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Energy audit of paddy cultivation practices in Kokan region of Maharashtra

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■ **ABSTRACT :** This study highlights the energy consumption pattern of paddy cultivation practices followed in Kokan region of Maharashtra. The study data were collected from eight regional research stations of Balasaheb Sawant Kokan KrishiVidyapeeth, Dapoli. The net energy, specific energy, energy output input ratio,energy productivity and water productivity for paddy cultivation was found to be 61738.52 MJ/ha, 0.86 MJ/kg, 2.22, 1.16 kg/MJ and 9.33 kg/m^3, respectively. The cost per energy input and cost per energy output was found to be 19.99 Rs./MJ, 0.8342 Rs./MJ, respectively. Diesel fuel contributed highest share of input energy for paddy cultivation. Seed (52 %) contributed highest share of output energy, it immediately followed by straw (48 %).The contribution of indirect energy (53.64 %) was higher than that of the direct energy (46.16 %). In direct energy, the highest share of diesel fuel (82 %) as well as in indirect energy chemical fertilizers (49 %) contributed highest share. The share of non renewable energy (72.86 %) was found to be more than that of renewable energy (27.14 %).Water contributed highest share (46 %) to renewable energy and it immediately followed by human energy (30 %) stand on second position.Diesel fuel (52 %) contributed highest share to non renewable energy used and it followed by chemical fertilizers (30 %). The costs of different sources of input energy used in paddy cultivation were 19.995 Rs./MJ and that of output energy from paddy cultivation was 0.8342 Rs./MJ.

■ **KEY WORDS :** Energy equivalent, Energy indices, Energy sources, Cost economics

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India has world's largest area devoted to rice cultivation, and it is the second largest producer of rice after China (Thiyagarajan and Gujja, 2013). Kokan is coastal part of Maharashtra between Western ghat and Arabian Sea. The climate is hot humid with annual rainfall of 3500 mm. This climatically condition proves paddy is major crop of this region. In Kokan, total 71.96 per cent farmers are marginal, 25.41 per cent are medium and 2.61 per cent farmers arelarge *i.e.* majority of farmer from marginal whose land holding is less than 1 ha. Due to this adverse condition for mechanization this district un-mechanized. Less mechanization indicates less energy used in field responsible to lower yield per ha (Mushtaq *et al.*, 2009; Deike *et al.*, 2008 and Hatirli *et al.*, 2006). In India, it revealed that the cropping intensity increases with an increase in per unit power availability. In India, it was 120 per cent with power availability of 0.48 kW/ha during

1975-76 and increased to about 139 per cent with increase in power availability to 1.71kW/ha in 2009-10 (Annan 2013b).In ancient time due to lack of availability machinery and mechanized practices,the farmers uses low energy inputs into their farms and were getting lower yields from their farm. In paddy cultivation the activity starts from the preparation of the soil for cultivation to harvesting and transportation operation. These operations were carried by using human, animal and tractor power sources (Tanate *et al.*, 2014).

At the time of data collection it was found that, except primary and secondary tillage operation in Kokan area, all cultivation practices followed in rice crop are done by manually it includes transplanting, intercultural operation, threshing, fertilizer and manure application. It has large scope to increase the power availability per ha. Many researcher worked on the energy requirement of paddy crop. The researcher are Ullaha (2009); Prasanna Kumar and Hugar (2011); Chamsing *et al.* (2006); Tanate *et al.* (2014); Islam *et al.* (2013); Shahan *et al.* (2008) and Akbarnia and Farhani (2014). These all researchers worked on particular area. Nobody has worked on Kokan region of Maharashtra which is one of the promising regions for rice production. Therefore this research work was undertaken with objective such as, to estimate energy requirement of paddy crop and to study energy use pattern of paddy cultivation. It helps for determination and understanding level of mechanization of respective area.

■ METHODOLOGY

Study area :

Konkan region is the narrow strip of 40 km width and running 750 km in length from north to south, and hilly terrain lying between Sahyadri ranges inthe east and Arabian sea in the west. It is located15^{o} 36’ to 20^{o} 21’ north latitude and 7^{o} 7’ to 74^{o} 13’east longitude on the world map. The region iscomprised of five districts *viz.*, Mumbai, Thane,Raigad, Ratnagiri and Sindhudurg. The hilly terrainreceives heavy rainfall ranging from 2000-4000 mm per annum. The climate is hot and humid almost throughout the year. The climatic conditions aresuitable for growing various fruit crops.The total geographical area of the region is 2.95million ha. Net sown area is 0.839 million hectare. The area under rice crop in Konkan is 0.45 million hectares with production of 2.114 million metric tonnes (Shahare, 2016). The data of *Kharif* rice were collected for this study from the different regional research station of Dr. BSKKV Dapoli. The respective, research stations were Wakoli, Repoli, Karjat, Wengurla, Palghar, Devgade, Shirgaon, Fonda ghat. The average data from all these research station should be considered for further analysis.

Energy requirement and conversion factors :

Energy requirement of paddy crop was satisfied by using different types of energy resources, which falls under conventional, non-conventional energy sources or direct, indirect energy sources. The conventional energy sources include chemicals (fertilizers and pesticides), fuels (petrol and diesel), etc. and non conventional include human, animal, seeds, manure, biomass, water, etc. To determine energy requirement of paddy crop, it was divided in two main groups *i.e.* input and output energy. The physical units of different inputs and output were converted into energy units by using the respective conversion factors *i.e.* energy equivalent available in the literature (Mandal *et al.*, 2002; Mushtaq *et al.*, 2009; Nassiri and Singh, 2009; Ozkan *et al.*, 2004; Singh *et al.*, 2002; Singh and Mittal, 1992 and Alipour *et al.*, 2012). The respective energy equivalents are given in Table A.

Energy sources and terminologies :

The direct energy is the energy that was consumed directly from the physical sources during different operations in the field as reported by Chamsing *et al.* (2006) that may be in the form of human, animal, machinery, electricity, and most important fossil fuels (Singh *et al.*, 2007). The indirect energy is the amount of energy that used in the production processes of goods and services required for the cultivation of the paddy. The indirect energy is used to produce the machinery, equipments, chemical fertilizers, farmyard manure, chemicals *i.e.* pesticides, fungicides etc., and biological energy *i.e.* seeds and hormones (Singh *et al.*, 2007 and Chamsing *et al.*, 2006).The human labour converted into energy units by multiplying the number of total human labour with working hours to the energy co-efficient available in the Table A. Mechanical energy inputs were calculated based on the fuel consumption (l/h) of the machinery, types of machinery and working hours per operation as well as the number of operation in the paddy planted area. The fertilizer energy inputs were calculated by multiplying the respective energy equivalents of (N,

Table A : Energy equivalent of different energy types

Sr. No.	Energy types	Energy equivalent		References
1.	Labour	1.96	MJ/man/h	Mittal *et al.* (1988)
2.	Fuel			
	Diesel	56.31	MJ/ liter	Mittal *et al.* (1988) and Tanate *et al.* (2014)
	Gasoline	39.7	MJ/ liter	
	Electricity	11.93	MJ/kW-h	
3.	Fertilizer			
	N	60.60	MJ/kg	Mittal *et al.* (1988) and Tanate *et al.* (2014)
	P_2O_5	11.10	MJ/kg	
	K_2O	6.70	MJ/kg	
4.	Manure	0.303	MJ/kg	
5.	Chemicals	120	MJ/kg	
6.	Pesticide			
	Insecticide	199	MJ/kg	Mittal *et al.* (1988) and Alipour *et al.* (2012)
	Fungicides	92	MJ/kg	
	Herbicide	238	MJ/kg	
7.	Machinery	62.70	MJ/ha	Alipour *et al.* (2012)
	Pumping (4 – 6 hp.)	84.93	MJ/ha	Mittal *et al.* (1988) and Tanate *et al.* (2014)
	Walking tractor (15 – 24 hp)	439.43	MJ/ha	
	Driving tractor (80 – 110 hp)	2110	MJ/ha	
	Harvesting tractor (100 hp)	2646	MJ/ha	
	Harvesting tractor (185 – 215 hp)	4437.25	MJ/ha	
	Track 4 well (120 hp)	1398.62	MJ/ha	
8.	Paddy seed	14.7	MJ/kg	Mittal *et al.* (1988) and Alipour *et al.* (2012)
9.	Straw	12.50	MJ/kg	Alipour *et al.* (2012)
10.	Water	0.63	m^3	Alipour *et al.* (2012)

P and K) to their respective percentage ingredients in the compound fertilizers used per unit area (ha). The sum of the energy of all the ingredients (N, P K) will give the fertilizers energy use per unit area.The energy equivalent of the different chemicals was calculated by multiplying the respective energy equivalents with the quantity of the chemical used.Paddy output is the main product from the rice farming. Straw and stalk are the byproducts of the rice production systems. The output of the paddy yield and straw (kg/ha) was converted into energy units by multiplying the total biomass produces per hectare with the energy equivalent. The following equation was followed to calculate the output of the energy of the biomass.

Human Labour (MJ/ha) = (WxHxEE)/ A

Mechanical energy (MJ/ha)= (FC× W × ND× EE)/ A

Fertilizer energy input = (Fertilizer (kg/ha)× (N, P, K %)/100

Energy of N= (Share of N × EE)/ A

Energy of P_2O_5= (Share of P_2O x EE)/ A

Energy of K_2O =(Share of K_2O x EE)/ A

Total energy input of fertilizer (MJ/ha) = N (MJ/ha) + P_2O_5 (MJ/ha) + K_2O (MJ/ha)

Seed energy (MJ/ha) =(Seed (kg/ha)× EE)/ A

Chemical energy input (MJ/ha) = (Quantity × EE) / A

Energy of the biomass produced=(Grain and straw (kg/ha)× EE)/A

where,

W = Total working hours of human labour, H = Total human labour, EE = Energy equivalent

ND =No. of days, A=Planted area (ha), FC = Fuel consumption, W= Total working hours of machinery, No. = Number of the farm machinery

Energy indices :

The relation between energy inflows and outflows was studied by different energy indices. The respective energy indices were energy efficiency, energy productivity, specific energy, water productivity and net yield. The formulas of respective, energy indices are given below.

Energy efficiency = Total energy output (MJ/ha) / Total energy intput (MJ/ha)

Energy productivity = Grain yield (kg/ha) /Total energy intput (MJ/ha)

Specific energy = Total energy input (MJ/ha)/Grain yield (kg/ha)

Water productivity = Grain yield (kg/ha) /Amount water applied (m^3/ha)

Net energy = Energy output (MJ/ha) – Energy input (MJ/ha)

(Alipour *et al.*, 2012)

Benefit to cost ratio :

Benefit to cost ratio was calculated by using following formula

$$\text{Benefit to cost ratio} = \frac{\text{Gross value of production (Rs./ha)}}{\text{Gross value of production (Rs./ha)}}$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Energy indices :

The energy indices were calculated from Table 1. It was found that, the net energy was 61738.52 MJ/ha. The energy needed per kg production that is specific energy was found to be 0.86 MJ/kg. The energy efficiency, energy productivity and water productivity was found to be 2.22, 1.16 kg/MJ and 9.33 kg/m^3, respectively.

The input-output energy used for paddy cultivation is given in Table 1 and the share of different types of input-output energy is given in Fig. 1 and 2. From Fig. 1 it is found that the diesel contributed higher share of energy input followed by fertilizers, machinery, water, human, seed and chemical, respectively, for paddy cultivation. The use of human energy was quite small as

Table 1 : Energy inputs, outputs and output-input ratio in paddy production

Sr. No	Energy source	Quantity used per unit area (ha)	Energy co-efficient (MJ/unit)	Total energy equivalent (MJ/ha)	Per cent
Input unit					
1.	Human labour (h)	2133	1.96	4180.68	8.23
2.	Machinery (h)	103.5	62.70	6489.45	12.77
3.	Fertilizer (kg)				
4.	Nitrogen fertilizer (kg)	165	60.60	9999	19.68
5.	Phosphorus P_2O_5 (kg)	55	11.10	610.50	1.20
6.	Potassium K_2O (kg)	55	6.70	368.50	0.73
7.	Manure (kg)	8500	0.303	2575.50	5.07
8.	Chemicals (kg)				
9.	Insecticides (kg)	1.225	199	243.775	0.48
10.	Weedicides (kg)	0.16	238	38.08	0.07
11.	Diesel oil (l)	81	238	19278	37.94
12.	Water for irrigation (m^3)	10000	0.63	6300	12.40
13.	Seed (kg)	50	14.7	735	1.45
Total energy input (MJ/ha)				50811.485	100
Outputs (unit)					
1.	Seed (kg)	4000	14.7	58800	52.24
2.	Straw(kg)	4300	12.50	53750	47.76
3.	Total energy output (MJ/ha)			112550	100
4.	Net energy (MJ/ha)				61738.52
5.	Specific energy (MJ/kg)				0.86
6.	Energy efficiency				2.22
7.	Energy productivity (kg/MJ)				1.16
8.	Water productivity (kg/m^3)				9.33

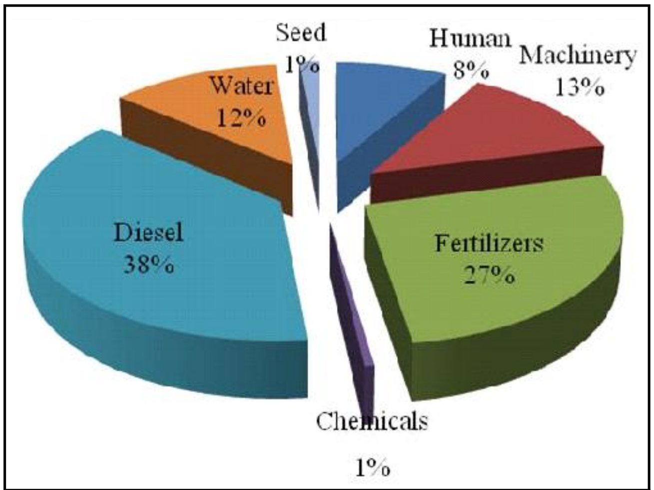

Fig. 1 : Share of different types of input energy used for paddy

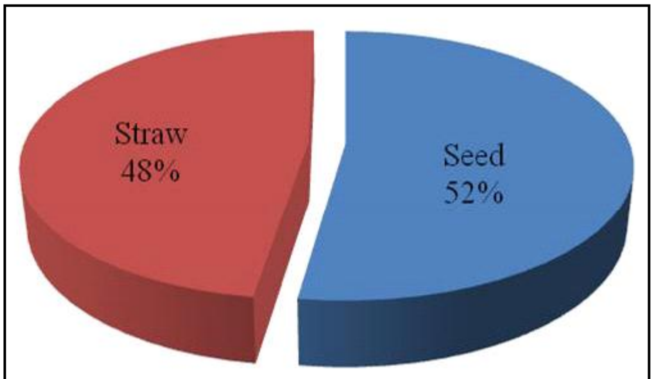

Fig. 2 : Share of different types of output energy comes from paddy

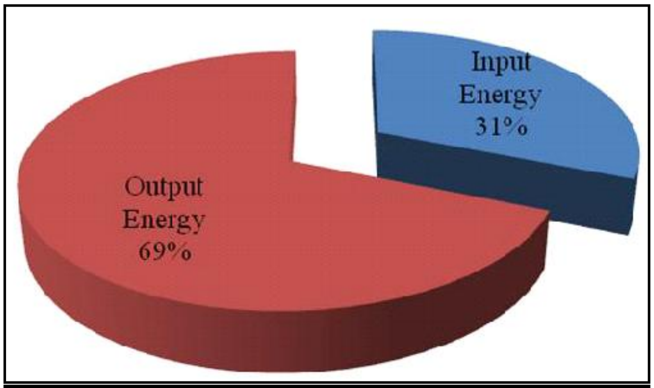

Fig. 3 : Share of different types of input:output energy for paddy

compared with machinery but it clearly indicates that there is less mechanization practices used in paddy cultivation. There is maximum scope to utilized machinery power by adopting zero tillage cultivation practices, which have chances to minimize the share of diesel energy. Also there is wide scope to develop machineries which run on combined effect of human and animal or individual, those increase the share of human as well as machinery energy input.

There are major two types of outcome from paddy crop *i.e.* seeds and straws. Fig. 1 shows that the share of different outcome energy came from paddy. It found that the share of seed energy was higher than the straw from the paddy. Fig. 3 shows that the energy balances of input-output constitute for paddy cultivation. It was found that the share of output energy was 68 per cent highest as compared with input energy.

Table 2; Fig. 4, 5 and 6 show the share of different forms of direct-indirect energy used for paddy cultivation. Direct energy has included only two forms of energy that is fuel and human energy. From Fig. 4 it was found that, the share of fuel was higher than that of the human energy. Practically, it was seen that, the fuel was used for tillage and puddling operation only *i.e.* the mechanization was done only for tillage operation. So, there was great scope to increase mechanization practices in transplanting, threshing and harvesting operation but practically, it was not feasible due to low land holding and small undulating structure of land. The adoption of machinery was possible when it used as for

Table 2 : Total energy input in the form of direct and indirect energy for paddy

Type of energy	(MJ/ha)	Per cent
Direct energy	23458.68	46.16
Indirect energy	27359.81	53.84

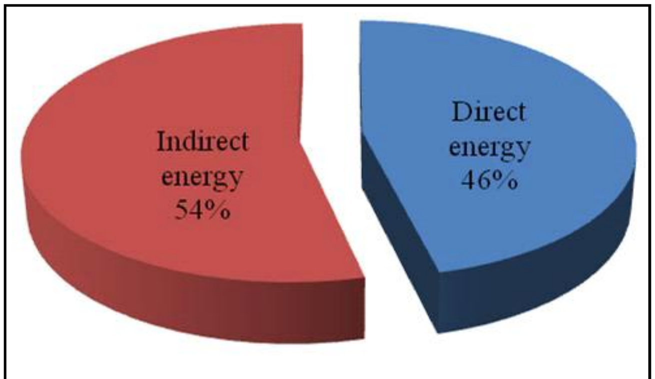

Fig. 4 : Share of direct and indirect energy used in paddy cultivation

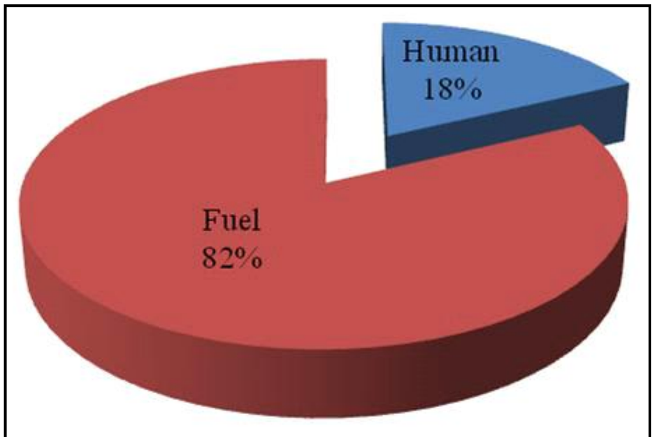

Fig. 5 : Share of different forms of direct energy used in paddy cultivation

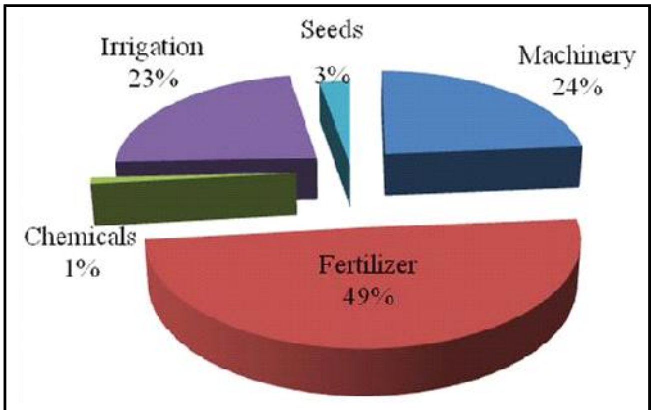

Fig. 6 : Share of different forms of indirect energy used in paddy cultivation

custom hiring basis for cultivation operation. The share of human energy was less as per energy analysis but practically there was 2133 human-h/ha was engaged in paddy cultivation. Fig. 5 shows that the share of different forms of indirect energy used for paddy cultivation, the fertilizers contribute highest share of indirect energy followed by machinery, irrigation water, seeds and chemical. From Fig. 6 it was found that the balances of direct and indirect energy used for paddy cultivation, the share of indirect energy was higher than that of direct energy used for paddy cultivation.

Table 3 : Total energy input in the form of renewable and non-renewable energy for paddy

Type of energy	(MJ/ha)	Per cent
Renewable energy	13791.2	27.14
Non-renewable energy	37027.3	72.86

Fig. 7, 8, 9 and Table 3 show that the different types of renewable and non renewable energy used for the paddy cultivation. The contribution of non renewable energy was 63 per cent greater than the renewable energy. In renewable energy sources the types of energy includes water, seed, manure and human energy. Fig. 8 showed that share of fuel was greater followed by fertilizers, machinery and chemical. The energy point of view, the contribution of chemical energy was very low.

Table 4 shows that the cost of different types of input energy used for paddy cultivation, it was found that the human contribute higher energy in terms of cost of input (Rs./MJ) followed by farm yard manure, plant protection chemicals, seeds, machine, and fertilizers, respectively. Similarly, the contribution in total share of cost of input for paddy was higher for human energy. Above statements clearly concluded that there is scope for improvement in mechanization of paddy cultivation. The cost energy used by human was near about 91.74 per cent greater than the machine. Therefore, maximum wastage of money or investment was done on human energy. Also it has more limitations during paddy cultivation period. The dependency on human for energy in paddy cultivation is possible to reduce by applications of paddy transplanter, thresher and harvester.

Table 4 : Costs of different sources of input energy use in paddy cultivation

Source	Energy use (MJ/ha)	Cost of input (Rs./ha)	Cost/use of energy (Rs./MJ)
Human	4180.68	32160/-	7.693
Machine	6489.45	4050/-	0.62
Seeds	735	1200/-	1.632
Farm yard manure	2575.5	13600/-	5.280
Fertilizers	10978	5202/-	0.47
Plant protection chemicals	281.85	1213/-	4.30
		Total	19.995

The costs of different sources of output energy come from paddy cultivation are given in Table 5. It was found that the maximum return came from seed. The

Table 5 : Cost of different sources of output energy comes in paddy cultivation

Source	Energy use (MJ/ha)	Cost of input (Rs./ha)	Cost/ use of energy (Rs./MJ)
Seed (kg)	58800	42000/-	0.7142
Straw(kg)	53750	6450/-	0.12
		Total	0.8342

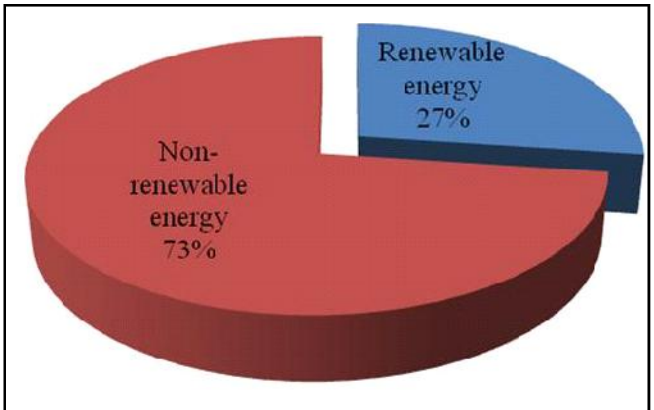

Fig. 7 : **Share of renewable and indirect non renewable energy in paddy cultivation**

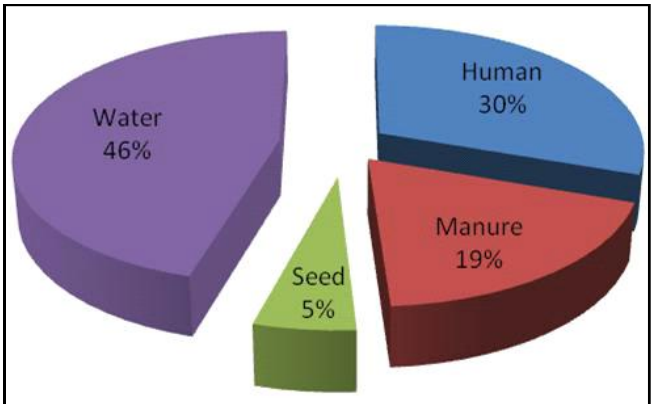

Fig. 8 : **Share of different forms of renewable energy used in paddy cultivation**

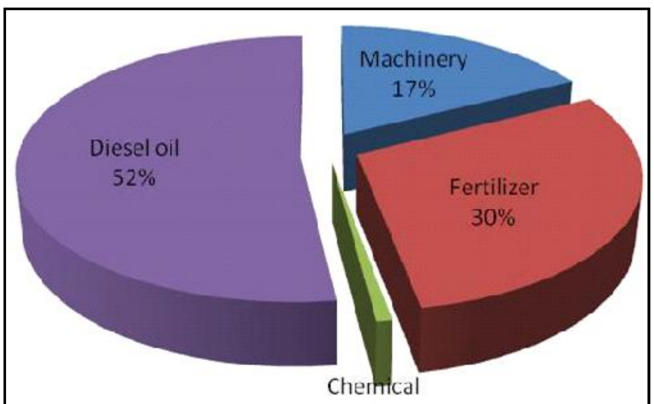

Fig. 9 : **Share of different forms of non renewable energy used in paddy cultivation**

straw has lower cost in market. Therefore, it contains lower cost per energy outcome.

Conclusion :

The analysis of result clearly concluded that, the paddy cultivation practices in Kokan was poorly mechanized. It was due to small land holding, undulating land structure, economically backward farmer and difficulty to use machinery in high rainfall area. There is scope and need to develop small scale machinery which should be utilizing human energy effectively, reduces drudgery involved in it, increases the share of renewable energy and possible to utilize in Kokan environment. It would be increased the net profit in the paddy cultivation.

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