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Energy and monetary analysis of soybean cultivation under climate smart sowing techniques in Malwa region of Madhya Pradesh, India

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Abstract

Energy is the most valuable input in agricultural production. Energy and monetary analysis is used to find the energy and economic indices for better management. This study was conducted during 2020-21 and 2021-22 in *kharif* season in Malwa region to analysis the energy and monetary indices for the soybean cultivation under climate smart sowing techniques. Three sowing techniques were adopted for the trial *i.e.* T_1- Sweep Blade type, T_2- Broad Bed furrow (BBF) and T_3- Furrow Irrigated Raised Bed System (FIRBS). Randomized Block Design statistical design with eight replications were applied for analysis. The energy equivalent of different inputs and output were used to determine the energy indices. FIRBS resulted highest seed yield (1403 kg ha^{-1}), net return (₹32729/-) and B:C (2.14) and followed by BBF. Despite erratic climate, yield under climate smart sowing techniques (FIRBS and BBF) were better than Farmer's practice. The lowest total input energy requirement 11141MJha^{-1} was noticed in T_1 and highest was 11847 MJha^{-1} in T_3. Difference in total input energy requirement occurred because of time taken for sowing and seed rate was differ in all sowing techniques. The maximum soybean output (seed and straw) energy obtained under FIRBS (54429 MJha^{-1}) and lowest was recorded in farmer's practice (43976 MJha^{-1}). The maximum energy ratio (4.59) obtained in FIRBS, followed by BBF (4.36) and lowest was recorded in farmer's practice (3.95). Among all the treatments, highest net energy return (42582 MJha^{-1}) was recorded with FIRBS sowing technique, followed by BBF (39042 MJha^{-1}). Energy profitability was highest (3.59) with FIRB system and closely followed by BBF system (3.36). Specific energy was minimum in FIRBS (8.44), while maximum observed in sweep blade system (10.00). Higher productivity with maximum net energy return of soybean cultivation can be achieved by adopting climate smart sowing techniques (FIRBS and BBF) as compared to other methods.

Keywords: BBF, climate change, FIRBS, energy analysis, Malwa, soybean

Introduction

Energy is the most valuable input in agricultural production, which is used in various forms such as mechanical, chemical and electrical (Singh and Ahlawat 2015) [34]. The productivity and profitability of agriculture depend upon energy use (Jat *et al.* 2015) [15]. The amount of energy used depends on the mechanization level, quantity of active agricultural work and cultivable land (Ozkan *et al.* 2004; Alam *et al.* 2005) [27, 1]. Increase in agricultural productivity with minimal energy utilization without any adverse impact on the environment is a pre-requisite of present agricultural practices (Prajapat *et al.* 2018) [29]. Energy input-output analysis is widely used to find the energy and economic indices for several crops. Within this context, several researchers have focused on determining efficiency in agricultural units, in different countries.

Soybean [*Glycine max* (L.) Merril] is one of the economical and valuable seed legume which has 25% contribution in global edible oil. India contributes 10% in total soybean area at global level. Soybean is known as "Golden bean", "Miracle crop" *etc*., because of its several uses. Soybean, a high-value nutritive crop, plays a significant role in overcoming problems of food and nutritional insecurity. Soybean crop played a pivotal role in solving the problem of malnutrition as it contains about 20% oil and 40% high quality protein (Rahangdale *et al.* 2022) [30].

The spread of the soybean in different regions of the country resulted into parallel growth of the oilseed industries and also earning foreign exchange through export of soy meal (Sharma *et al*. 2016) [32]. Soybean cultivation in India has steadily increased. It was a minor crop during the early 1970s but at present, it occupies third place in the oilseed production in India. Soybean crop became a lifeline for small and marginal farmers, but now scenario is changing due to climate change effects. Madhya Pradesh is known as 'soy state'. Currently Madhya Pradesh accounts for nearly 87% of the area under the crop in the country and contributes about 83% of the total national production (Kumari *et al*. 2019) [18]. Soybean raised mostly under rainfed conditions and important for the livelihood of small and marginal farmers in arid and semi-arid areas of the country. The soybean crop presently covers an area of about 12 million hectares with a total production of about 14 million tonnes.

Agricultural sector is most vulnerable to climate change which is supporting large proportion of population (Dupare *et al*. 2020) [8]. Erratic nature of rainfall and temperature due to climate change increases the risk for crops (Colussi *et al*. 2023) [6]. The negative impact of climate change on crop productivity has been reported globally (Bates *et al*. 2010; Lobell *et al*. 2011; Vermeulen *et al*. 2012) [2, 22, 36] and in India (Kumar and Parikh 2001; Mall *et al*. 2006; Zacharias *et al*. 2014) [17, 23, 37] also. The agricultural productivity for the entire world is going to decline due to climate change between 3 and 16% by 2080 (Cline 2007) [5]. Climate change is likely to reduce world food levels by about 1.5% per decade without adaptation mitigation strategies (Lobell and Gourdji 2012) [21]. The negative impact of climate change on soybean productivity also reported in India (Lal *et al.* 1999; Mall *et al*. 2006; Mohanty *et al*. 2017) [19, 23, 25]. The area of soybean in the country increases from merely 30,000 hectares in 1970-71 to more than 11.6 million ha during 2018-19 (Sharma *et al*. 2016) [32]. The average productivity of soybean improved but since last few years, it is stagnated around 1000 kg/ha and need to pay attention because of climate change.

The soybean crop is grown mainly in rainfed areas and variability in rainfall exposes the crop to dry spell as well drainage problem. The delayed monsoon, longer dry spells or early withdrawal of monsoon have been identified as major constraints for poor performance of the soybean crop (Peshin *et al*. 2018) [28]. The rainfall during sowing time and vegetative growth of the soybean crop has been disturbed. Soil, water and nutrients are basic factors for plant growth and development (Gupta *et al*. 2022; Jadav *et al*. 2022) [9, 11]. For soybean crop, water is limiting factor and in climate change scenario, management is required. Moisture conservation techniques can enhance production and productivity of the crop (Jadav *et al*. 2022) [11]. Climate smart sowing techniques based on land configuration can be manage water and other resources to improve soybean productivity. Resource conservation technologies such as ridge and furrow and raised bed planting have been found very effective in efficient use of water and minimizing soil erosion (Billore *et al*. 2018) [3].

In Malwa region, many times during *kharif* season, soybean crop suffer due to poor drainage during growth stage and moisture stress during dry spells. The *in-situ* moisture conservation practices make sure the production of crop through safe disposal of runoff or its retention for profile moisture as and when required. Excess rainfall during recent years severely affects the *kharif* crops production, therefore, urgent needs to adopt new sowing techniques which can be mitigate adverse effect of climate change on soybean production (Negi *et al*. 2018) [26]. Most of the farmers used seed drill for sowing of soybean on flat bed system, but due to improper drainage in the field, the yield of soybean reduced drastically. The climate smart technology of sowing on changed land configuration (BBF or FIRBS) have been found effective in mitigating the adverse effect of water stress and improvement in soil physical and biological environment. Plants get benefit from the improved drainage and aeration because roots penetrate readily. The planting of soybean on altered land configuration [broad bed furrow (BBF) or furrow irrigated raised bed system (FIRBS)] may reduce the deleterious effect of both extreme situations (deficit and excess) of rains (Jadav *et al*. 2022) [11]. Soybean crop can perform better under excess as well as deficit rainfall conditions if sown on ridges instead of flat land. This study was conducted to analysis the energy input-output and monetary indices for the of soybean cultivation under climate smart sowing techniques in Malwa region of Madhya Pradesh, India.

Materials and Methods

The field experiment was conducted during *kharif* season of two consecutive years (2020-21 and 2021-22) with collaboration of KVK Dewas of Malwa region in Madhya Pradesh. Three sowing techniques were adopted for the trial i.e. T_1- Sweep Blade type, T_2- Broad bed and furrow (BBF) and T_3- Furrow Irrigated Raised Bed System (FIRBS). Randomized Block Design (RBD) statistical design with eight replications were applied for experiment. JS 95-60 verity of soybean were sown for the experiment. Plot size was 10.0 m X 5.40 m. Seed rate for soybean was 80 kg/ha and row to row spacing was maintained at 45cm. 20:60:40 kg NPK basal were applied as recommended dose of fertilizer. Hand weeding was done to remove weeds from crop area. At 30 days after sowing, spray of Chloropyrifos 50% + Cypermethilin 5% @1 lit/ha carried out to control diseases. The experimental area have clayey soil. (Clay 59.3%, silt 30.42% and sand10.28%) with medium to deep in depth. Soil have pH of 7.4 and contain 0.44% organic carbon. Availability of Nitrogen, Phosphorus and Potash in the soil is 189 kg/ha, 17.3 kg/ha and 265 kg/ha respectively.

Methods of energy analysis

The energy requirements ($MJha^{-1}$) of each input for soybean production were calculated, determined and presented. General inputs in soybean production were machinery, human labor, chemical fertilizers, fuel, pesticide and seed. Output was soybean seed and straw as a product. The energy equivalent of different inputs and output were used to determine the energy values (Table 2 and 3). The human energy as an energy input was calculated by multiplying the number of man-hours (hr/ha) by estimated power rating of human labor ($MJha^{-1}$).

Energy indices

Following the calculation of energy input and output equivalents, to assess the indices of soybean production. The energy ratio, net energy return, energy profitability and specific energy were calculated as follow (Burnett 1982; Mittal and Dhawan, 1998) [4, 24].

$$\text{Energy Ratio (ER)} = \frac{\text{Output Energy (MJ/ha)}}{\text{Input Energy (MJ/ha)}}$$

$$\text{Net Energy Return} = \text{Energy Output (MJ/ha)} - \text{Energy Input (MJ/ha)}$$

$$\text{Energy profitability} = \frac{\text{Net Energy Return (MJ/ha)}}{\text{Input Energy (MJ/ha)}}$$

$$\text{Specific Energy (MJ/kg)} = \frac{\text{Energy Input (MJ/ha)}}{\text{Soybean Yield (kg/ha)}}$$

Monetary indices

Following formula were used to calculate different monetary parameters as follows:

Net returns (₹/ha) = Gross income (₹/ha) – Total cost of cultivation (₹/ha)

$$\text{B:C ratio} = \frac{\text{Gross returns (₹/ha)}}{\text{Cost of Cultivation (₹/ha)}}$$

Results and Discussion

The field experiment was conducted to analyze energy and monetary indices for soybean cultivation under climate smart sowing techniques. Results recorded as follows for this study.

Yield and monetary return

Data presented in Table 1 showed that maximum soybean yield of seed and straw was obtained 1403 kg ha^{-1} and 2705 kg ha^{-1} respectively under FIRBS. Under farmer's practice seed and straw production of soybean were 1114 kg ha^{-1} and 2208 kg ha^{-1} respectively. Planting of soybean using FIRBS seed drill resulted in seed yield by 21.93 percent over flat sowing (Singh *et al*. 2012) [33]. The yield enhancement to the extent of 33.3% obtained for soybean in raised bed planting over others (Dhakad *et al*. 2020) [7]. Planting of soybean on broad bed furrow system enhances the productivity by 21.19% as compared to flatbed planting (Jain, 2019) [14]. These findings also support our results. During experimental period, soybean crop yield was very low due to excess and continuous rainfall during crop growth period (*Kharif* season). Uniform distribution of rain was not occurred. July august witnessed dry spells whereas, during maturity/harvesting period got heavy rainfall. Seasonal rainfall (Above 1200 mm) occurred than normal rainfall (980 mm). However yield under climate smart sowing techniques (FIRBS and BBF) were better than Farmer's practice (Sweep blade System). FIRBS and BBF are performing better because during dry spell it conserve in-situ soil moisture. If excess rainfall occurred than better drainage facility was provided. Data presented in Table 1 showed that soybean (JS 95-60) recorded highest net return of ₹32729/- and B: C Ratio of 2.14 with treatment T_3 (FIRBS) followed by T_2, BBF (net return ₹ 27296/- and B:C Ratio of 1.97). The lowest was recorded with T_1, Sweep Blade type seed drill (net return ₹20600/- and B: C Ratio of 1.73). The monetary return were higher for the raised bed system than other methods (Jha *et al*. 2014) [16].

Less consumption of fuel was recorded in conventional seed drill but the productivity of soybean was observed highest in FIRB seed drill. The FIRBS is economically feasible as compared to other seed bed configurations in Malwa region of Madhya Pradesh (Gupta *et al*. 2018) [10]. The net returns are the best index of profitability of soybean crop and higher net returns per ha was recorded for soybean crop under the FIRBS whereas lower was recorded under BBF and other. The results of experiment indicated that for achieving higher productivity of soybean crop, the soybean crop should be sown in furrow irrigated raised bed system (FIRBS) (Verma *et al*. 2018; Jain 2019; Dhakad *et al*. 2020) [35, 14, 7].

The results showed that the practice of soybean cultivation on FIRBS and BBF were found superior in comparison with sweep blade system. Results also showed that BBF is at par with FIRBS. The results of the study indicated that the higher productivity with maximum net return of soybean cultivation can be achieved by adopting climate smart sowing techniques as compared to other method of sowing in Malwa region of Madhya Pradesh.

Energy analysis

The energy analysis of conducted study was aimed to estimating the difference in total energy inputs and outputs for soybean production under different sowing techniques. The inputs were in the form of mechanical power, human labour, seed, diesel fuel, chemicals, chemical fertilizers, farmyard manure and electricity. The data was then transformed into energy terms (MJ ha^{-1}) by applying the appropriate conversion factors. Input – Output energy analysis with energy indices were calculated for this study.

Input-Output energy

Data presented in Table 2 for energy in soybean cultivation revealed that the lowest total input energy requirement 11141 MJha^{-1} was noticed in T_1 (Sweep blade System) and highest was 11847 MJha^{-1} in T_3 (Furrow Irrigated Raised Bed System) followed by 11617 MJha^{-1} in T_2 (Broad Bed Furrow system). Difference in total input energy requirement occur because of time taken for sowing and seed rate was differ for all sowing techniques. Table 2 clearly indicate that seed bed preparation alone is require about 30% input energy from total energy input for soybean cultivation in all cases. Fertilizer application and threshing accounted 18% and 11% share of total energy input respectively. Table 3 also presented output energy of soybean. The maximum soybean output (seed and straw) energy obtained under FIRBS (54429 MJha^{-1}), after that followed by BBF (50659 MJha^{-1}). Lowest output energy was recorded in Sweep Blade system (43976 MJha^{-1}). Soybean production consumed a total of 8887 MJha^{-1} energy, which is mainly from commercial sources in Malwa region of Madhya Pradesh.[2] Diesel and fertilizer energy was the biggest energy input for soybean production and account for more than 70% of total energy (Jat *et al*. 2015) [15]. Among various field operations, seedbed preparation was observed to be maximum energy-consuming operation for soybean production under the different farmer's category. Seed bed preparation, sowing, harvesting and threshing were the main operations for energy consumption (Jat *et al*. 2015) [15]. Total output energy (71.90 x 10^3 MJha^{-1}) and net energy returns (62.32 x 10^3 MJha^{-1}) also reported for soybean cultivation (Lal *et al*. 2016) [20].

Energy indices

Energy ratio, net energy return, energy profitability and specific energy were calculated for each treatment separately (Table 4). This enabled comparing different management options in terms of energy use with reference to seed and straw yield, in order to identify the most energy efficient sowing techniques.

Energy ratio

Energy ratio is the indicator which shows the energy output under any treatment with each unit of input energy required. Energy output-input ratio varied across sowing techniques depending upon the yield of seed and straw (Table 1). Results presented in Table 4 showed that maximum energy ratio (4.59) obtained in FIRBS, followed by BBF (4.36). Lowest energy ratio was recorded in farmer's practice (3.95). Higher the biomass production (seed and straw), higher energy ration obtained.

Net energy return

There was lowest net energy return of 32835 MJha^{-1} obtained when the soybean was sown with sweep blade system (Table 4). However, it increased when crop was sown with advanced technique (BBF and FIRBS). Among all the treatments, highest net energy return (42582 MJha^{-1} was recorded with FIRBS sowing technique, followed by BBF (39042 MJha^{-1}). Net energy return increased with increase in yield of soybean under different treatment.

Energy profitability

Table 4 revealed that energy profitability varied with adoption of sowing techniques and increase when adopted advance sowing system. Energy profitability correlated with total biomass (Seed and straw) productivity. Sweep blade system gave lowest energy profitability (2.95). Energy profitability was highest (3.59) with FIRB system and closely followed by BBF system (3.36).

Specific energy

Specific energy varied across sowing techniques depending upon the yield of seed and straw (Table 5). Higher the biomass production (seed and straw), lower specific energy obtained. It was minimum in FIRBS (8.44), while maximum observed in sweep blade system (10.00) after that followed by BBF (9.03). Researcher also found same results *i.e.* energy ratio (7.50) and energy profitability (6.50) (Lal *et al.* 2016) [20].

Table 1: Yield and economics of soybean cultivation influenced under different sowing techniques (Mean data of 02 years)

Treatments	Seed yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Cost of Cultivation (₹/ha)	Gross Return (₹/ha)	Net Return (₹/ha)	B:C Ratio
T_1-(SB)	1114	2208	28376	48976	20600	1.73
T_2- (BBF)	1286	2541	28726	56522	27796	1.97
T_3- (FIRBS)	1403	2705	28801	61530	32729	2.14
SEm (±)	17.9	38.54	-	-	667	0.03
CD at 5%	53.2	99.88	-	-	1890	0.08

Table 2: Energy input for soybean cultivation influenced under different sowing techniques (Mean Data of 02 years)

Input	Qty/ha			Unit	Energy equivalent (MJ/unit)	Total Energy use (MJ)		
	T_1	T_2	T_3			T_1	T_2	T_3
Cultivator	2	2	2	hr	22.8	45.6	45.6	45.6
Panji	2.5	2.5	2.5	hr	37.62	94.05	94.05	94.05
Rotavator	3	3	3	hr	6.69	20.07	20.07	20.07
Tractor	7.5	7.5	7.5	hr	303.6	2277	2277	2277
Driver	7.5	7.5	7.5	hr	1.96	14.7	14.7	14.7
Diesel	22.5	22.5	22.5	Lit	56.31	1267.0	1267.0	1267.0
Seed drill	1.5	2.5	3	hr	12.54	18.81	31.35	37.62
Tractor	1.5	2.5	3	hr	303.6	455.4	759	910.8
Seed	80	76	72	Kg	3.6	288	273.6	259.2
Sowing labour	1.5	2.5	3	Man hr	1.96	2.94	4.9	5.88
Driver	1.5	2.5	3	Man hr	2.96	4.44	7.4	8.88
Diesel	4.5	7.5	9	Lit	56.31	253.40	422.33	506.79
Nitrogen- DAP (18:46))	20	20	20	Kg	60.6	1212	1212	1212
Phosphorus	60	60	60	Kg	11.1	666	666	666
Potash -MOP (K-60%)	40	40	40	Kg	6.7	268	268	268
Labour	8	8	8	Man hr	1.96	15.68	15.68	15.68
Tractor Dora	6	6	6	hr	37.62	225.72	225.72	225.72
Tractor	6	6	6	hr	303.6	1821.6	1821.6	1821.6
Labour	6	6	6	Man hr	1.96	11.76	11.76	11.76
Persuit (Herbicide)	0.91	0.91	0.91	Kg	288	262.08	262.08	262.08
Profenopos + Cypermethline	0.91	0.91	0.91	Kg	237	215.67	215.67	215.67
Water used in spray	1	1	1	m^3	1.02	1.02	1.02	1.02
Sprayer	32	32	32	hr	0.17	5.44	5.44	5.44
Labour	32	32	32	Man hr	1.96	62.72	62.72	62.72
Labour for harvesting	160	160	160	Man hr	1.96	313.6	313.6	313.6
Thresher	6	6	6	hr	200	1200	1200	1200
Electricity for threshing	6	6	6	Kwh	11.93	71.58	71.58	71.58
Labour	24	24	24	Man hr	1.96	47.04	47.04	47.04
Total Input						11141	11617	11847

Table 3: Energy Output of Soybean cultivation influenced under different sowing techniques (Mean Data of 02 years)

	Output (kg/ha)			Unit	Energy equivalent (MJ/unit)	Energy output (MJ)		
	T_1	T_2	T_3			T_1	T_2	T_3
Seed Yield	1114	1286	1403	kg	14.7	16376	18897	20617
Straw Yield	2208	2541	2705	kg	12.5	27600	31763	33813
Total output						43976	50659	54429

Table 4: Energy indices of soybean cultivation influenced by different sowing techniques (Mean Data (2020-21 and 2021-22)

Treatments	Input (MJ)	Energy Output (MJ)	Energy Ratio	Net Energy Return ($MJha^{-1}$)	Energy profitability	Specific energy ($MJkg^{-1}$)
T_1-(SB)	11141	43976	3.95	32835	2.95	10.00
T_2- (BBF)	11617	50659	4.36	39042	3.36	9.03
T_3- (FIRBS)	11847	54429	4.59	42582	3.59	8.44

Conclusion

It can be concluded that the higher productivity with maximum net return of soybean cultivation can be achieved by adopting climate smart sowing techniques (FIRBS and BBF) as compared to other method of sowing. These techniques are best suited in excess and less rainfall events. Higher the biomass production (seed and straw), higher energy ratio obtained. Net energy return increases on adoption of climate smart techniques as compare to traditional methods. Energy management should be considered as an important issue in terms of sustainable, efficient and economic use of energy. Increasing the use of renewable sources would be useful for higher net energy return and also for reducing negative effects on environment.

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Conflict of Interest

The authors declare no conflict of interest.

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