as ecological point of view.

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Received: January 3, 2022 Accepted: April 2, 2022