Energy Consumption Pattern in Irrigated Paddy Cultivation in Thiruvanamalai District of Tamil Nadu : A Case Study

ABSTRACT

A large amount of energy is consumed in different stages of paddy cultivation. On-farm energy use patterns in paddy crop systems, both source-wise and operation-wise, were determined to prepare an energy audit in irrigated paddy cultivation. The data on energy consumption from different sources for the production of paddy were collected from different parts of the Tiruvannamalai district in Tamil Nadu. Energy consumption was categorizedinto direct energy and indirect energy. Energy consumption by various machineries, various inputs and by various farmer categories based onthe size of land holding was analyzed.It was found that there is a large scope of mechanization in marginal farmers. It was found that for marginal farmers there is a large scope of mechanization. The adoption of mechanization results in reduced human energy and increased fuel energy. But proper adoption of machineries results in proper time management, less human drudgery and more energy-efficient operation.

Keywords: Energy consumption, Irrigated Paddy Cultivation, Equivalent energy coefficients, Energy ratio

1. INTRODUCTION

Pudupalyam, Vandavasi and Polur regions are major rice producers in the Tiruvannamalai district of Tamil Nadu. Three different types of soils are found in these regions. A fully mechanized cropping pattern is rare. The farmers use both conventional and modern methods in paddy cultivation. For the same operation, different types of farm machineries are adopted based on land conditions, availability of machineries and labors (Jat *et al*, 2013). To assist the increasing demand of rice in future, it has been approximately found that 1140 lakhs tons of additional milled rice necessary to be generated by 2035, which is equals to an overall increase of 26% in coming 11 years. The possibility of the area extended under rice cultivation is bounded. Consequently, the additional production has to be achieved through increase in productivity. The major challenges to attain this target less resources (Input energies) which produces securing long term sustainability (Kumar and Ladha 2011; Komatineni et al 2023).

The main motive of usage of farm machinery are to reduce the input and improve output, which means with less input energy consumption (labor, machinery etc) to attain high output (grains and forage). This case study is to analyze the energy consumed (both direct and indirect) in each stage of paddy cultivation right from the land preparation to harvestingfor analyzing the energy consumption and energy gained. The computation of energy consumed in each stage gives an idea about the energy consumption pattern and helps to optimize the energy usage by adopting suitable machineries and techniques (Zhang *et al*, 2013).which will provide the awareness among the progressive farmers for optimizing their inputs to attain high output. Moreover, they can analyze the energy losses in operation which can rectified to attain high efficiency

2. MATERIALS AND METHODS

The details regarding farm machineries used in various stages of paddy cultivation in Pudupalayam, Vandvasi and Polur regions were collected. The regions were selected based on the differences in soil type, irrigation facility, land holdings and cultural practices. A proforma was prepared to collect required information related to land holdings, cultural practices, machineries used in various stages, time of operation, fuel consumption, electricity consumption along consumption of seed, fertilizer and chemicals. The data were collected by making personal contact with 121 farmers individually. The energy consumption was calculated using the associated energy equivalents. (NRRI, 2018). The energy was categorized into direct and indirect energy.Both direct and indirect forms of energy are needed in agricultural production processes. Direct energy includes electricity, mechanical power, solid, liquid and gaseous fuels. Indirect energy, on the other hand, refers to the energy required to manufacture inputs such as machinery, farm equipment, fertilizers and pesticides. The total input energy was assessed in terms of human, animal, machinery, irrigation, fertilizer, chemical and seed. Total output energy was determined based on the energy value associated with paddy grain (14.7 MJ/kg dry grain) and energy associated with the paddy straw (13.75MJ/kg dry straw). The ratio of output-input energy was calculated based on the use of both direct and indirect energies in the production process and yield of grain and straw.

2.1.Energy calculation

Specific mathematical models for calculating energy balance (Reference: NRRI, 2018)

Energy involvement in different rice cultivation methods

Energy input

Energy Input =Human energy + Fuel/electrical energy + Machine energy

Human energy

Human energy = Useful man hour spent in operation× man energy factor (MJ/ kg)

Fuel energy

Fuel energy =Fuel consumption (l/h) × Energy factor for diesel (MJ/ l)

Machinery energy

Machinery energy = Weight of the machine (kg) × Self-propelled machine energy equivalent factor (MJ/ kg) × Useful working hours (h/ ha) × Useful life of machine

Energy output

Energy output = [Total grain production × grain energy equivalent factor] + [Total straw production × straw energy equivalent factor]

The net energy gain and energy profitability were calculated as

Net energy gain = Energy output (MJ/ ha) - Energy input (MJ/ ha)

Energy profitability (%) = $\frac{\text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)}}{\text{Energy input (MJ/ha)}}$ x 100

3. Results and discussion

3.1. Energy consumption of machineries in various stages of paddy cultivation

The energy consumed by various machineries in irrigated paddy cultivation were calculated and summarized in Table.1

Table.1 Energy consumption by various machineries in paddy cultivation

Name of Operation	Machinery used	Human	Fuel	Machinery	Total
Initial Tillage	Tractor + rotovator (2)	7.3	1208.4	68.4	1284
	Power tiller+ rotovator (2)	26.3	943.2	35.4	1004.9
	Tractor + cultivator (2)	9.8	854.5	79.6	943.9

Puddling	Tractor+9 Tyne cultivator 2+planker1	13.4	1542	119.1	1674.5
	Powertiller+rotovator2 +planker1	42.0	1507	72.5	1621.4
	Tractor+rotovator2	12.9	1783.9	107.3	1904.1
Sowing	Drum seeder	31.0	882 (seed)	8.9	921.91
	Direct Broadcasting	15.7	1470(seed)	-	1485.68
	Manual line sowing	203.6	882(seed)	-	1085.62
Transplanting	Transplanter	1292.2	573.0	65.8	1931
	Manual Random Transplanting	3441.1	-	-	3441.1
	Manual Line transplanting	3605.4	-	-	3605.4
Weeding	Power weeder	627.2	262.9	4.6	894.7
	Manual weeding	881	-	-	881
	Manual single row weeder	835.2	-	40.0	875.3
Spraying	Power operated knapsack sprayer	412.4	127.1	1.4	540.9
	Battery operated knapsack sprayer	490	14.3	3.7	508.0
	Hand held sprayer	559	-	1.9	560.9
Fertilizer broad casting	Fertilizer Broadcaster	53.4	-	17.1	70.4
	Manual	65.3	-	0.0	65.3
Harvesting (Combine)	standard- 60 hp, 7 feet	6.7	813.7	319.4	1139.8
	class, 60 hp, 12 feet	9.8	1055.8	363.7	1429.3
	john Deere- 75 hp, 12 feet	5.8	827.8	276.2	1109.7
Straw baling	Tractor operated baler	4.9	492.7	53.4	551.0
	Manual	235.5	-	-	235.5
	Tractor operated baler	3.4	526.5	36.4	566.3

3.1.1. Energy consumption in initial tillage

Tractor attached rotovator and cultivator, power tiller attached rotovator were the major machineries used by the farmers for tillage operation. The total energy was highest for rotovator (1288 MJ/ha) because of high fuel consumption followed by power tiller (1004.9 MJ/ha) and cultivator (943.8 MJ/ha). The human energy was high for power tiller operation (26.3 MJ/ha) since its field efficiency is low when compared to other machineries. The machinery selected for tillage operation depends up on land area, soil type and availability of machineries.

3.1.2. Energy consumption in puddling

Tractor attached rotovator and cultivator, power tiller attached rotovator were the major machineries used by the farmers for puddling operation. The total energy was highest for rotovator puddling (1904.1 MJ/ha) because of high fuel consumption followed by cultivator (1674.5 MJ/ha) and power tiller attached rotovator (1621.4 MJ/ha). The human energy was high for power tiller operation (26.3 MJ/ha) since its field efficiency is low when compared to other machineries. For red gravely soil, to avoid percolation of water, tractor attached rotovator is used. In clayey type soil at Vandavasi region cultivator attached puddling is mostly used.

3.1.3. Energy consumption in Sowing

Different methods of sowing practices are direct broad casting, drum seeding and manual line sowing. The total energy is high for direct broad casting (1485.68 MJ/ha), because it requires more seeds when compared to drum seeding and manual line sowing. But human energy is high for manual line sowing.

3.1.4. Energy consumption in Transplanting

Transplanting is one of the laborious task in paddy cultivation. Only Vandavasi region uses transplanter for paddy transplanting remaining all areas in Tiruvanamali district follow conventional manual rice transplanting which consumes large amount of manual energy. The manual line transplanting consumed highest amount of enery(3441.12 MJ/ha) followed by manual random transplanting (3441.12 MJ/ha).Using transplanters for rice transplanting reduced manual energy considerably.

3.1.5. Energy consumption in weeding

In rice cultivation weeding is tedious task. Different weeders were used by the farmers. But most of the areas followed the conventional manual weeding. In Direct broadcasting of paddy, power weeder cannot be operated because of non-uniform spacing. The total energy was highest for

power weeder (894.7 MJ/ha)because of fuel consumption. Human energy was highest for manual weeding.

3.1.6. Energy consumption in spraying

Both power operated and battery operated knapsack sprayer were used by the farmers in Thiruvanamalai district. The total energy consumption by all the sprayers range between 500-600 MJ/ha. The high width of coverage of power operated knapsack sprayer resulted in low human energy when compared to other sprayer types. The total energy was highest for Hand held type (1288 MJ/ha) because of low width of coverage.

3.1.7. Energy consumption in fertilizer application

The energy in fertilizer application by manual (65.31 MJ/ha) and fertilizerbroad caster (70.43 MJ/ha) was almost comparable.

3.1.8. Energy consumption in harvesting

Most of the farmers in Thiruvanamalai used combine harvester for harvesting. From the survey it was observed that the total energy of combine harvester depends on its make, model and size of land holding. Highest amount of energy is observed in small farmers (1429.27 MJ/ha) followed by marginal (1139.8 MJ/ha) and medium (1109.71 MJ/ha).

3.1.9. Energy consumption in straw baling

Manual and baler operated straw bailing were practiced in different areas of the district. The total average energy in baler operated straw bailing was 551.02 MJ/ha and for manual bailing was 235.5 MJ/ha.

3.2.Energy consumption at various stages of paddy cultivation.

The maximum amount of energy is consumed in irrigation stage (12573.3 MJ/ha) followed by transplanting (2028.65MJ/ha) and puddling (1733.355 MJ/ha) (Fig.1).

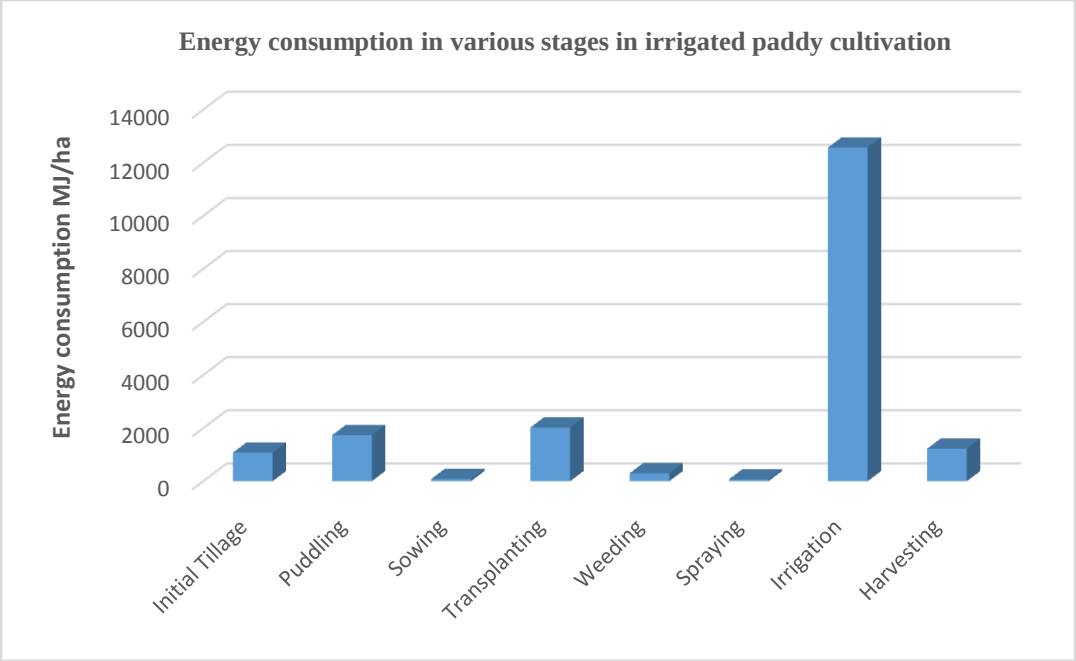

Fig.1: Stage wise energy consumption

Since paddy cultivation consumes large amount of water hence proper energy management should be done in installation and maintenance of pump, choosing correct size of pimp, proper piping etc. Most of the farmers followed traditional method of transplantation which need considerable human energy.

3.3.Source wise energy consumption

Among different categories of farmers, the fuel energy consumption was found to be maximum, followed by fertilizer, electrical, human, chemical, machinery energy and seeds are given in Table.2 The increased fuel energy consumption shows the increased use of machineries by the farmers. The average fuel energy consumption by marginal, small and medium category farmers were 15214.51, 15877.79 and 17462.54 MJ/ha, respectively. The marginal, small and medium category farmers consumed almost equal amount of fertilizer energy.

The high electricity consumption is caused by irrigation which uses electric driven pumps. The irrigation requirement also depends on the variety of paddy, its duration and soil type. Higher water requirement is required in medium deep red gravely loam soil followed by red gravely clayey soil and medium deep clay soil.

The tractor machinery energy was comparatively low since paddy cultivation is more labour-intensive task. In comparison to other crops human energy consumption in paddy crops was more; 1,954.07, 1,986.84, 2,173.73 MJ/ha for small, medium and large category farms,

respectively. The average chemical energy consumption in paddy was 580 MJ/ ha. The effect of land holdings was found to be significant for human, fuel, machinery and electrical energy consumption. With the increase in land size energy consumption per ha also increased. But energy consumption per ha in seed, chemical and fertilizer have no significant change with change in landholding size.

Table.2 Source wise energy consumption data

Energy MJ/ha	Farm Size		
	Marginal	**Small**	**Medium**
Human	1754.78	1189.612	2652.01
Fuel	15214.51	15877.79	17462.54
Machinery	430.95	668.126	503.06
Electrical	11200	12792	13770
Seed	323.4	294	260.1
Fertilizer	13224	13326.38	13616.75
Chemical	560	580	600
Total Input energy	42707.64	44727.91	48864.47

3.4.Estimation of output energy and energy ratios

Among different inputs, human, fuel, electricity contributes the direct energy inputs and seed fertilizer, chemical, machinery are the indirect energy inputs. The maximum energy was contributed by the fuel consumption associated with different machinery (36%) followed by fertilizer (29%) and electricity (28%) associated with irrigation requirement. The direct energy contributed 67.43 % of the total inputenergy.

The total energy output was highest (157510.12 MJ/ ha) for marginal farmers followed by small (140071.32 MJ/ha) and medium farmers (132803.13 MJ/ha), respectively (Table 3). But, the energy ratio was lowest (2.72) for medium farmers followed by small (3.13) and marginal farmers (3.69), respectively. Also the specific energy was highest for marginal farmers followed by small and medium farmers, but energy productivity was lowest in case of medium farmers followed by small and marginal farmers (Table.4).

Table.3 Estimation of output energy

Output	Farm Size		
	Marginal	**Small**	**Medium**

Yield (kg/ha)	6458.0	5743.0	5445.0
Yield Energy output (MJ/ha)	94932.6	84422.1	80041.5
Straw output (kg/ha)	5006.2	4451.9	4220.9
Straw energy output	62577.5	55649.2	52761.6
Total energy output MJ/ha	157510.1	140071.3	132803.1

Table.4 Estimation of energy ratios

Output	**Farm Size**		
	Marginal	**Small**	**Medium**
Energy ratio	3.69	3.13	2.72
Specific energy (MJ/kg)	6.61	7.79	8.97
Energy productivity (kg/MJ)	0.15	0.13	0.11
Net Energy yield	114802.48	95343.42	83938.66

4. CONCLUSION

The energy consumption depends on various factors such as size of land holding, availability and suitability of machineries, soil and crop characteristics, economic stability of farmer, and transfer of technology. From the energy consumption data, human, Fuel, Machinery, Electrical, Seed, Fertilizer and chemical energies are considered as Input energies whereas as the paddy grains and harvested forage are consider as output energies. The farmers are classified into three categories small, marginal and medium farmers. From the data it is concluded that the input energy consumption of small, marginal and medium framers is 44727.91, 42707.64 and 48864.47 mJ/ha with respective to the output energy of 140071.3, 157510.1 and 132803.1mJ/ha.A total of 36 percentage of the operational energy was consumed by fuelfollowed by fertilizer and irrigation which showed the increased use of machineries in various stages of paddy cultivation. The direct and indirect source of energy consumption were 67.2 and 32.4 percent, respectively. Fuel energy was the major source of direct energy consumption. The electricity energy mainly depends on irrigation requirement which again depend up on type of soil, paddy variety, duration of crop, climate etc. Energy productivity was high in comparison to input energy consumption due to the utilization of machinery for farm operations. This study showed the scope of usage of machineries in marginal level farmers. The energy consumption in various stages can be

maintained at optimum level by choosing suitable machineries, proper installation and maintenance of pump, timely practices etc.

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