Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.6316

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **6 (4):** 303-323 (2018)

International Journal of Pure & Applied Bioscience

Review Article

OPEN ACCESS

Energetics in Various Cropping Systems

Shilpha, S. M.[1*], Soumya, T. M.[2], Mamathashree, C. M.[3], Girijesh, G. K.[4]

[1*]Senior research fellow, [2]Assistant professor, [3]Ph. D scholar, [4]Professor

Department of Agronomy, College of Agriculture, UAHS, Navile, Shivamogga, Karnataka

*Corresponding Author E-mail: shilphasm92agri@gmail.com

Received: 9.03.2018 | Revised: 15.04.201 | Accepted: 21.04.2018

ABSTRACT

Energy is one of the most valuable inputs in agriculture. It is being invested in various forms such as mechanical, chemical, electrical etc. The amount of energy used in agricultural production, processing and distribution should be significantly higher in order to feed the expanding population and to meet other social and economic goals. Agriculture in a way is an energy conversion industry. Energy use in agricultural production has been increasing faster than that of in many other sectors of the world economy because agricultural production has become more mechanized and commercial fertilizers dependent. Energetics is an approach to gauge, quantify and determine relationship between input and output energy to augment energy use efficiency and crop productivity. The study of energetics, which is relatively a stable index unlike economics of production, assumes paramount importance in the present era of energy crisis. It can be used to evaluate a given cropping system. The approach reduces the various factors and forces involved in a cropping system for energy units and describe the production process as energy transformation. In agriculture, because of the multi-stage character of production processes, the question of energy efficiency of production technologies becomes important.

Key words: *Energy, Input, Output, Cropping systems, Efficiency, System intensification*

INTRODUCTION

Energy is the basic need of human life and main stay of our nation economy. Alarming increase in population of India needs nine billion joules total energy for producing more than 250 million tonnes of food grain. The era of cheap energy is now ending and the population is becoming energy consumption conscious, due to rising cost of energy. Agriculture in a way is an energy conversion industry. Through photosynthesis plant transform solar and chemical energy derived from the soil into storable chemical energy as carbohydrates, proteins, fats and all cellulose. The production systems developed and adopted during green revolution were explorative and natural resources like soil and water were subjected to immense pressure beyond carrying capacity. This has led to degradation of not only crop system but also the life-supporting system as a whole.

Cite this article: Shilpha, S.M., Soumya, T.M., Mamathashree, C.M., Girijesh, G.K., Energetics in Various Cropping Systems, *Int. J. Pure App. Biosci.* **6(4):** 303-323 (2018). doi: http://dx.doi.org/10.18782/2320-7051.6316

The energy use in crop production has not been given adequate importance in earlier years, but the time has come, where more focus is to be given on renewable and non commercial source of energy, which are actively involved in crop production processes using intensive energies directly or indirectly. In crop production large share of energy is used for land preparation (20-25%), fertilizers (25-30%) and irrigation (25-35%), which require commercial non-renewable sources of energy like petroleum products. The non-renewable energy is expensive and liable to exhaust in near future. The steady decline in the energy-use efficiency in the present agriculture is a matter of great concern.

Intensive tillage and improper application of irrigation and nitrogen (N) fertilizer in conventional crop production systems results in higher cost of production and energy consumption. Generally, Indian soils are poor in organic carbon due to tropical climate. Moreover, continuous imbalanced use of fertilizers also deteriorates the soil health. This situation warrants opting to organic nutrient management for sustaining productivity of cropping system. Ultimately, energy productivity is decreasing as a consequence of escalating of inputs cost without proportionate improvement in output of particular crops. Zero tillage (ZT) technique is an ecological approach for soil surface management and seed bed preparation resulting in less energy requirement, less weed problem, better crop residue management and higher or equal yield[9] and is also energy efficient as compared to conventional tillage (CT) practices. The conservation tillage and adoption of integrated approach for nutrient management offer most potential measures to minimize the dependency on non-renewable energy leading to increased share of renewable energy, which will pave the way for sustainability.

What is energetics?

According to oxford dictionary mean science of energy, while system refers to an organized body of things. Therefore in relation to cropping systems, energetics is an approach to gauge, quantify and determine relationship between action and reaction, input and output energy to augment energy use efficiency and crop productivity both singly and in various adoptable combinations.

Need of energetics:

- ✓ The study of energetics, which is relatively a stable index unlike economics of production, assumes paramount importance in the present era of energy crisis and It's another analysis and management tool available to technicians, agriculturists and the general community.
- ✓ Research on energetics gained momentum through seventies out of unavoidable food needs and global fossil fuel crisis.
- ✓ Amount of energy invested through use of these inputs and quantity that is used by plants govern the crop growth and yield during their life cycle. It allows knowing how much energy is necessary to produce another type of energy.
- ✓ Energy use in agricultural production has been increasing faster than that in many other sectors of the world economy because agricultural production has become more mechanized and commercial fertilizer dependent. Owing to the high energy consumption during the production of agricultural inputs, in particular mineral nitrogen fertilizers, it is often questioned as to whether agricultural production is still energy efficient.
- ✓ In agriculture, because of the multi-stage character of production processes, the question of energy efficiency of production technologies becomes important.
- ✓ It also helped in the identification and re-alignment of energy resources in total and backward areas to push up productivity and to check the erosion of ecological balance.

The developed and developing nations are currently fully seized of and committed to resolve the energy problem through integrated and economically viable operational programmes. In India systematic studies on energetics were initiated with inception of All India Coordinated Research Project (AICRP) on Energy requirement in agriculture sector during 1971-72. It encompasses the consideration of an integrated approach to boost crop productivity through efficient use of energy to suggest paths for monitoring production strategies for feeding an increasing population.

Cropping system:

Cropping system is a critical aspect in developing an effective ecological farming system to manage and organize crops so that they best utilize the available resources such as soil, air, water, sunlight, labour, equipments etc. It cropping patterns used on the farm and their interaction with farm resources and farm enterprises and available technology which determine their makeup. It is executed in the field level.

Cropping systems followed in india:

- Rice based cropping systems - paddy fallow,paddy-paddy,paddy-wheat, paddy-potato
- Maize based cropping systems-maize-wheat, maize-mustard,maize-barley,maize-chickpea
- Sorghumbased cropping systems- Sorghum-chickpea,sorghum-berseem,sorghum-redgram
- Pearl millet cropping systems –PM-wheat, PM-chickpea, PM-wheat-groundnut
- Cotton based systems – cotton-wheat,cotton-sorghum,
- Groundnut based systems- groundnut-berseem, groundnut-wheat

Need of energetics in cropping systems: The energetics approach utilizes a system of calorific quantification of both the input materials, forces and the outputs products. It can be used to evaluate a given cropping system. The approach reduces the various factors and forces involved in a cropping system to energy units and describe the production process as energy transformation. It does not involve the vagaries of the market pricing system, and presumes stability of the energy units and of their relationships within and across commodities and communities. Energy analyses in agriculture include computation of the energy content in inputs that go into crop production and comparison of the same with the energy content in the output.

Need of energy analysis: Energy analysis has been used to provide an accurate overall evaluation of the non-renewable energy consumption linked to agriculture. By reaching beyond agricultural boundaries and including all the steps of crop input production, energy analysis is a useful indicator of environmental and long-term sustainability when comparing cropping systems in multi-criteria analyses and Life Cycle Assessments. Consequently, energy analysis helps develop sustainable agriculture. As summarized by Zahedhi *et al.*[15]. Energetic sustainability of agriculture “implies efficient use of non-renewable resources and the progressive substitution of renewable for non-renewable resources”. Energy use and output production knowledge in different cropping systems is needed to investigate how to improve EUE while maintaining crop production to free up land for energy crops .Unlike economic analysis, energy analysis indirectly provides information on both non-renewable energy depletion and climate change burdens linked to crop production, and it is not biased by the artificial changes in the price of goods. As a consequence, energy analysis can provide synthesized information useful to farmers and decision makers[15].

Energy measurement: Energy is a capacity to do work and is measured in unit joules(J) named after James Prescott Joule who carried out fundamental experiments and demonstrated the equivalence of heat work. Joule is too small a unit to be convenient in describing world energy supplies and resources, hence prefixes such as Mega Joule (106) and Giga Joule (109)are used. It is also expressed in Mega Calories. one Mega calories is equal to 10^6 calories. one calories is equal to 4.18 joules.

Energy classification:

On the Basis of source:

Direct energy: Energy sources which release directly. Ex.: Human, animal, electricity, motors, diesel engines , power tillers etc.

Indirect energy: Energy sources which do not release energy directly but release it by conversion process. Ex.: seed, manure, chemicals, fertilizers, and implements etc.

Renewable energy: Energy sources which can be used and replenished subsequently. Ex.: Human, Animal, solar, Wind, seed, Manure etc.

Non-renewable energy: - Energy sources which are not renewable in near future. Ex: coal, Fossil fuels, chemicals, fertilizers, implements manufacturing etc.

On the basis of economic value

Commercial energy: Energy sources like petroleum products and electricity which are capital intensive are called commercial sources of energy. Ex.: petrol, diesel, electricity.

Non-commercial energy: Energy sources which are available at relatively cheaper cost called non-commercial sources of energy. Ex: Human labour, bullocks, agro-wastes etc.

Fig 1: Trends of energy consumption in Indian agriculture

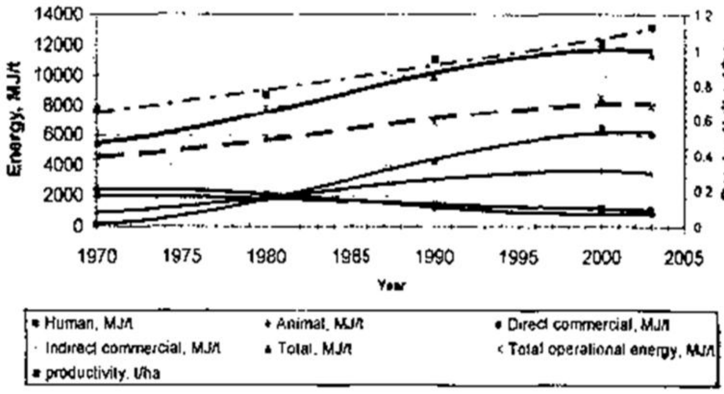

Fig 1: Trends of energy consumption in Indian agriculture

With increase in food grain productivity from 872 kg/hain 1970 to 1707 kg/ha in 2003, the total energy consumption in production agriculture increased from5440 MJ/t to 11391 MJ/t. The operational energy also increased from 4531 MJ/t (33.3% of total energy) in1970 to 7935 MJ/t (69.7% of total energy) in 2003, The share of fertilizer energy increased from 16.4to 30.1 %, electricity from 0.19 to 42.4% and diesel from2.4 to 10.6%. On the other hand, the share of human energy decreased from 36.7 to 9.4% and animal energy from 43.9 to 7.3%[4].

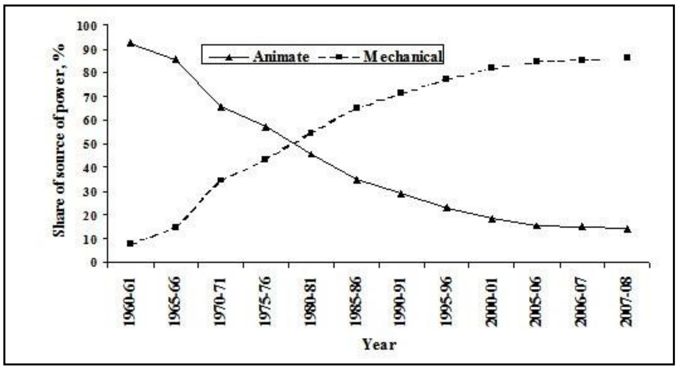

Fig 2: Animate and mechanical power scenario

Draught animals, particularly bullocks, are still the predominant source of mobile power on about 60% of the cultivated area consisting of about 85 million ha. They are very versatile and dependable source of power and are used in sun and rain under muddy and rough field conditions. They are ideal for rural transport where proper roads are not available. They reduce dependence on mechanical sources of power and save scarce petroleum products. About 4-5 decades back most of the farm operations, water lifting, rural transport, oil extraction, sugarcane crushing, chaff cutting etc, were being done using draught animals only.

Over the years the shift has been towards the use of mechanical and electrical sources of power, while in 1960-61 about 92.31% farm power was coming from animate sources. In 2008-09 the contribution of animate sources of power reduced to about 14.20% and that of mechanical and electrical sources of power increased from 7.70% in 1960-61 to about 85.30%[4].

Food grains productivity in India has increased from 0.710 t/ha in 1960-61 to 1.856 t/ha in 2008-09, while farm power availability has increased from 0.296 kW/ha to 1.600 kW/ha during the same period. Thus, food grains productivity is positively associated with unit power availability in Indian agriculture[4].

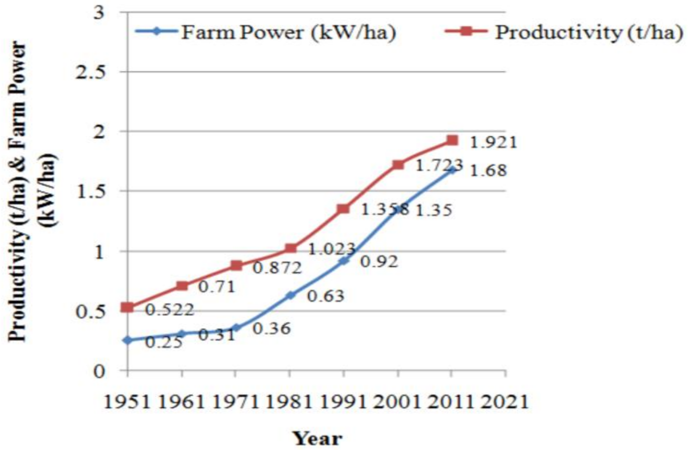

Fig 3: Farm Power Availability and Productivity of Food Grains in India (1951-2011)

Table 1: Energy use and energy productivity of major crops in India

Crops		Total energy (MJ/ha)	Energy productivity (kg/MJ)
Cereals	Rice	13076	0.239
	Wheat	14657	0.196
	Maize	9956	0.215
	Sorghum	4745	0.200
Pulses	Greengram	4315	0.118
	Blackgram	3870	0.105
	Bengalgram	5464	0.190
Oilseeds	Mustard	8051	0.119
	Soybean	6382	0.171
Cash crops	Sugarcane	59192	1.039
	Cotton	9972	0.094
	Potato	31352	0.495

The national weighted average scenario (based on different cultivation practices) of major crops covering 71.3% of gross cropped area in the country (Table. 2) indicates that among major food grain crops, wheat and paddy are high energy consumers due to relatively high fertilizer and irrigations provided in majority of the areas. As compared to paddy, maize (22.4% of area irrigated) requires 76 % of energy and sorghum (92% area rain fed) consumes about one-third of energy. The pulse crops (87.5 % of area rain fed) consume less than 50% of that for wheat and paddy. The oilseed crops also consume lower energy in the range of 6382 - 8051 MJ/ha. Cash crops like sugarcane and potato with high fertilizer and irrigation energy use are high energy consumers. Due to high crop productivity, cash crops like sugarcane and potato have high energy productivity of 1.039 kg/MJ and 0.495 kg/MJ respectively. The food grains have higher energy productivities than oilseeds and pulses. Among them, paddy and wheat receiving higher inputs had higher crop productivities than coarse cereals resulting into better energy-use efficiencies. Most of the pulses and oilseeds have low energy productivities due to inadequate cultivation inputs and low crop yields[4].

Table 2: Diesel and electricity consumptions in cultivation of some major crops in India

Crops	Diesel (Litre/ha)	Electricity (kW/ha)	Diesel (Litre/kg)	Electricity (kWh/kg)
Paddy	39.11	96.32	0.012	0.031
Wheat	45.42	224.99	0.019	0.078
Maize	38.18	41.11	0.018	0.019
Sorghum	5.60	19.81	0.002	0.021
Greengram	1.42	12.42	0.003	0.024
Blackgram	2.14	8.53	0.005	0.021
Gram	18.99	57.85	0.018	0.056
Mustard	32.69	44.01	0.034	0.046
Soybean	24.67	18.47	0.023	0.017
Sugarcane	55.49	425.74	0.001	0.007
Cotton	14.78	36.97	0.016	0.039
Potato	51.69	198.09	0.005	0.013

The consumption rates of diesel and electricity by major crops are indicated in above table .Electricity, where available, is preferred for irrigation and threshing. Sugarcane, wheat and potato are major consumers of diesel and electricity. Paddy and wheat (Table 3) cultivations presently consume highest diesel (1.5 and 1.26 MT respectively). Electricity consumption is highest for wheat cultivation (5939.7 million kWh), followed by paddy and sugarcane (4228.3 and 1830.7 million kWh), respectively[4].

Energy requirements for major cropping systems

Sorghum-chickpea system showed a highest energy ratio of 11.4 and also the highest energy productivity of 2780 g/MJ. This data shows that there is a need of systematic documentation of energy ratio and energy productivity for various cropping systems to assist in selection of most energy efficient cropping systems and also to carry out further research on identifying high energy consuming components and increasing energy use efficiency[13].

Table 3: Energy requirements for major cropping systems

cropping systems	Input energy (MJ/ha)	Output energy (MJ/ha)	Energy ratio	Energy productivity (g/MJ)
Paddy-paddy	65390	183995	2.8	104
Paddy-wheat	66035	226882	3.5	150
Maize-wheat	44025	213450	4.9	141
Maize-chickpea	17075	43115	2.5	152
Sorghum-wheat	16650	67062	4.0	576
Sorghum- chickpea	12455	142065	11.4	2780
Pearl millet-chickpea	10795	36280	3.4	485
Groundnut - mustard	16620	42154	2.5	140

Table 4: Specific energy and energy ratio for different dryland crops

Crop	Specific energy (MJ/kg)	Energy ratio (output/Input)
Castor	3.10	13.60
sorghum	4.16	8.99
Finger millet	5.84	6.25
Pearl millet	6.62	5.51
Groundnut	8.26	3.84
sesamum	12.85	2.68

Specific energy and energy ratio of major dryland crops shows that sesamum required highest specific energy followed by groundnut and lowest was castor. Energy ratio was highest in castor followed by sorghum. The results indicate that castor is most energy efficient crop among dryland crops[13].

Energy components used in energetics:

- ✓ Input energy,
- ✓ Output energy
- ✓ Total energy

The amount of energy inputs from different energy sources such as human, animal, machineries, fuel sources, seed, fertilizers, farm yard manure, pesticides were recorded at different stages of their application. The amount of output energy was calculated from the yield (main product and by product).The total energy was calculated from the total material input energy with their required operational energy.

Energy indices:

1. Energy efficiency (%) (output : input ratio)
$$\text{Energy efficiency (\%)} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

2. Specific energy (MJ/kg)
$$\text{Specific energy (MJ/kg)} = \frac{\text{Energy input (MJ/ha)}}{\text{Grain yield (kg/ha)}}$$

3. Energy productivity (kg/MJ)
$$\text{Energy productivity (kg/MJ)} = \frac{\text{Total output (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

4. Net energy (MJ/ha) = Output energy (MJ/ha) - Input energy (MJ/ha)

5. Energy intensity (MJ/kg)
$$\text{Energy intensity (MJ/kg)} = \frac{\text{Energy output (MJ/ha)}}{\text{Total output (kg/ha)}}$$

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

7. Energy intensiveness = $$\frac{\text{Energy output (MJ/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

8. Net energy return(MJ/acre) = $$\frac{\text{Output energy (MJ/acre)}}{\text{Input energy (MJ/acre)}}$$

Table 5: Equivalents for Direct and Indirect sources of energy

	Units	E. E (MJ)	Remarks
A. Inputs			
1. Human labour			
a. Adult men	Man-hour	1.96	
b. Women	Women-hour	1.57	1 adult women =0.8 adult man
2. Animals			
a. Large bullocks	Pair-hour	14.05	>450 kg body weight
b. Medium bullocks	Pair-hour	10.10	352-450 kg
c. Small bullocks	Pair-hour	8.07	<350 kg
d. Buffalo	Pair-hour	15.15	buffalo=1.5 medium bullock
3. Diesel	Litre	56.31	Includes lubricant cost
4. Petrol	Litre	48.23	Includes lubricant cost
5.Electricity	KWh	11.93	
6. Machinery			
a. Electric motor	kg	64.80	
b.Prime movers (self-propelled machines)	kg	64.80	
c. Farm machinery excluding self propelled machines	kg	62.70	
7. Chemical fertilizers. (a) N	kg	60.60	
(b) P2O5	kg	11.10	
(c) K2O	kg	6.70	
(d) NPK (12:32:60)	Kg	19.8	
8. FYM	kg	0.3	Dry matter
9. Chemicals a.Superior chemicals	kg	120	Chemical requiring dilution at the time of application
b. Inferior chemicals	kg	10.0	Gypsum etc
10. Seed (a) Output of crop prod. system (not processed)	-	-	Same as that of output of crop production system
(b) Output processed before using it as seed(cotton and groundnut, etc)	-	-	Add 1.5, 1.0 and 0.5 MJ/kg for potato, g.nut and other seeds respectively to the equiv. energy of product.
B. **Output**	**Main Product**		

1.Cereals –wheat, maize, sorghum, bajra, barley, oat & rice	kg (dry weight)	14.7	Main output is grain
2. Pulses- moong, lentil, pigeonpea, soybean, peas, beans	kg (dry weight)	14.7	Main output is grain
3. Oilseeds- Cotton seed, groundnut pods, sesamum, mustard, linseed, sunflower seeds	kg (dry weight)	25.0	Main output is seed (except groundnut)
4. Sugarcane	kg (dry weight)	5.3	Main product is cleaned canes
5. Fibre crops- cotton, sunnhemp, jute etc	kg (dry weight)	11.8	Main prod. fibre
6. Fodder crops-berseem, lucerne, bajra, oats, maize etc.	kg	18.0	Main product is dry or green fodder
7. Green manure crops-sunnhemp etc.	-	-	Energy equivalent to the amount of nutrients added to the soil
8. Fuel crops-sunnhemp, dhaincha	kg dry	18.0	Main product is fuel wood
9. Crops for : Fodder, fuel & green manure			
(a) Fodder from cereal crop	kg dry	14.7	Main output is seed
(b) Other fodder crops: berseem, lucerne etc. and fuel crops	kg dry	10.0	Main output is seed
II By product			
1. Straw	kg (dry weight)	12.5	
2. Stalks, cobs and fuelwood	kg (dry weight)	18.0	
3. Leaves and straw from leaves	kg (dry weight)	10.0	
4. Cotton seed	kg (dry weight)	25.0	
5.Fibre crop seed other than cotton & fuel crop seed	kg (dry weight)	10.0	
6. Sugarcane leaves & tops	kg (dry weight)	16.10	

E.E - Equiv. Energy, MJ- Mega Joule **Devasenapathy *et al*. (2009)**

Energetics in mono cropping systems:

Table 6: Effect of different tillage methods on energetics of sorghum

Energy indices	Kharif sorghum	Rabi sorghum	Mean
A. Energy ratio			
1.Mechanical tillage	6.36	7.92	7.14
2.Conventional tillage	12.73	9.42	11.08
3.Shallow tillage	11.63	9.55	10.59
Mean	10.24	8.96	-
B. Specific energy			
1.Mechanical tillage	4.47	6.21	5.34
2.Conventional tillage	2.42	4.87	3.65
3.Shallow tillage	2.90	5.56	4.23
Mean	3.27	5.55	-
C. Energy productivity			
1.Mechanical tillage	0.224	0.162	0.193
2.Conventional tillage	0.413	0.206	0.310
3.Shallow tillage	0.345	0.181	0.263
Mean	0.328	0.217	-

The output energy in rabi sorghum was found less due to the less grain and fodder yield. The energy analysis are given in Table. 6. The maximum energy ratio in conventional and shallow tillage was due to more output energy and less input energy .However the less energy ratio in mechanical tillage method was due to more input as compared to conventional and shallow tillage method. The energy ratio was improved for Kharif Sorghum (12.73) in conventional tillage and shallow tillage method (11.63). However among the crops, the mean energy ratio in conventional and shallow tillage methods did not show any significant difference. The mean energy ratio among the crops for mechanical tillage was found very less (7.14) than the conventional (11.08) and shallow tillage (10.59). The mean specific energy requirements were 3.27 and 5.55 MJ/kg for Kharif sorghum and Rabi sorghum, respectively. The specific energy required for rabi sorghum was more as compare to the Kharif Sorghum. Among the tillage methods, specific energy was found maximum in mechanical tillage (5.34 MJ/kg) as compared to conventional tillage (3.65 MJ/kg) and shallow tillage (4.23 MJ/kg)[10].

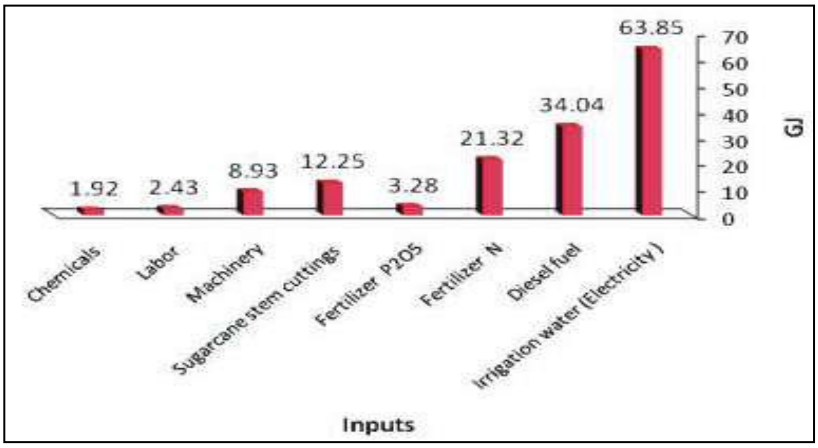

Fig 4: Energy inputs in sugarcane production in Debel khazai Agro-Industry (plant cane)

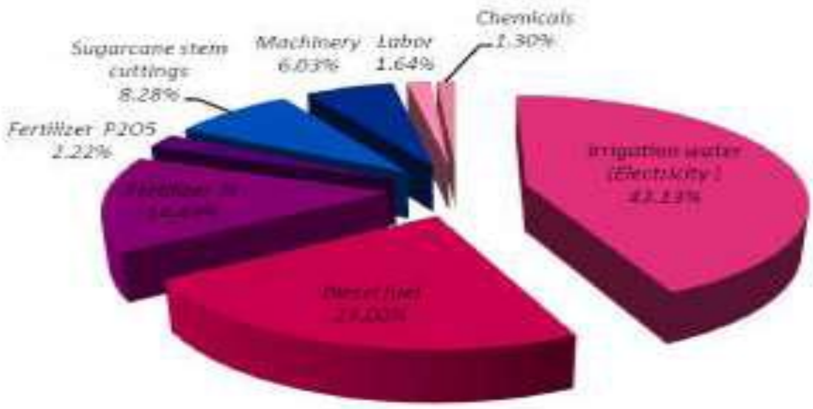

Fig 5: Share of energy inputs in sugarcane production in Debel khazai Agro-Industry (plant cane)

Total energy uses to grow 1 ha of sugarcane were148.02 for plant cane. The share of indirect energy is about one-third of total energy inputs (32%). Electricity is the main energy input accounting for 43% in the plant cane. The second single largest energy input in plant cane is diesel fuel used in the farm machinery and transport accounting for 23.0% (34.04 GJ), followed by nitrogen fertilizer 14.4% (21.32 GJ), sugarcane cuttings8.3% (12.25 GJ) and machinery 6.0% (8.93 GJ). Chemicals are the smallest of all inputs with 1.3% (1.92 GJ). A total of 1225 h of labor were used in the plant cane. Energy outputs in

Agro-Industry farms with93.5 ton/ha yield were 112.22 GJ ha 1 for plant cane. The output to input energy ratio was calculated as 0.76.Energy productivity, Specific energy and Net energy gain were 0.63 kg/MJ, 1.59 MJ kg 1 and-35.8 GJ ha 1,respectively.Obviously, the major energy inputs are electricity,fuel, nitrogen and machinery as well as cuttings. It is agood maintenance of the trucks wouldnormal practice in intensive large farming systems in Iran harvested cane with large amounts of waste leaves andto use more irrigation water, high power machinery and other extraneous matter.more chemicals to ensure high yields.[11].

Effect of different paddy establishment methods on energy balance and energy use efficiency

Mahanthesh *et al*., 2010 reported that among the different rice establishment methods, zero tillage recorded significantly highest energy use efficiency (16.05%) which might be due to very least energy input used in the cultivation of paddy by this method (Table. 7). However, rice cultivation by the SRI method recorded highest energy use efficiency(13.25) than drum seeding, self-propelled mechanical transplanting and hand transplanting and it was on par with the aerobic method due to higher biomass production and total energy output. SRI method recorded highest net energy returns (1, 64,517 MJ ha-1) and lowest net energy returns(1,29,403 MJ ha^{-1}) was recorded in zero tillage. The straw yield also contributed significantly for the enhancement of energy output.

Table 7: Effect of different paddy establishment methods on energy balance and energy use efficiency

Treatments	Input energy (MJ/ha)	Output energy (MJ/ha)	Energy use efficiency	Net energy returns (MJ/ha)
Zero tiilage	8593	137996	16.05	129403
Aerobic method	13212	167889	12.70	154677
SRI method	13424	177941	13.25	164517
Drum seeding	14169	160400	11.32	146231
Self-propelled mechanical transplanting	14176	155859	10.99	141683
Hand transplanting	14194	149879	10.55	135685
S.Em. ±	121.1	2397.40	0.56	2369.23
CD at 5%	365.26	7192.21	1.70	7107.7

Table 8: Energy input and output for autumn sown maize as influenced by different soil tillage systems

Tillage systems	Mouldboardplough	cultivator	Zero tillage
Total input energy(MJ/ha)	12387	11383	11301
Output energy(MJ/ha)	64386	58388	46099
Net energy gain (MJ/ha)	51999	47005	34798
output-input ratio	5.19	5.12	4.07

Memon *et al*., 2015 reported that total input energy was observed maximum under mould board plow (12387 MJ ha^{-1}) followed by cultivator (11383 MJ ha^{-1}) and lowest input energy was found in zero tillage (11301 MJ ha^{-1}). The result indicated that higher output energy was obtained in mould board plow (64386 MJ ha^{-1}), followed by cultivator (58388 MJ ha^{-1}) and minimum output energy found in zero tillage (46099 MJ ha^{-1}). The net energy was find out maximum in mouldboard plow (51999 MJ ha^{-1}), followed by cultivator (47005 MJ ha^{-1}) and the minimum net energy observed in zero tillage (34798 MJ ha^{-1}). Mould board plow used high energy as compared to cultivator and zero tillage, for the farmers who cannot afford much inputs energy cost, cultivator can be recommended to grow maize crop successfully on the basis of energy input-output.

Table 9: Energy input, energy output and net energy of soybean cultivation as influenced by weed management options

Treatments	Grain yield (t/ha)	Energy input (x10 ^{3} MJ/ha)	Energy output (x10 ^{3} MJ/ha)	Net energy (x10 ^{3} MJ/ha)	Energy-use efficiency
Weed management options					
Control	1.847	7.64	83.56	75.93	10.97
Weed free	2.477	8.11	105.47	97.36	13.13
Pendimethalin @ 0.75 kg/ha as PE	2.100	7.76	90.28	82.52	11.69
Chlorimuron ethyl @ 6 g/ha as PoE	1.977	7.68	85.93	78.25	11.20
Pendimethalin @ 0.75 kg/ha as PE + 1 HW	2.203	7.99	95.05	87.05	11.94
Pendimethalin @ 0.75 kg/ha as PE+ Chlorimuron ethyl @ 6 g/ha as PoE	2.032	7.80	84.87	77.06	10.93
SEm±	0.051	-	2.89	2.89	0.398
CD (P=0.05)	0.18	-	8.33	8.33	1.150

The highest energy output of 105.5 × 103 MJ/ha was obtained under weed-free treatment, while the lowest output was obtained in the control (83.6 × 103 MJ/ha). There was 26.2% higher energy output owing to control of weeds(Table. 9). The maximum net returns of 30,614 were obtained under conventional tillage raised-bed planting, closely followed by zero tillage raised-bed (29,674). Application of pendi methalin + 1 HW was found more remunerative with net returns of 28,019/ha, followed by application of only pendi methalin (27,840). Energy requirement in conventional tillage was 31.3% higher than the zero tillage flat-bed. Net energy output was the maximum in conventional tillage raised-bed, while maximum energy-use efficiency was obtained on zero tillage raised-bed system of planting[12].

Effect of tillage and herbicides on energy parameters and economics in wheat.

The field experiment was conducted by Jain *et al.*[9], at NRC weed science, Jabalpur (Table 16), the soil was clayey with objective to study the effect of tillage and herbicide on energy of wheat after transplanted rice (Table. 10). The energy consumption was higher under deep tillage followed by conventional tillage compared to both the zero tillage packages was due to more number of tillage operations including ploughing and harrowing. In weed control practices, higher energy was consumed by herbicidal treatments than weedy check due to energy inputs in terms of herbicides and man-hours required for their application. However the energy consumption was more under iso-proturon + 2,4-D than clodinafop followed by 2,4-D due to more quantity of iso-proturon required for weed control.

The energy production was higher under conventional tillage (87 193 MJ/ha) followed by zero tillage with chemical stale seedbed (83 930 MJ/ha) due to slightly higher grain and straw yields compared to other tillage packages. Among the weed control practices, the higher grain and straw yields under clodinafop followed by 2,4-D resulted in higher energy production than isoproturon + 2,4-D due to effective weed control of Avenaludoviciana which covered around 70 %

of the total weed population. The energy use efficiency (energy output input ratio) was the highest under zero tillage immediately after rice (5.95) and least under deep tillage (4.87). The highest energy use efficiency under zero tillage immediately after rice was due to no requirement of energy for land preparation whereas it was the least under deep tillage due to the highest energy consumption for land preparation. However, under weed control practices, although herbicidal treatments required more energy in terms of input but due to identical increase in grain and straw yields, the energy use efficiency was more under clodinafop followed by 2,4-D followed by isoproturon.

Table 10: Effect of tillage and herbicides on energy parameters and economics in wheat

Treatment	Grain yield (kg/ha)	Energy consumption (MJ/ha)	Energy production (MJ/ha)	Energy use efficiency	Net monetary return (Rs. /ha)	B : C ratio
Tillage practices						
Zero tillage immediately after rice	2679	13833	79898	5.95	9885	2.07
Zero tillage with chemical stale seedbed	2787	14127	83930	5.93	8865	1.80
Conventional tillage	2870	14863	87193	5.86	10423	2.03
Deep tillage	2635	16453	80350	4.87	7886	1.72
CD (P=0.05)	NS	-	-	-	-	-
Weed management						
Weedy check	1534	14470	57288	3.98	2315	1.25
Isoproturon + 2.4-D	2309	14850	75851	5.13	6658	1.66
Clodinofopfb 2 4 -D	4385	14801	115389	7.85	18822	2.61

Energetic of different maize based intercropping systems

Girijesh, 2010 reported that higher energy ratio was recorded by sole crop of maize sown at uniform row spacing (20.56) and significantly higher specific energy was recorded in sole crop of French bean raised for grain purpose (19456.5 MJ tonne^{-1}). The sole crop of maize sown at URS of 60 cm resulted in significantly higher productivity per unit of energy used (1215.5 g MJ^{-1}) than other treatments, among intercrop treatments (T12-T19), the highest energy productivity was achieved by maize + field bean var. local (999.6 g MJ^{-1}) which was due to higher biomass and maize equivalent yield in this treatment(Table.11). Significantly, lower energy ratios were obtained under sole crop of intercrops. Among different intercrop treatments (T12-T19) highest energy ratio of 16.6 was obtained in maize + French bean (grain) was followed by maize + field bean var. local (16.29). The higher energy ratio in these treatments is due to higher stover yield of maize and lesser input energy compared to intercrop treatments due to fewer requirements of chemical fertilizers and labour for weeding and harvesting. The lowest input energy under sole cropping compared to mixed stands was also reported by Mohapatra and Pradan. Significantly higher energy spent to produce one tonne of the produce was with sole crop of French bean raised for grain purpose (19456.5 MJ tonne^{-1}). The lower energy required to produce one tonne of the produce was estimated with sole crop of maize sown at URS (829.3 MJ tonne^{-1}) and sole crop of maize sown under paired row system (891.8 MJ tonne-1). In all, the specific energy recorded across intercrop treatments was found at par to specific energy recorded under sole crop of maize.

Table 11: Energetic of different maize based intercropping systems

Treatment	System Energy ratio	Specific energy (MJ/t)	Energy productivity for biological yield (g MJ^{-1})
T_1 Sole maize at URS of 60 cm	20.56	829.3	1215.5
T_2 Sole maize at PR of 45-75-45 cm	19.29	891.8	1141.6
T_3 Sole Soybean (Vr. KHSb 2)	2.98	4582.4	223.0
T_4 Sole Soybean (Vr. KB- 79)	3.10	4331.6	233.3
T_5 Sole Red gram (Vr. Hyd- 3c)	9.10	1878.7	536.3
T_6 Sole Red gram (BRG -1)	9.95	1721.5	590.6
T_7 Sole field bean (Var.- HA_3)	4.37	3231.3	332.2
T_8 Sole field bean (Local Avare)	8.18	1615.5	621.3
T_9 Frenchean (Var. Arka Komal) Vegetable	1.55	7072.6	180.2
T_{10} French bean (Var. Arka Komal) Grain	1.96	19456.5	147.5
T_{12} Maize (PR) + Soybean var. KHSb-2	15.42	1113.2	919.9
T_{13} Maize (PR) + Soybean var. KB- 79	14.32	1217.3	856.3
T_{14} Maize (PR) + Red gram var. Hyd - 3c	14.86	1179.8	876.1
T_{15} Maize (PR) + Red gram var. BRG-1	15.90	1105.1	938.3
T_{16} Maize (PR) + Field bean var. HA- 3	15.67	1126.3	933.2
T_{17} Maize (PR) + Field bean var. Local	16.29	1024.0	999.6
T_{18} Maize (PR) + French bean var. Arka Komal V)	15.79	1093.9	957.1
T_{19} Maize (PR) + French bean var. Arka Komal (G)	16.60	1017.3	990.9
S. Em ±	0.29	235.7	23.5
C.D. (P=0.05%)	0.80	653.2	65.24

Table 12: Energy Productivity and energy budgeting of maize + greengram intercropping system

Treatments	Maize equivalent yield (t/ha)	Net return (Rs./ha)	B : C ratio	Input energy ($x10^3$ MJ/ha	Output energy ($x10^3$ MJ/ha)	Net energy ($x10^3$ MJ/ha)	Energy efficiency	Energy productivity (g/MJ)
Sole maize	3.37	28247	2.56	9.8	199.5	189.7	20.4	1713.0
Sole greengram	4.77	32415	2.99	4.8	49.3	44.4	10.1	678.6
Maize + greengram (1:1)	5.64	47124	3.28	10.3	196.6	186.3	19.1	1569.4
Maize + greengram (2:1)	4.21	30733	2.57	10.2	147.5	137.3	14.5	1172.0
Maize + greengram (3:1)	3.72	27444	2.43	10.2	158.0	147.8	15.5	1273.5
Maize + greengram (1:2)	5.63	42280	3.09	10.2	128.1	117.9	12.6	991.5
Maize + greengram (1:3)	5.49	40190	3.10	10.2	103.3	93.1	10.1	785.6
SEm±	0.51	-	-	-	-	-	-	-
CD (P=0.05)	1.61	-	-	-	-	-	-	-

The experiment was conducted at ICAR Research complex, NEH, Nagaland for two years to evaluate the systems for better management of resources. The grain yield (Table 15) of intercropped maize decreased by 15.13%, 25.51%, 21.07%, 45.10% and 59.24 % in the intercropping system T3, T4, T5, T6, and T7, respectively over maize sole cropping. The input energy differences were due to the energy value under different row proportions. The highest output energy was recorded under sole maize closely followed by maize + greengram (1:1) than others. However, it is dependent on grain and Stover/straw yields under different treatments and higher yields registered greater output energy. Hence energy efficiency (output: input ratio) and energy productivity per unit of energy used (in MJ) may be considered for energy relationships. Besides maize sole cropping, among different row proportions, 1:1 row ratio recorded maximum energy efficiency (19.1) and energy productivity (1 569.4 g/MJ), than other intercropping system. This may be due to higher energy production under the said system. Thus results of the present investigation clearly demonstrate that maize/greengram intercropping system in 1:1 or 1: 2 row ratios can be practiced to achieve better land utilization, high yield as well as profitability and energy efficiency than their sole crop under rainfed sandy loam soils[1].

Energetics in relay intercropping systems: Effect of different relay or sequence cropping systems on sustainability index, Maize equivalent yield (MEY) and energy use efficiency (Pooled data of 2 years).

Prakash *et al.,*[14] reported that maize (green cobs) + tomato + garden pea + french bean relay intercropping sequence recorded significantly highest maize equivalent yield(71.3 t/ha) due to fairly good yiela of tomato and its get good market price and highest sustainability index (0.91) , production efficiency (195.4 kg/day/ha) and economic efficiency (Rs 656/ha/day), system energy output (10,83,760 MJ/ha), system net energy return (10,40,856 MJ/ha) and system energy-use efficiency (2,852 MJ/ha/day) was recorded in the same sequence due to inclusion of more number of vegetables in the system and higher system productivity(Table. 13). The lowest maize grain equivalent yield (18.8 t/ha), net returns (Rs 48,020/ha), production efficiency (51.5 kg/day/ha) and economic efficiency (Rs 132/ha/day) were recorded under maize (green cobs) - garden pea sequential cropping.

Table 13: Effect of different relay or sequence cropping systems on sustainability index, Maize equivalent yield (MEY) and energy use efficiency (Pooled data of 2 years)

Treatments	Sustainability index	MEY (t/ha)	System energy input(10^3 × MJ/ha)	System energy output(10^3 × MJ/ha)	System net energy return(10^3 × MJ/ha)	System energy-use efficiency (MJ/ha/day)
Maize-garden pea	0.81	18.8	24.61	285.76	261.15	715
Tomato-garden pea	0.91	53.9	27.79	820.04	792.25	2171
French bean-garden pea	0.50	30.7	23.62	466.64	443.02	1214
Maize + tomato+ garden pea+ French bean	0.69	71.3	42.90	1083.76	1040	2852
Maize + French bean+ garden pea + French bean	0.56	51.5	43.90	783.56	739.66	2026

Energetics in Sequential cropping systems:

Input energy use in field operations of cropping systems (MJ/ha)

The interculture and weeding operation consumed least amount of energy use in all treatments which varied from 1098 to 1803 MJ/ha only. However, among six cropping systems, rice-vegetable pea-wheat-greengram was found to be more energy consuming system in all operations followed by rice-wheat, rice-mustard-greengram, maize-vegetable pea-wheat(Table. 15). The lowest energy was consumed in soybean-wheat and pigeonpea-wheat system in all operations. The higher energy use in rice-veg. pea-wheat-greengram was due to high intensity of cropping sequence. However, in two green manuring systems, rice-mustard-greengram and rice-vegetable pea-wheat-greengram, the total input energy use was 43614 MJ/ha and 65052 MJ/ha in which 5546 MJ/ha and 5311 MJ/ha energy was consumed for green manuring crop in greengram as input (grain + crop residue use), respectively.

Input and output energy of different cropping system

Chaudhary *et al*.[2], repoted that the total input energy utilization was highest in rice-veg. pea-wheat-greengram (65052 MJ/ha) due to more crop management and pudling operation and total output energy was highest in rice-wheat (153126 MJ/ha) followed by rice-vegetable pea-wheat- greengram (149922 MJ/ha) and rice-mustard-greengram (146403 MJ/ha).The net energy return was found highest in rice-wheat (102865 MJ/ha) and output to input ratio highest in soyaben-wheat sequence(Table. 16). It was because of the intensification of crops in a year of growing period consumed higher input energy than the obtained output energy. The vegetable pea and greengram contributed only 6.6 and 3.7 per cent to the total output energy of the system, whereas, the input energy used was taken as 14.6 and 8.3 per cent of total input energy of system, respectively. The output-input ratio was highest in pigeonpea-wheat (3.8) followed by soybean-wheat (3.6), rice-mustard-greengram (3.4), rice-wheat and maize-vegetable pea-wheat (3.0 in both the systems). The pigeonpea-wheat and soybean-wheat systems were more efficient due to lower input and higher output energy. The lowest output-input ratio was noticed in rice-vegetable pea-wheat-greengram (2.3). Numerically, maximum net energy was found in rice-wheat and rice-mustard-greengram than other systems. The rice-wheat system gained 27.7, 21.2 and 10.8 per cent higher net return energy than soybean-wheat and pigeonpea-wheat systems, rice-vegetable pea-wheat-greengram and maize-vegetable pea- wheat systems, respectively.

Table 14: Energy conversion factors used in the above study:

Crop produce	units	Equivalent energy(MJ)
Rice	kg	14.70
Wheat	kg	15.70
Vegetable pea	kg	3.91
Greengram	kg	14.03
Maize	kg	15.10
mustard	kg	22.72
Pigeonpea	kg	14.07
soybean	kg	18.14

Groundnut equivalent yield and energetics of different cropping sequence.

Ganajaxi *et al*.[5], reported output energy was significantly higher in groundnut–sorghum (199.1 1×103 MJ/ha) groundnut–sunflower (1 88.33×103 MJ/ha) sequencesdue to the higher yield of their byproducts and input energy differed due to difference in energy use under different sequences (Table. 17). Output- input ratio was significantly higher in soybean-sorghum (10.14) over other sequences due to lower input energy required by it (12.77×103 MJ/ha) compared to its output energy (129.47×103 MJ/ha). The output energy, however, is dependent on economic part of the crop as well as dry fodder and straw yields of different sequences. Hence energy use efficiency is good indicator to interpret energy relationship of different sequences.

Effect of rice crop establishment and nutrient management practices in rice - greengram cropping systems on energetics of greengram production (pooled data of 2 years)

Mohanty *et al*., reported thata for the pooled data, methods of rice establishment did not influence the yield and energetics of subsequent greengram (Table. 18). Residual effect of sole organic nutrient management being at par with integrated nutrient management came out to be the best in terms of yield and energy indices like energy output, energy productivity and energy ratio. 50% RDF + BF application to greengram recorded the highest seed yield (930 kg ha^{-1}). This treatment also recorded the highest energy output (55.7 $MJx10^3$), energy productivity (247.3 Kg/MJ x 103) and energy ratio (14.81) due to the residual effect of organic nutrition, though it remained at par with the residual effect of INM during both the years.

Table 15: Input energy use in field operations of cropping systems (MJ/ha)

Cropping systems	Seedbed preparation	Puddling	Nursery raising & transplanting	Sowing/ planting	Interculture/ weeding	Crop management	Harvesting /threshing	Green Manuring	Total input energy ,MJ/ha
Rice – Wheat	3955	2878	1347	2826	1411	34817	3030	0.0	50264
Rice-mustard-greengram	4252	2878	1347	1082	1098	30111	2847	5546	43614
Rice-vegetable pea-wheat-Greengram	7161	2878	1347	4572	1803	43476	3813	5311	65052
Maize – vegetable pea-wheat	5578	0.0	0.0	4986	1333	31913	2221	0.0	46031
Pigeon pea –wheat	3729	0.0	0.0	2770	1098	19432	1986	0.0	29015
Soybean-wheat	3729	0.0	0.0	3718	1098	20328	1986	0.0	30859

Table 16: Input and output energy of different cropping system

Particulars	Rice-wheat			Rice –mustard-greengram				Rice-vegetable pea-wheat-greengram				
	Rice	Wheat	Total	Rice	Mustard	greengram	Total	Rice	Veg. pea	Wheat	Green gram	Total
Input energy (MJ/ha)	28421	21843	50264	28421	9647	5546	43614	28421	9477	21843	5311	65052
Output energy (MJ/ha)	71957	81169	153126	74088	66002	6314	146403	75044	9834	59503	5542	149922
Net energy (MJ/ha)	43536	59326	102862	45667	56355	768	102790	46623	357	37660	231	84871
Output-input ratio	2.5	3.7	3.0	2.6	6.8	1.1	3.4	2.6	1.0	2.7	1.0	2.3
Net returns (Rs,/ha/ Year)	9798	18178	27976	10581	31795	952	43328	10932	3375	11761	182	26250

Particulars	Maize-veg,pea -wheat				Pigeonpea-wheat			Soybean- wheat		
	maize	Veg.pea	wheat	Total	Pigeonpea	wheat	Total	soybean	wheat	Total
Input energy (MJ/ha)	14711	9477	21843	46031	7122	21283	29015	9016	21843	30859
Output energy (MJ/ha)	70291	9892	58718	1388901	24693	85251	109949	27936	83289	111224
Net energy (MJ/ha)	55579	416	36875	92869	17521	63408	80929	18920	61445	80365
Output : input ratio	4.8	1.0	2.7	3.0	3.4	3.9	3.8	3.1	3.8	3.6
Net returns (Rs,/ha/ year)	8626	3450	11441	23517	13600	19842	33442	1956	19042	20998

Table 17: Groundnut equivalent yield and energetics of different cropping sequence

Cropping sequence	GEY Kg/ha	B : C ratio	Input energy (10^3 MJ/ha)	Output energy (10^3 MJ/ha)	Output : input ratio	Energy use efficiency (kg /1000 MJ)
Potato-sorghum	5439	2.90	23.92	145.84	6.10	223.09
Potato-chickpea	6428	3.31	22.12	132.46	5.99	285.96
Potato-sunflower	6691	3.45	23.60	162.74	6.90	278.53
Potato-wheat	5478	2.84	24.55	129.08	5.26	217.81
Groundnut-sorghum	3823	2.87	19.81	199.11	9.21	176.59
Groundnut-chickpea	4387	3.10	21.61	175.51	8.86	221.56
Groundnut-sunflower	4068	2.90	19.81	188.33	8.85	190.68
Groundnut-wheat	3812	2.69	21.29	183.79	8.27	169.69
Soybean-sorghum	2135	2.13	22.23	129.47	10.14	172.14
Soybean-chickpea	2659	2.44	12.77	102.41	9.05	249.03
Soybean-sunflower	2592	2.41	11.31	120.31	6.17	212.78
Soybean-wheat	2056	1.90	19.49	100.39	7.49	156.64
CD (P=0.05)	272	0.42		13.32	0.83	27.71

Table 18: Effect of rice crop establishment and nutrient management practices in rice - greengram cropping systems on energetics of greengram production (pooled data of 2 years)

Treatments	Energy input(MJ×10^3)	Energy output(MJ×10^3)	Energy productivity (Kg/MJ×10^3)	Energy ratio
Crop establishment methods in rice				
SRI*	3.71	47.7	212.3	13.07
Drum seeding	3.71	49.8	223.2	13.60
Conventional tillage	3.71	45.3	200.3	12.44
SE m(±)	-	1.02	4.15	0.245
CD(0.05)	-	NS	NS	NS
Nutrient management in rice				
RDF*	3.71	43.9	193.3	12.04
Organic management	3.71	51.5	231.1	14.06
INM	3.71	47.4	211.4	13.01
SE m(±)	-	1.20	5.84	0.321
CD(0.05)	-	3.5	17.0	0.94
Nutrient management in greengram				
RDF**	4.65	51.0	180.5	10.96
50% RDF + Biofertilizers	3.76	55.7	247.3	14.81
No fertilizer	2.71	36.1	208.0	13.33
SE m(±)	-	0.92	4.71	0.254
CD(0.05)	-	2.6	13.3	0.72

RDF*=Recommended dose of fertilizers(80kg N,40 kg P2O5 and 40kg K2O ha-1) , SRI=system of rice intensification, OM=organic management(50% N through vermicompost +25% N through vermicompost , INM =Integrated nutrient management, RDF**=Recommended dose of fertilizers (20 Kg N , 40 kg P2O5 and 40kg K2O ha-1). BF=biofertilizers (Rhizobium and PSB seed inoculation)

Input and output energies and energy use efficiency of different cropping systems (pooled data of 3years)

Honnali and Chittapur, 2014 revealed that among all the systems, the highest energy input was recorded in rice–rice cropping system among the systems and the lowest energy input was in Bt cotton alone because the double cropping systems of rice utilized the maximum input and hence required more cultural practices(Table. 19). Energy output was the highest with rice–rice followed by maize– chickpea and the lowest energy output was in chilli + onion. However, energy–use efficiency was the highest for maize–chickpea followed by transplanted Bt cotton, while the lowest in chilli + onion because of the fact that chilli and onion had lowest energy conversion values among all. Nevertheless, energy productivity was the highest with transplanted Bt cotton because of higher productivity and low energy input compared to all cropping systems. Systems net energy returns were the highest with maize– chickpea followed by transplanted Bt cotton because of more output energy and low input energy associated with these systems. Energy intensiveness was the highest in maize–chickpea followed by rice–rice again due to higher output energy and lower cost of cultivation.

Table 19: Input and output energies and energy use efficiency of different cropping systems(pooled data of 3years)

Treatments	Total input energy (10^3 MJ/ha)	Total output energy (10^3 MJ/ha)	Energy use efficiency (%)	Energy productivity (Kg/MJ)	System Net energy returns (10^3 MJ/ha)	Energy intensiveness (MJ/ha)
Bt cotton-	14.0	31.1	222	0.15	17.1	1.30
Bt cotton-greengram	22.2	38.8	175	0.11	16.6	1.13
Btcotton-green manure crop	20.2	33.4	165	0.11	13.2	1.04
Bt cotton-sesame	20.3	40.1	197	0.13	19.8	1.18
Maize-chickpea	28.4	81.7	288	0.09	53.3	3.53
Sunflower-wheat	38.4	50.8	132	0.04	12.4	2.18
Sunflower-chickpea	27.3	48.2	176	0.07	20.8	2.29
Chilli+cotton	32.2	1.34	4	0.07	-30.8	0.05
Transplanted cotton	16.2	40.4	250	0.17	24.3	1.41
Rice-rice	105.7	127.1	130	0.02	21.4	2.69

Yield, energy input, renewable to non-renewable energy ratio and energy output as influenced by tillage and fertility levels under soybean-based cropping system.

Energy input analysis revealed that the renewal energy input remained unchanged due to different tillage systems. While the non-renewable energy and total energy inputs were the highest with conventional tillage; the differences between minimum and no till being at par. Renewable energy to non-renewable energy ratio and the share of renewable energy to total energy showed an decreasing trend with the degree of tillage. The values for these two were maximum in no till, followed by minimum and conventional tillage. The gross and net energy output was maximum in conventional tillage, which remained at par with minimum tillage. A similar trend was also noticed in non-renewable and total energy-use efficiency. The highest gross energy output was recorded in poultry manure + recommended dose of fertilizer, while the poultry manure + 50% of recommended dose of fertilizer, farmyard manure + recommended dose of fertilizer and recommended dose of fertilizer differed non-significantly among themselves. Significantly maximum net energy output was recorded with farmyard manure + 50% of recommended dose of fertilizer, the integration of organic manure with recommended dose of fertilizer showed higher energy intensiveness than their lone application of organic manure.

Table 20: Yield, energy input, renewable to non-renewable energy ratio and energy output as influenced by tillage and fertility levels under soybean-based cropping system

Treatment	Soybean equivalent Yield (kg/ha)	Energy input (MJ/ha)			RE:NRE input ratio	RE % of total energy input	Energy output (MJ/ha)	
		RE	NRE	Total			Gross	Net
Tillage								
Zero	3533	8316	5517	13829	1.58	60.58	51935	39526
Minimum	3872	8339	6102	14441	1.42	58.14	56918	42231
Conventional	3883	8374	7115	15490	1.21	54.38	57080	42282
CD (P=0.05)	42.4	-	-	-	-	-	NS	NS
Cropping system								
Soybean-wheat	3876	8441	7419	15860	1.14	53.22	56977	41695
Soybean-chickpea	3722	8245	5070	13315	1.63	61.92	54713	41373
CD (P=0.05)	34.7	-	-	-	-	-	755.3	NS
Fertility level								
Control	3384	6934	2979	9913	2.34	69.96	49745	39825
RDF	3901	6934	9527	16461	0.78	43.10	57345	40892
PM@ 2.5 t/ha	3713	9120	2979	12100	3.07	75.38	54581	42481
PM+50 % RDF	3939	9120	6220	15340	1.52	59.82	57903	42071
PM + RDF	4115	9120	9527	18648	1.03	49.80	60491	41851
FYM@ 2.5 t/ha	3653	8505	2979	11484	2.86	74.06	53699	42208
FYM+50 % RDF	3781	8505	3883	12388	1.42	69.26	55581	43193
FYM + RDF	3938	8505	11914	18134	0.96	48.07	57889	39755
CD (P=0.05)	62.7	-	-	-	-	-	1284	730.3

The highest non-renewable energy and total energy input (Table 8) was associated with conventional tillage. Renewable energy to non-renewable energy ratio and renewable energy percentage to total energy input were the maximum in no till. The gross and net energy output and renewable energy-use efficiency were the maximum in conventional tillage. Soybean – chickpea system had an edge over soybean – wheat in case of renewable energy productivity and intensiveness. The integration of organic manure with recommended dose of fertilizer showed higher energy intensiveness than their lone application of organic manure.

The study was conducted at Chatha by Gupta *et al*.[7] and soil was sandy clay loam (Table 9). The two tillage methods recorded similar grain energy output. This was on account of statistically similar grain yield under two tillage systems. Energy output was statistically higher in N3 split (33:33:33), which was at par with N2 (20:40:40) and N4 (50:25:25) but better than Ni (0:50:50) and N2 (50:50:0) splits. Energy use-efficiency and energy productivity were significantly more under zero tillage than conventional tillage. Each mega joule of input energy produced significantly maximum wheat yields under zero tillage as compared to conventional tillage. This could be attributed to lesser energy (operation time, manual labour and fuel) requirement under zero tillage than conventional tillage. Energy use-efficiency and energy productivity exhibited phenomenal decrease with each increment in N level from 75 to 125% of recommended. This may be because of lesser inputs used at lower fertility levels as compared to higher fertility levels. Similar to energy output, energy use-efficiency and energy productivity were significantly higher when N was applied in three splits than application of N in two splits. So zero tillage with 100 % RDF and nitrogen application in three equal splits was better.

CONCLUSION

Energy consumption pattern of Indian agriculture significantly increasing over the decades. Among the crop groups, energy productivity is in the order of sugar crops > cereals > oilseeds > pulses. Energy input is higher with mechanical tillage, whereas energy output is higher with conventional tillage. Among rice establishment methods higher energy input is associated with hand transplanting where as higher energy output and net energy gain with SRI. Among the rice based cropping system rice-wheat cropping system having higher energy productivity, higher output energy and net energy gain. Zero tillage found energetically efficient tillage method over conventional method. Higher energy use efficiency is associated with reduced fertilizer usage. Under zero tillage practice soybean-wheat/chickpea were proved to be the best cropping systems than rice-wheat cropping system. Soybean – wheat crop rotation with residue management under zero tillage reduced the use of fertilizer. Drip method or alternate furrow irrigation method with mulching practice is best for sugarcane.

REFERENCES

1. BAISHYA, L. K., ANSARI, M. A., WALLING, I., SARMA, P. K. AND PRAKASH, N., Productivity, profitability and energy budgeting of maize(*Zea mays*)/ greengram (*Vigna radiata*) intercropping system under rainfed conditions of Eastern Himalayan Region. *Indian J. Agric. Sci.*, **84 (9):** 1073-7 (2014).
2. CHAUDHARY, V. P., GANGWAR, B. AND PANDEY, D. K., Auditing of Energy Use and Output of Different Cropping Systems in India. *CIGR E journal. Manuscript EE 05 001* **8: (**2006).
3. DEVASENAPATHY, P., SETHILKUMAR, G. AND SHANMUGAMP, M., Energy management in crop production. *Indian J.Agron.* **54(1):** 80-90 (2009).
4. DIPANKAR, D. E., Energy use pattern and future energy requirement for crop production by 2020. *J. Agril. Engg,* **43(3):** 71-77 (2006).
5. GANAJAXI, HALIKATTI, S. I., HIREMATH, S. M. and CHITTAPUR, B. M., Productivity, Profitability and energy-use efficiency of different cropping sequences in northern transition zone of Karnataka. *Ind. J. Agric. Sci.,* **81(10):** 921–6 (2011).
6. GIRIJESH, G. K., studies on yield stability of rainfed maize in southern transition zone of Karnataka. *Ph. D (Agri.) Thesis,* UAS, Bangalore (2010).
7. GUPTA, M., BALI, A. S., SHARMA, S. AND DIXIT, A. K., Potential role and influence of zero tillage technology on energy saving in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. *Indian J. Agric. Sci.,* **77(10):** 657-659 (2007).
8. HONNALI, S. N. AND CHITTAPUR, B. M., Efficient cropping systems and their energetics for sustainable irrigated tropical ecosystems. *Ind. J. Agron.,* **59(4):** 556-560 (2014).
9. JAIN, N., JAIN, V., MISHRA, J. S. AND KEWAT, M. L., Effect of tillage packages and herbicides on energy and economics of wheat in transplanted rice (*Oryza sativa*) - wheat (*Triticum aestivum*) system. *Indian J. Agric. Sci.,* **77(3):** 174-176 (2007).
10. KALBANDE, S. R. AND MORE, G. R., Assessment of Energy Requirement for Cultivation of Kharif and Rabi Sorghum. *Kar. J. Agric. Sci.,* **21(3):** 416-420 (2008).
11. KARIMI, M., RAJABI POUR, A., TABATABAEEFAR, A. AND BORGHEI, A., Energy analysis of sugarcane production in plant farms a case study in debel khazai agro-industry in Iran. *American-Eurasian J. Agric. & Environ. Sci.,* **4(2):** 165-171 (2008).
12. MONSEFI, ALI. AND BEHERA, U. K., Effect of tillage and weed-management options on productivity, energy-use efficiency and economics of soybean (Glycine max). *Indian J. Agron.,* **59(3):** 481-484 (2014).
13. PAL, M., SINGH, K. A., SAXENA, J. P. AND SINGH, H. K., Energetics of cropping systems. *Ind. J. Agron.,* **30(2):** 1-61 (1985).
14. PRAKASH, V., KUMAR, N., BHATTACHARIYYA, R. M., KUMAR. AND SRIVASTVA, A. K., Productivity, economics, energetics and soil properties of vegetables-based relay intercropping systems. *Ind. J. Agron.,* **52(4):** 300-304 (2007).
15. ZAHEDI, M., MONDANIB, F., HAMID, R. E., Analyzing the energy balances of double-cropped cereals in an arid region. *Energy reports,* **1:** 43-49 (2015).