STUDY OF ENERGY INFLOW-OUTFLOW PATTERN IN PADDY CULTIVATION WITH SPECIFIC REFERENCE TO TILLAGE TREATMENTS

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled **'Study of energy inflow-outflow pattern in paddy cultivation with specific reference to tillage treatments'** is a bonafide record of project work done by us during the course of project and that this report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this project report entitled **'Study of energy inflow-outflow pattern in paddy cultivation with specific reference to tillage treatments'** is a record of project work done jointly by **Mr. Jayachandran. S, Miss. Jayasree. G. S, Miss. Sobhalatha. P. K. and Mr. Suresh Kumar. P. R.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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SYMBOLS AND ABBREVATIONS

Agric.	-	Agricultural
ASAE	-	American Society of Agricultural Engineers
CIAE	-	Central Institute of Agricultural Engineering
cm	-	centimetre(s)
contd.	-	continued
CRRI	-	Central Rice Research Institute
Dept.	-	Department
Engg.	-	Engineering
et. al.	-	and others
etc.	-	et cetera
Fig.	-	Figure
FPM	-	Farm Power and Machinery
FPME	-	Farm Power, Machinery and Energy
ha	-	hectare(s)
hp	-	horse power
hr(s)	-	hour(s)
IARI	-	Indian Agricultural Research Institute
ICAR	-	Indian Council of Agricultural Research
ie.	-	that is
IIT	-	Indian Institute of Technology
ISAE	-	Indian Society of Agricultural Engineers
KCAET	-	Kelappaji College of Agricultural Engineering and Technology
kcal	-	kilocalorie(s)
kg	-	kilogram(s)
kmph	-	kilometres per hour
kW	-	kilowatt(s)
kWhr	-	kilowatt hour
Ltd.	-	Limited
m	-	metre(s)
Mcal	-	million calorie(s)
MJ	-	megajoule(s)
mm	-	millimetre(s)
No.	-	Number
PAU	-	Punjab Agricultural University
pps:	-	pages
Proc.	-	Proceedings
q	-	quintal(s)
rpm	-	revolutions per minute
Rs.	-	Rupees
sec	-	second
SJC	-	Silver Jubilee Convention
TNAU	-	Tamil Nadu Agricultural University
USA	-	United States of America
Vol.	-	Volume
°	-	degree
'	-	minute
/	-	per
%	-	per cent
"	-	second (angle)

INTRODUCTION

Agriculture is the backbone of Indian economy . The pace of agriculture and rural development can only be accelerated by assured and reliable supply of socio-technical infra- structure. To improve agricultural productivity, our villages need cheaper and reliable technology in the field of agriculture.

Rice is the unique major food crop of the world by the virtue of its extent and variety of uses and adaptability to a broad range of climatic and cultural conditions. About half of the world's population is dependant on rice as their principal energy supplying food grain. Considering the importance of rice, it was described as the "grain of life" by the United States in 1966.

India is the second largest rice producing country in the world and is charecterised with high population density and generally small farm holdings. According 1992 census, Indian population is about 886 million and the per capita consumption of rice is 74 Kg /year. So with the explosion of population, the demand for food grain is increasing day by day. This can only be achieved by increasing the production through intensive cropping and by enhancing productivity. Indian agriculture is of the subsistence type. There is not much scope for increasing the cultivable area. Therefore the only way is to improve on yields per unit area by intensive agriculture through better inputs and better management. Increased power inputs for agricultural operations is vital for efficiency and timeliness.

Kerala State has a total area of 21.84 lakh hectares under cultivation of which about 5.6 lakh hectares is under paddy with a productivity of about 1900 Kg /ha. Average size of operational holdings in Kerala is only 0.36 ha and more than 67.5% of the operational holdings are of the size below 2ha. Yearwise data on the area of cultivation under paddy and average production is given in the table.

Year	Area x 1000 ha	Average yield Kg/ha
1980-81	896.99	1587
1981-82	806.87	1660
1982-83	778.49	1678
1983-84	740.01	1632
1984-85	730.38	1720
1985-86	678.28	1729
1986-87	664.00	1708

Source: Directorate of Economics and Statistics, Trivandrum.

From this table, it is clear that the area under rice production is drastically decreasing though there had been a considerable increase in average yield. Reduction in area under paddy is mainly because of the reason that rice cultivation is now a days becoming uneconomical owing to the high labour cost and low level of mechanisation. Since we have reached saturation points in case of area under cultivation, usage of high yielding varieties of crops and fertilizer application, we have to introduce specific machines for tillage, transplanting, harvesting and threshing operations to make rice cultivation profitable.

Energy plays a key role in the developmental process of a country and the quantum of energy inputs in different sectors including agriculture determines the level of progress and the standards of living of its people. It is known that production on a farm is influenced by the energy input to the farm. It is an established fact that nations having higher power availability per unit area have also higher agricultural productivity. An estimate showed that power availability on Indian farm is 0.655 kW/ha which is still below the minimum recommended level of 0.746 kW/ha (ICAR, 1986). This demand for increased power input can be made available from one, or a combination of three alternatives: viz. hand labour, draught animal or engine power. The decision as to which of these three and to what extent will vary with the situation such as soil conditions, size of holdings, availability of labourers etc.

Moreover, the world is passing through an energy crisis and so, efficient and economical utilization of available energy resources is essentially needed. Technically, sources of energy in agriculture are classified into commercial and non-commercial, and renewable and non-renewable. Commercial sources of energy are direct as coal, oil, natural gas and electricity, and indirect such as chemical fertilizers, plant protection chemicals, machinery etc. Non-commercial energies could also be direct such as human labour, draught animals, vegetative fuels as well as indirect like seeds, organic manures etc. Coal, oil, natural gas and fossil fuels are non-renewable where as solar energy, biomass, wind energy, human labour and draught animals are renewable. In view of observed correlation between the commercial energy inputs and agricultural productivity, (Pathak, 1985) the demand for commercial energy in the agricultural sector is likely to increase very rapidly. On the other hand, the global availability of conventional energy resources is expected to diminish sharply by the turn of this century. The combination of these two factors, namely, the increasing demand for commercial energy inputs and possible constraints of commercial energy supplies will force the planners and technologists to give increasing attention to more efficient utilisation of energy sources in production agriculture.

Another aspect of energy consumption pattern in agriculture is of its peculiar nature. Agriculture is a seasonal industry where demand of energy fluctuates through out the year. There are certain months of the year when agriculture needs more energy to meet its requirements to complete crucial operations like land preparation, sowing, transplanting, harvesting, threshing etc. in time. This is achieved by energy efficient and suitable equipments and machineries.

There is lack of knowledge in the farmers of Kerala regarding the efficient and economical utilisation of agricultural production system. Farmers are using traditional tools and implements for different agricultural operations, most of which are not energy efficient. There is a need to substitute these implements from available efficient implements in order to obtain high yield per hectare. Our ultimate aim is to attain self sufficiency in the field of food production.

Agriculturists are constantly attempting to modify, through cultural practices, the chemical and physical environment of soil to make it more favourable for plant growth. One such practice is tillage ie. mechanical manipulation of the soil for the preparation of seed bed and root bed destroying weeds, incorporating plant residues and chemicals, establishing desired soil configuration and controlling soil erosion. Tillage produces changes in soil water, soil temperature, nutrients supply, composition of soil atmosphere and soil strength (Chaudhary et. al, 1983). It is noted that about 30-35% of energy required is for tillage treatments.

There is a need to assess the present status of energy available and utilised for different farming systems on fields since such studies have yet not been conducted in Kerala State. Hence a study was conducted to analyse the energy inflow-outflow pattern in paddy cultivation with specific reference to tillage treatmets, with the following objectives:

1. To quantify the energy input and output in paddy cultivation

2. To find out the input-output ratio for different tillage treatments

3. To identify the most energy efficient tillage practice

REVIEW OF LITERATURE

A brief review of tillage equipments, conventional tillage practices and research works conducted in this field are discussed under the following headings.

1. Tillage equipments
2. Conventional tillage practices for paddy and
3. Studies on energy flow pattern.

Rice can be grown in three seasons as indicated below depending on the availability of water and other local conditions.

Virippu - First [autumn] crop, April-May to Sept.-Oct.

Mundakan - Second[winter] crop, Sept.-Oct. to Dec.-Jan.

Punja - Third [summer] crop, Dec.-Jan. to March-April.

2.1. Tillage equipments

Soil tillage consists of breaking the compact surface of the earth to a certain depth and to loosen the soil mass, so as to enable the roots of the crops to penetrate and spread into the soil. The primary objectives of tillage are

i) to prepare suitable seed bed

ii) to destroy competitive weeds

iii) to improve the physical conditions of the soil.

Tillage equipments are classified as

a) Primary tillage equipments and

b) Secondary tillage equipments.

Equipments used to open up any cultivable land with a view to prepare a suitable seedbed for growing crop are known as primary tillage equipments. It may be tractor-drawn or bullock-drawn implements and it includes indigenous ploughs, mouldboard ploughs, disc ploughs, chisel ploughs, subsoil ploughs, etc.

Secondary tillage is the stirring of soil at comparatively shallow depths. The main objectives are

i) to pulverise the soil of the seedbed in the field

ii) to destroy grasses and weeds in the field

iii) to cut crop residues and mix them with the topsoil and

iv) to break the big clods and to make the field surface uniform and levelled.

They include various types of harrows, cultivators, rollers, pulverisers and rotary cultivators.

2.2. Conventional tillage practices for paddy cultivation

Conventional tillage is the method commonly found all over the world when horses and cattle were used as the main power sources. Tractor power is also used in extensive manner later on. Ploughing, disking once or twice to break the clods and harrowing to pulverise the soil and to collect the plant materials are the common practices for a number of years.

2.2.1. Conventional tillage tools

The various conventional tillage tools used on the farm includes desi plough, mouldboard plough, rotary tiller, cage wheel, disc harrow, cultivator, leveller, etc.

2.2.1.1. Desi plough

Desi plough is one of the most common implement used by the Indian farmers. In addition to ploughing, it is used for sowing crops like paddy, wheat, barley, gram, etc, for interculture and harvesting the underground parts of the crops. The main parts of the plough are body, shoe, share, beam and handle, of which share is the working part of the plough and is attached to the shoe with which it penetrates into the soil and breaks it open. The beam, made of wooden piece connects the main body of the plough to the yoke. Handle is attached vertically to the body and it enables the operator to control the plough. It is made of wood. All India Implement Survey Report published by the ICAR reported that the shoe and the body are in one piece, in the case of ploughs used in Kerala. Desi plough is making trapezoidal furrows. The unit pull required by this ploughing is larger than that of bullock-drawn mouldboard plough.

The angle between the shoe and body varies from 116 to 160 . The length of shoe without joint varies from 45 to 90 metres, width from 7.5 to 23 cm and thickness from 5 to 13.5 cm . The working of the share to the ground varies from 10 to 30 . The share is prepared from a square mild steel bar 0.6 to 1.2m in length and 1.5 to 2.5 cm in width. In some cases flat iron bar, shaped one end like a spear head is used as share. Handle is 0.6 to 1m long, 5 to 7.5 cm thick and 7.5 to 12.5cm wide. The beam size varies from 2.7 to 4.5 cm and in section from 6 × 7.5 to 10 × 23 cm.

2.2.1.2. Mould board plough

Iron mould board ploughs are commonly used by farmers. In general, this plough is used in areas where there is sufficient rainfall to produce a good crop. It is also used to turn under heavy growth of green manure crops to help proper decay and addition of humus to the soil. It consists of plough bottom, beam, handle and clevises. Gauge wheels, coulter, jointer,etc are the plough accessories which improve the performance of the plough. The size of the plough is expressed by the width of furrow that it is designed to cut. Walking type ploughs are usually available between 15 to 12 cm. Among the tractor-drawn ploughs 30, 35 and 40 cm plough bottoms are used commonly.

2.2.1.3. Rotary tiller

Rotary tiller is a primary tillage tool commonly operated by a 5 to 12 hp power tiller. It consists one or two gangs of tyne sections. Each tyne section has 2 to 3 tynes. There may be 3 to 6 tyne sections on a gang, depending upon the size of the power tiller. The tynes are either hook shaped or L-shaped. The L-shaped tynes perform better hook shaped. The tyne sections are mounted on a shaft which is driven by PTO of the tractor at about 300 to 400 rpm. Each gang is covered by hood to protect the soil from flying away and falling on the operator. The tynes generally rotate in the direction of rotation of the tractor. The forward speed is about 2 to 3 kmph. The action of the rotary tillers result in a well pulverised and evenly distributed soil. The crop residues and weeds are thoroughly cut by tillers and it can also be used for manure mixing and puddling of paddy fields.

2.2.1.4. Cage wheels

It is used with tractor and power tillers for wetland puddling operations. It consists of a wheel structure on which tilling blades made of mild steel are attached. Cage wheel is specified by its diameter and weight is also an important factor in their selection. For use with power tillers, small diameter wheels are used whereas with tractors, large diamter wheels are employed ; corresponding changes in the weights are also experienced.

2.2.1.5. Disc harrows

The disc harrow is designed to work under different soil conditions. It consists of discs, arbor bolts, spools, bumpers, bearing frame, scraper and transport wheels. The discs are made of hardened steel. Diameter of the disc varies from 40 to 45 cm. Amount of concavity is about 5 to 10 cm. The frame is made of steel.

2.2.1.6. Cultivator

The cultivator is employed for dryland farming operations. It consists of shovels, tynes, frames, handle and a lever. The shovels are used for stirring the soil and killing the weeds. They are bolted to the tynes which are connected to the toolbar on the frame. Lever is provided for changing the spacing between the shovels. Clevis is provided for changing the point of hitch. The shovels made of high carbon steel are generally 5 to 7 cm wide and 22.5 to 25 cm long.

2.2.1.7. Leveller

In irrigated areas, land levelling is an essential operation for farming. Levelled field receives uniform penetration of irrigation water with high efficiency. The possibility of water logging and soil erosion is reduced considerably. Land levelling is usually done in the slack season when the field is free from crops and the man and bullocks are idle. Wooden logs or planks are the most common type of field levellers used by farmers. They are operated in ploughed land to collect the loose soil from high spots and to dump it into depressions.

2.2.2.Power sources

Power sources required for tillage operations in the field are classified as human,animal and mechanical power.

Human beings are the main sources of power for operating small tools and implements and for doing stationary works. On an average, a man develops nearly 0.1 hp.

The most important source of power in the farm in India is animal.Generally a medium sized bullock can develop between 0.5 to 0.75 hp.

Tractor is a self propelled power unit having wheels or tracks for operating agricultural implements and machineries. In agriculture, it is used for ploughing, harrowing, sowing, harvesting, transporting, pumping etc. Agriculturaltractors are generally of 35 to 50 hp size.

Power tillers are two wheel small tractors in the power range of 5 to 12 hp. Power tillers are being introduced in Indian farming as a new source of power for farmers 2 to 10 hectares holding group. These tractors have already gained wide popularity in advanced agricultural countries with small holdings like Japan, Taiwan etc. Power tillers are the only suitable mechanical units for wetland cultivation. They are very suitable for puddling of paddy fields. For tillage operations, they must be provided with rotary tiller. their field efficiency is considerably high.

2.2.3. Conventional tillage practices

The conventional system usually prepares a firm seedbed that is relatively free of clods and soil aggregates are are finely divided. Under conventional tillage system, the tendency of most farmers is to have a fine seedbed by ploughing a number of times with traditional equipment.

Conventional tillage practices can be classified as

i) Wet system practices and

ii) Dry and semi dry system practices.

2.2.3.1. Wet system practices

It is practiced when there is an assured and adequate supply of water. In this system, the land is thoroughly ploughed with an animal-drawn country or iron mould board plough with 2 to 3 inches of standing water in the field. Tractors and power tillers fitted with cage wheels are also used for the ploughing purposes. The field is ploughed repeatedly three or four times with an intervel of about four days between each ploughing and then levelled before planting with a wooden plank or leveller. The aim of puddling operation is to get a soft soil with a fairly impervious subsoil so that the transplanted paddy seedlings can establish quickly and the plant nutrients in the top soil are not washed down too much. After preparation of the land, broadcasting of seeds or transplanting of the seedlings from the early prepared nurseries are done. Cattle manure at about 2 tonnes per ha is sometimes applied after the first two or three ploughings. At the time of sowing wood ash is applied at about 1100 kg per ha.The seedrate used is 120 to 130 kg per ha in the case of broadcasting. Now a days fertilizer mixture [NPK] is applied just before levelling the field. After one month of planting, fertilizers are applied in split doses also Plant protection chemicals are applied as needed with hand operated sprayers,and weeding, harvesting and threshing are done manually.

2.2.3.2. Dry and semi dry system practices

These systems of cultivations are met within all rice growing states, but are mainly confined to tracts which get either the south-west or the north-east monsoon or both,and do not have adequate irrigation facilities. In this system, the land is ploughed a number of times with mould board plough or indigenous ploughs operated with bullocks. Tractors with mouldboard plouhgs, desi ploughs and harrows, tine ploughs and cultivators are also used for land preparation. Power tiller with tilling blade attachment is also used.

Seeding behind the plough in the furrow is usually used for sowing. In some areas, for drilling cultivator with seeding attachment is also used. Fertilizer application is practised along with sowing. Interculture operation with hoes, cultivators etc. are done. Plant protection chemicals are applied as needed with hand operated sprayers. Weeding, harvesting and threshing are done manually.

2.3. Studies on energy flow pattern

Production on a farm is influenced by the total amount of energy input to the farm. Indian farming suffers from lack of sufficient energy spent on farm resulting in low yield per ha. It is estimated that the availability of energy on Indian farm is about 0.4 hp/ha against the projected optimum requirement of 1 hp/ha [Maurya, 1985]. An elaborate study in determining the relationship between the yield and power per ha was conducted by the President's Advisory Committee in USA in the late sixties. The result revealed that the rate of increase of yield per hp showed a gradual decline and attained a constancy beyond 0.87 hp. It was therefore concluded that the power range for satisfactory yields should between 0.5 and 0.87 hp/ha [Agric. Engg. Today, 1986].

A study conducted by Singh et. al.[1978] revealed that rotary blade puddler and rotavator performed better in terms of energy requirements and overall economy as compared to cultivator and double cage wheels. Rotavator gave better uniformity of puddling and rotary puddler was economical to operate, but required more times as compared to rotavator.

Singh and chancellor[1974] observed thatthe total energy used per ha of growing crops increased with increase in mechanisation levels.

Shyam Murari and Nagaich, B. B.[1981] reported that draft power accounted for about 24% of the total energy demand and it is significant to note that most of the draft power was contributed by animals whereas for irrigation, maximum contribution was of electrical power followed by diesel and animals.

Dutt, B.K.[1982] found that among different phases of transplanted rice production, maximum energy was takem by tillage. Human energy involved in tillage was 21.5% and 29.3% in Kharif and Rabi respectively and those of bullock energy was 64.7% and 47.2% respectively. The total input energy was 17280.1 Mcal and 17882.8 Mcal in Kharif and Rabi respectively.

For raising the transplanted paddy, it was observed that the effect of tillage including puddling operation was found to be more significant on yield [ICAR, 1982]. Therefore, puddling equipments and improved matching implements should be popularised. Transplanted paddy resulted in 30 to 40% more yield than the broadcast one. The interculturing weeder which saves energy and cost for weeding in paddy should be encouraged. In paddy-wheat rotation, use of rotavator over disc harrow saved 10 to 20% energy for dry seedbed preparation and puddling. The bullock-drawn improved implements not only require less energy but are economical also. The use of energy for the cultivation of paddy had direct relationship with the production of farm. About 69 to 95% of the total energy for the paddy cultivation was only for chemicals, fertilizers and seeds The field operation had a meagre share of less than 7%. Hence research efforts should be directed towards reducing the components of chemicals, fertilizers and seed through better application and proper management. The manual operation of paddy transplanting was the costliest operation which accounted for 26 to 34% of the total energy cost. However, the share of human labour in total energy requirements was 4.2 to 6.2%. The energy inflow of paddy-wheat rotation on tractor farms was 18397, on bullock farms 17771 and on power tiller farms 188350 MJ/ha, out of which the share of energy from fertilizer and seed were 13388 and 2037 MJ/ha. The direct energy varied according to sources of power and it was 2980 on tractor farm, 2350 on bullock farm and 2735 MJ/ha on power tiller farm. The output-input ratio on the basis of main product as well as the total product was higher on tractor firms as compared to bullock and power tiller firms because of comparatively higher yield. For raising paddy crop, the energy inflow on tractor, bullock and power tiller farming were 9968, 9446 and 9508 MJ/ha respectively. The energy on account of fertilizer and seed was 7860 and 380 MJ/ha respectively on all types of farming. The direct energy on tractor farming was 1458, bullock farming 1202 and power tiller farming 1268 MJ/ha. The total output-input ratio in tractor farming was found to be the highest [11.0] followed by bullock farming 9.37 and power tiller farming 7.61. The tillage operation consumed 30 to 35% of the direct energy followed by irrigation 28 to 30%. Harvesting and threshing operation consumed 20 to 25% of the direct energy. The tillage, irrigation, harvesting and threshing operations consumed together about 85% of the direct energy. The yield of paddy was found to be highest on tractor farming, ie. 40 q/ha followed by bullock farming 33 q/ha and by power tiller farming 26.2 q/ha. The yield on tractor farming was high because of the good quality puddling.

Panesar et. al. [1983] showed that the major operations like seedbed preparation, sowing, irrigation, harvesting and threshing consumed more than 80% of the total energy for field operation.

ICAR [1984] reported that in kharif season, paddy is the major crop which is sown over 38.7% of the area. Energy for the crop production is provided by human [1.21%], animal [4.21%], diesel [19.26%], electricity [6.57%], seed [33.61%], fertilizer [19.85%] and machinery [15.29%]. Tractor operated farms [TOF] consumes 52.14% energy whilebullock operated farms[BOF] consumes only 47.86%. The energy input per ha on BOF and TOF is 996280 Kcal and 2367130 Kcal respectively. Output-input ratio for the two farming systems are 18.01 on BOF and 9.07 on TOF with an overall ratio of 13.72.

Dhewan et. al [1985] stated that energy requirement for paddy varies from 2934 MJ/ha to 7700MJ/ha. It means that there exists a lot of variations in the energy requirement for paddy crop.

Studies on energy requirements on farm [ICAR, 1985] revealed that in mechanised farming, power tiller as well as tractor were found to be equally efficient for paddy production. The puddling index achieved in this tillage level varied from 70 to 75%. Manual uprooting and transplanting of paddy required 30 to 40 mandays/ha consuming about 22 to 24% of total human energy.

For paddy and wheat cultivation, it is observed that two passes of power tiller rotopuddling and two passes of rototilling respectively gave the highest output-input ratio of 4.37 and 3.57. Total power availability on selected West Bengal farms in different agro-climatic zones varied from 0.44 to 3.86 kW/ha for doing different farm operations. The average value was 1.33 kW/ha.

ICAR [1986]in a study on energy requirements in agricultural sector stated that the use of bullockdrawn mould board and soil stirring ploughs for wheat and puddler for paddy gave 24.8 to 40.9% higher output-input energy ratio for paddy-wheat rotation as compared to tractor-drawn disc harrow and rotavator. However, the difference in yield was not significant under these treatments. For paddy, marginal farmers obtained maximum output-input ratio of 4.38 and specific energy requirement was lowest ie. 5.21 MJ/kg and were found to have better management of energy inputs. The energy inputs through fertilizers for paddy was 6% more as compared to recommended doses.

Status of energy needs for paddy crop production under irrigated conditions in Punjab [ICAR, 1986].

Parameters	Observed values
1. Total energy in operation (MJ/ha)	18660
2. Energy operationwise (%)	
Seedbed preparation	8.5
Sowing	1.7
Bund making	0.3
Irrigation	81.9
Weeding	0.1
Fertilizer application	0.3
Harvesting and threshing	4.2
Transportation	1.3
Post-harvest operation	0.2
3. Total energy input (MJ/ha)	33410
4. Energy sourcewise, (%)	
Human	6.5
Animal	1
Diesel	29.3
Electricity	28.1
Fertilizers and chemicals	32.1
Machinery	1.1
5. Yield (kg/ha)	5696
6. Output-input energy ratio	3.92
7. Specific energy (MJ/kg)	5.87
8. Nonrenewable energy, % of total energy	89

Study on energy requirement for the cultivation of rice under different puddling implements was carried out by ICAR [1988]. Results showed that among different puddling implements under bullock as the source of power, total energy required for puddling was found least in treatment- one MB ploughing + 3 passes of factory, BBSR made bullockdrawn puddler (642.5 MJ/ha) followed by treatment- one MB ploughing + 4 passes of drum disc puddler (865.6 MJ/ha) and treatment- one MB ploughing + 2 passes of desi ploughing (1249.6 MJ/ha). No significant difference in yield was found due to different puddling treatments under bullock as the source of power.

ICAR [1989] revaeled that the total energy required for different field operations for the production of aman paddy was found to be minimum (4279 MJ/ha) under treatment - one bullockdrawn MB ploughing + 2 puddling with puddler as against a maximum energy (6299 MJ/ha) in case of treatment- rototilling x 3 with power tiller. OPerationwise, for aman paddy production among the major field operation, field preparation consumed maximum amount of energy (19% to 45%). This was followed by irrigation (28 to 41%); transplanting (13 to 20%); harvesting and threshing (11 to 16%) of the total operation energy under different treatments. Energy from commercial sources contributed 78% for growing aman paddy and 22% from noncommercial sources. Statistical analysis of yield data of paddy indicates that there was no significant difference at 5% level.

ICAR [1989] conducted a study in village Thulsigata in West Bengal and reported that the farmers raise only aman paddy in kharif season and cropping intensity is 10% only. Sourcewise, energy contributed for crop production is maximum by human (38.91%) followed by animal (19.88%), seed (17.67%), fertilizers (12.86%), diesel (7.41%). Farmyard manure, machinery and chemical are not used by farmers at all.

Md. Saleque Uddin and Forde, M. Shah[1989] reported that field capacity of tractors and power tillers was higher than that of bullocks but the cost is lesser than that of bullocks and also operations are energy efficient.

Jan Muhammed Baloch, et.al.[1991] repoted that the power requirement is dependant variables of soil moisture content and type of soil.

Leonard, L. Bashford, et. al.[1991] observed that the choice of implements can result in reduced energy and fuel requirement for some tillage treatments.

Paneswar, et. al.[1991] reported that the average power requirement for seedbed preparation decreased linearly with increase in time required to complete the seedbed preparation.

MATERIALS AND METHODS

Study of energy requirement for the virippu cultivation of paddy was carried out during the year 1992. Different tillage treatments were taken to find out the most energy efficient treatment under tractor, power tiller and bullock as the power sources.

3.1 Field location

The place is near the bank of Bharatapuzha river and is located at 10° 53′ 30" north latitude and 76° east longitude. This area receives medium rainfall of 1000-2000 mm with an average rainfall of 1500 mm per annum, mainly concentrated during monsoon from June to October.

3.2 Field experiments

Field experiments were conducted at The Instructional Farm of K.C.A.E.T, Tavanur under Kerala Agricultural University. The aim was to evaluate the energy requirements in various farm operations for crop production, under varied tillage treatments following conventional methods of farming with animal and mechanical power sources, with four replications each. The treatments followed in the field were:

1. T1 - Bullock drawn Desi ploughing × 5 + levelling × 1
2. T2 - Power tiller with cage wheel × 4
3. T3 - Tractor with cage wheel × 4

The mechanical power sources used were 12 hp KUBOTA power tiller and 35 hp HMT tractor.

The various implements and machines used in the field during the course of the experiment are illustrated in the plates. Details of the experiment are given in Appendix-1. Since our main aim was concentrated to find out the effect of tillage treatments, other energy inputs to the field have been kept constant. Bund making and trimming of the previous bunds were made manually. Uprooting, transplanting and transportations of the seedlings which were raised in the nursary have been done manually. Since cultivation was done in virippu season, energy requirements for irrigation purposes is neglected. Fertilizer application was done according to the recommendations of package of practices. Factomphos and murate of potash were spread manually at the rate of 175 kg/ha and 37.5 kg/ha respectively. Urea was applied after 28 days of transplanting at the rate of 75 kg/ha followed by murate of potash at the rate of 37.5 kg/ha. Due to unfavourable conditions, weeding and pesticide applications were not done. Harvesting of the crop and its transportation to the threshing yard were done manually. LCT thresher fitted with 7.5 hp engine was used for threshing the whole paddy.

3.3 Methods of Measurement of the Experimental Data

The datas recorded in conducting the field experiments include time required for completing various field operations by different power sources like human, animal pair, other power

Plate No.1. Bullockdrawn Desi plough

Plate No.2. Bullockdrawn Desi plough in operation units and machines, fuel consumption by mechanical power sources, crop yield etc.

3.3.1 Operation Time

Time for each operation starting from field preparation to threshing was recorded with the help of stop watch. Time at the beginning of operation and time at the end of operation were observed and recorded. Time spent on major break downs or resting time of the labourer, if any was excluded from time difference between the beginning of the operation and end of operation. Time for minor field adjustments was included in the operation time. Time for tillage, planting, weeding, harvesting, threshing etc. were noted for each plot seperately.

3.3.2 Fuel Consumption

Fuel consumption for tractor and power tiller were recorded by top filling method. Before starting the operation, tractor or the power tiller was brought to a level ground and filled with fuel upto its brim. Then after completing the field operation tractor was again brought to same level ground and measured quantity of fuel was added to the fuel tank and filled upto the top mark. This measured quantity of fuel was recorded as the consumed fuel. While filling the fuel in the fuel tank, tractor was shaken at end to remove any air bubbles in the fuel tank. Fuel consumption for stationary oil engine used for threshing operation was also measured by top filling method.

3.3.4 Physical Inputs

The physical inputs like seeds, fertilizers and chemicals used in the experiments were as per the recommended doses for this area. These amounts were measured.

3.3.5 Crop Yield

Bulk weight of the paddy as such from the field was weighed. After threshing and winnowing operations the quantity of cleaned grain was weighed for each plot seperately. Weight of straw can be then obtained by deducting the weight of the grain from the bulk weight.

3.3.6 Total Energy of the Crop

To calculate the total energy of the crop, the energy requirements for various operations are added; ie. it is the sum of the energies contributed by human labour, animal, mechanical power sources and other physical inputs like seeds, fertilizer, pesticides etc. and is expressed in MJ/ha.

3.3.7 Specific Energy of the Crop

The specific energy of the crop for a particular treatment was obtained by dividing the total energy requirements of the crop and yield of main produce obtained in that particular treatment and expressed in MJ/q.

Plate No.3. Bullockdrawn leveller

Plate No.4. Bullockdrawn leveller in operation

3.3.8 Output-Input Energy Ratio

To calculate the energy input and output, different power sources and material parameters of seed, fertilizer, chemical, machinery, diesel, petrol, human and animal were converted to energy unit in MJ using energy coefficients. The output energy was calculated by taking the energy for main product as well as crop residues and the input energy was calculated considering the direct and indirect energy consumed for field operations . The output-input energy ratio was obtained for the main as well as by-product and total product of the crop.

3.3.9 Statistical Analysis

The analysis of variance for specific energy and grain yield under different treatments of the experiment were done with respect to the plots to test whether there is any significant difference in the yield of grain under different treatments by calculating F-factors.

3.4 Theoretical Considerations

Energy required for intensive agricultural production is mainly obtained from human, animal, mechanical (using fossil fuels like diesel and petrol etc.) and electrical energy sources.

3.4.1 Classification of Energy on the Basis of Sources

The energy can be classified as direct and indirect energy on the basis of the source from which it is obtained.

3.4.1.1 Direct Energy Sources

The direct energy sources are those which release energy directly like human labour, bullock, stationary and mobile mechanical or electric power units such as diesel engines, electric motors, power tillers and tractors. The direct energy may be further classified as renewable and non renewable sources of energy depending upon their replenishment.

3.4.1.1.1 Renewable Direct Source of Energy

In this category, the energy sources which are direct in nature, but can be subsequently replenished are grouped. This energetics which may fall in the group are human beings, animals, solar, wind and hydro-power, fuel wood, agricultural waste etc.

3.4.1.1.2 Non Renewable Direct Source of Energy

In this category, direct energy sources which are not renewable are classified. Coal and fossil fuels examplify non renewable direct sources of energy.

3.4.1.2 Indirect Energy Sources

The indirect energy sources are those which do not release energy directly but release it by conversion process. Some energy is involved in producing indirect sources of energy seeds, manures, chemicals, fertilizers and machinery are classified under indirect sources of energy. On the basis of

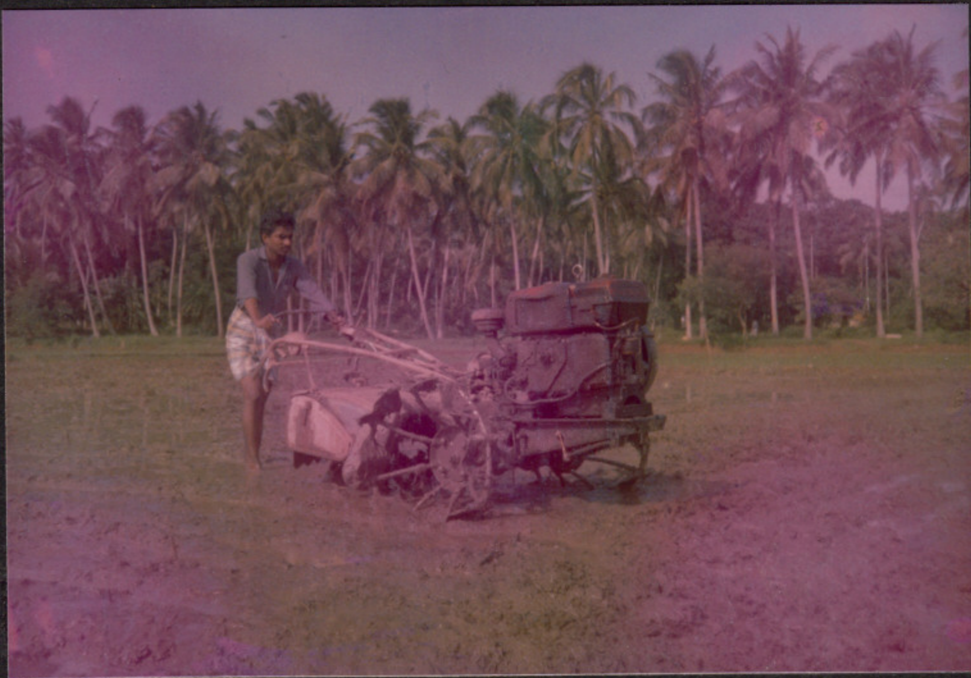


Plate No.5. Power tiller with cage wheel in operating condition

Plate No.6. Tractor with cage wheel in operation their replenishment, these can be further classified into renewable and non renewable indirect sources of energy.

3.4.1.2.1 Renewable Indirect Source of Energy

Seed and manure can be termed as renewable indirect sources of energy as they can be replenished in due course of time.

3.4.1.2.2 Non Renewable Indirect Source of Energy

The energy sources which are not replenished came under non renewable indirect sources of energy. Chemicals, fertilizers and machinery manufacturing are the non renewable indirect sources of energy.

3.4.2 Classification of Energy on the Basis of Comparative Economic Value

On the basis of comparative economic value, the energy may be classified as commercial and non-commercial.

3.4.2.1 Non-commercial Energy

Each and every source of energy has some economic value. Some energy sources are available comparatively at low cost where as others are capital intensive. The energy sources which are available cheaply are called non-commercial sources of energy where as the ones which are capital intensive are called commercial energy sources.

Plate No 7. Threshing by LCT Thresher

$$\text{Direct energy (MJ/ha)} = \frac{1.96HLH + 1.57WLH + 10.1BPH + 56.1DC + 11.9EC}{OA}$$

where,

HLH = Human labour hour

WLH = woman labour hour

BPH = Bullock pair hour

DC = Diesel consumption in litres

EC = Electrical consumption in kWhr, and

OA = Operational area in ha

Indirect energy which is a function of weight of the machinery and power sources; life of the implements and machineries and hours of use of the power source is calculated by the following equation;

$$\text{Indirect energy (MJ/ha)} = \frac{(HUP \times WP \times 64.8) + (HUP \times WM \times 62.7)}{OA}$$

where,

HUP = Hours of use of power sources

WP = Weight of power sources per life in hours

WM = Weight of machine per life in hours, and

OA = Operational area in ha

Assumptions made for the calculation of indirect energy is presented in Appendix II.

Indirect energy provided by physical inputs such as seeds, fertilizers, chemicals etc. were converted into respective energy equivalents as presented in Appendix II and added to get the total indirect energy supplied by them to the field which when divided by the operational area gives the indirect energy supplied in MJ/ha. This is added to the value obtained from the above equation to get the total indirect energy to the field (MJ/ha). Since the application of physical inputs was kept almost a constant, it will not have any pronounced effect.

Output energy from each plot is seperately calculated from amount of main products as well as by products. The energy coefficients used for the conversion of these products into equivalent energy are presented in Appendix II.

Using these values of input and output energies, the output-input ratio for each plot is calculated seperately.

RESULTS AND DISCUSSION

Field experiments were conducted with conventional practices using conventional implements as well as farm power machinery package prevalent in Kerala State to establish the energy requirement of transplanted paddy. All the three power sources namely tractor, power tiller and bullock were utilised along with their matching implements for the production of rice. Under bullock as the source of power, the implement treatment combination used was Desi ploughing five times followed by levelling once with a wooden plank. Under power tiller and tractor as the power sources, four passes of cage wheel were carried out. These treatments were designated as T1 ,T2 and T3 respectively. The main aim of the experiment was to find out the most energy efficient practice of tillage under these three treatments which are prevalent all over the State of Kerala. The results of the study are discussed below.

4.1 Total Input Energy Requirement

Least total input energy was found in the case of tractor as the power source (T3) followed by bullock as the power source (T1). This is because of the good quality puddling obtained by T3 compared to the other two. Total direct energy was found to be the lowest in treatment T3 and the lowest total indirect energy was found in T1. This is because of the reason that tractor consumed less fuel and less man hours due to less working hours when compared with the other operations and in the case of

Table 1. Total input, direct and indirect energy flow

Treatments	Total input energy (MJ/ha)	Total direct energy (MJ/ha)	Total indirect energy (MJ/ha)
T1	14186.47	4385.27	9081.20
T2	14928.49	4920.60	10007.89
T3	13935.20	4034.16	9901.60

T1, indirect energy contribution due to machinery was very less. The values of total input energy, direct energy and indirect for the three treatments are given in Table: 1. Total input energy variation under different treatments is shown in the bar diagram:2.

4.2 Operation Wise Energy Requirements

The operation wise energy requirements for paddy cultivation under different tillage treatments are presented in Table:2. It is observed that the energy requirement is very high in the case of field operation under T2 when compared to T1 and T3. The energy requirement for field preperation are 1225.21, 2068.11 and 1161.96 MJ/ha respectively for bullock farming, power tiller farming and tractor farming. It constituted 8.64 %, 14 % and 8.44 % of the total input energy for T1 , T2 and T3 respectively. This suggests that minimum energy is required for field preperation under tractor farming followed by bullock farming. Though irrigation is regarded as a major energy input to the field, its contribution in this experiment has been neglected owing to the high rainfall received during the season. For transplanting 4.85 %, 4.5 % and 5.0 % of the respective total energy were used. Slight variations observed in this energy requirement of transplanting may be due to the extend of tilth. Out of the different operations, fertilizer application gave the highest energy input to the field. It is computed that 50 %, 47.04 % and 50.4 % of the total input energy were contributed by fertilizers under T1, T2 and T3 respectively. Weeding and

Table 2. Direct and Indirect energy (MJ/ha) requirements for the cultivation of wet land paddy under different tillage treatments for field preparation. K.C.A.E.T., Tavanur, 1992.

No.	Operations/ treatments		Direct energy			Indirect energy			
			Renewable	Non renewable	Total	Renewable	Non renewable	Total	Grand total
1	Tillage/ Puddling	T1	1195.99	--	1195.99	--	29.22	29.22	1225.21
		T2	68.54	1823.61	1892.15	--	175.96	175.96	2068.11
		T3	15.57	1017.37	1032.94	--	129.02	129.02	1161.96
2	Nursary Preparation	T1	66.15	241.93	308.08	1140.00	231.22	1371.22	1679.30
		T2	66.15	241.93	308.08	1140.00	231.22	1371.22	1679.30
		T3	66.15	241.93	308.08	1140.00	231.22	1371.22	1679.30
3	Nursary uprooting and transportation	T1	328.20	--	328.20	--	--	--	328.20
		T2	328.20	--	328.20	--	--	--	328.20
		T3	328.20	--	328.20	--	--	--	328.20
4	Bund forming and trimming	T1	81.60	--	81.60	--	05.36	05.36	86.96
		T2	81.60	--	81.60	--	05.36	05.36	86.96
		T3	81.60	--	81.60	--	05.31	05.36	86.96
5	Transplanting	T1	328.14	--	328.14	--	--	--	328.14
		T2	288.20	--	288.20	--	--	--	288.20
		T3	318.13	--	318.13	--	--	--	318.13
6	Fertilizer application	T1	29.40	--	29.40	--	6990.10	6990.10	7019.50
		T2	29.40	--	29.40	--	6990.10	6990.10	7019.50
		T3	29.40	--	29.40	--	6990.10	6990.10	7019.50
7	Gap filling	T1	32.36	--	32.36	--	--	--	32.36
		T2	32.36	--	32.36	--	--	--	32.36
		T3	32.36	--	32.36	--	--	--	32.36
8	Harvesting	T1	798.20	--	798.20	--	--	--	798.20
		T2	737.31	--	737.31	--	--	--	737.31
		T3	620.15	--	620.15	--	--	--	620.15
9	Transportation	T1	150.80	--	150.80	--	--	--	150.80
		T2	150.80	--	150.80	--	--	--	150.80
		T3	150.80	--	150.80	--	--	--	150.80
10	Threshing	T1	255.94	876.56	1132.50	--	1405.30	1405.30	2537.80
		T2	255.94	876.56	1132.50	--	1405.30	1405.30	2537.80
		T3	255.94	876.56	1132.50	--	1405.30	1405.30	2537.80

pesticide applications were not done owing to unfavourable circumstances. Harvesting and transportation contributed 6.7 %, 6.0 % and 5.6 % of the respective total energy and threshing consumed 17.9 %, 17.0 % and 18.4 % of the total input energy under T1, T2 and T3 respectively. These results are represented in the pi-diagrams 1, 2 and 3.

For operations like nursary preparation, fertilizer application, harvesting, transportation and threshing, the consumption of the energy have been almost same for all the treatment combinations. The slight variations observed in the energy requirement for harvesting and threshing operations may be mainly due to the variation in the quantity of crop harvested and amount of weed growth.

Energy required for puddling under different puddling treatments are represented in the bar diagram: 21.

4.3 Source Wise Energy Requirement

Source wise energy requirement for the cultivation of paddy under different tillage treatments are presented in Table: 3. Under tractor and power tiller farming, maximum energies were contributed by fertilizer and chemicals followed by diesel, human, machinery and seed as presented in Table: 3 and pi-diagrams 4 and 5. Under bullock farming also, fertilizer and chemicals contributed about 51.3 % of the total energy followed by human, machinery, seed, diesel and bullock as presented in the pi-diagram: 6 and Table: 3.

TABLE.3. Sourcewise energy requirement for the cultivation of paddy under different tillage treatments for field preparation.

Sources of energy	T1	T2	T3
1. Human	2265.17	2038.45	1898.24
2. Bullock	1001.61	– –	– –
3. Diesel	1118.49	2942.10	2135.87
4. Seed	1140.00	1140.00	1140.00
5. Fertilizer & Chemical	7194.48	7194.48	7194.48
6. Machinery	1466.72	1613.46	1566.90
7. Total energy	14186.47	14928.49	13935.11

PIE — DIAGRAMS

Source Wise Energy Components Under T1,T2 & T3

F.C - Fertilizer and Chemical

H - Human Energy

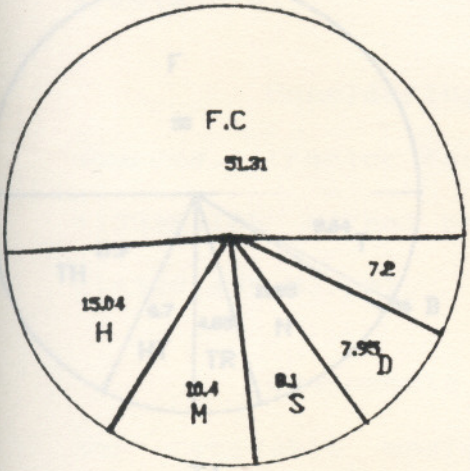
M - Machinery

S - Seed

D - Diesel

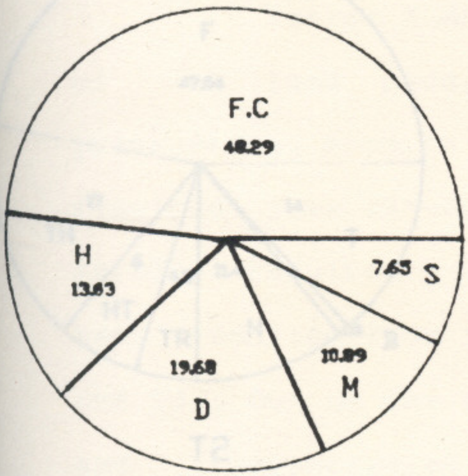
B - Bullock Energy

1.



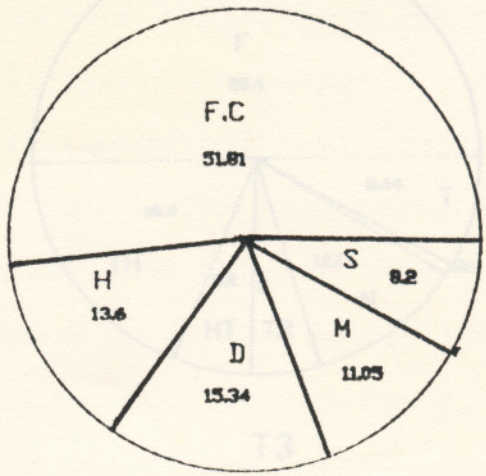
T1

2



T2

3

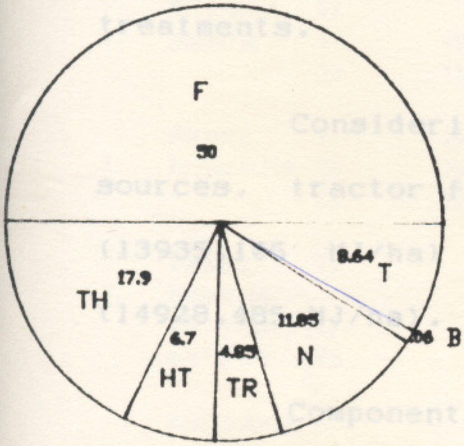


T3

Operation Wise Total Energy Requirement

Under T1,T2 & T3

4



T1

F - Fertilizer appln.+ fertilizer

T - Tillage

B - Bund forming

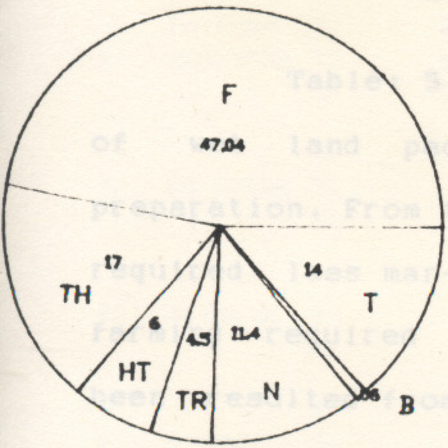
N - Nursary preperation

TR - Transplanting

HT - Harvesting and Transportation

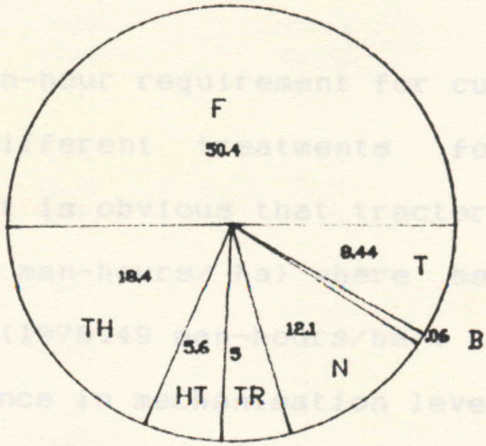
TH - Threshing

5



T2

6



T3

Human energy contribution was 2265.17, 2038.45 and 1898.24 MJ/ha respectively under T1, T2 and T3 . ie. Tractor farming required less human energy where as bullock farming consumed the highest. Diesel consumption was highest in the case of power tiller farming system. Fertilizer and chemicals together accounted for a constant energy input of 7194.48 MJ/ha and seed contributed a constant input of 1140.0 MJ/ha for all the three treatments.

Considering over all energy requirement from different sources, tractor farming accounted for the minimum total energy (13935.105 MJ/ha) and power tiller farming required the highest (14928.485 MJ/ha).

Components of total energy contributed by renewable and non renewable energies are presented in Table: 2 and by commercial and non-commercial energies are given in Table: 4.

4.4. Man-hour Requirement

Table: 5 shows the man-hour requirement for cultivation of wet land paddy under different treatments for field preparation. From this table, it is obvious that tractor farming required less man-hours (968.2 man-hours/ ha) where as bullock farming required the highest (1078.49 man-hours/ha). This has been resulted from the difference in mechanisation levels of T1 and T3 . Out of the different operations in the field, harvesting and transportation accounted for the highest man- hour requirement followed by transplanting and nursary uprooting and transportation.

Table 4. Commercial and non-commercial energy requirement for cultivation of paddy under different tillage treatments for field preparation KCAET, Tavanur.

No.	Operation/ treatments		Commercial energy	Non-commercial energy	Total energy
1.	Tillage/ puddling	T1	29.22	1195.99	1225.21
		T2	1999.57	68.54	2068.11
		T3	1146.39	15.57	1161.96
2.	Nursary Preparation	T1	1613.15	66.15	1679.30
		T2	1613.15	66.15	1679.30
		T3	1613.15	66.15	1679.30
3.	Nursary Uprooting and transportation	T1	--	328.20	328.20
		T2	--	328.20	328.20
		T3	--	328.20	328.20
4.	Bund forming and trimming	T1	5.36	81.60	86.96
		T2	5.36	81.60	86.96
		T3	5.36	81.60	86.96
5.	Transplanting	T1	--	328.14	328.14
		T2	--	288.20	288.20
		T3	--	318.13	318.13
6.	Fertilizer Application	T1	6990.10	29.40	7019.50
		T2	6990.10	29.40	7019.50
		T3	6990.10	29.40	7019.50
7.	Gap filling	T1	--	32.36	32.36
		T2	--	32.36	32.36
		T3	--	32.36	32.36
8.	Harvesting	T1	--	798.20	798.20
		T2	--	737.31	737.31
		T3	--	620.15	620.15
9.	Transportation	T1	--	150.80	150.80
		T2	--	150.80	150.80
		T3	--	150.80	150.80
10.	Harvesting	T1	2281.86	255.94	2537.80
		T2	2281.86	255.94	2537.80
		T3	2281.86	255.94	2537.80

Table 5. Man-hr requirements for the cultivation of paddy under different tillage treatments for field preparation, K.C.A.E.T., Tavanur, 1992.

Operation/ treatments	Average values of man-hr/ha required for various operations								Average total
	Tillage/ puddling	Bund forming	Nursary prepa- ration	Nursary uprooting and trans- portation	Transplanting and gap filling	Fertilizer application	Harvesting and trans- portation	Threshing	
T1	99.20	41.63	33.75	167.18	183.93	15.00	407.24	130.56	1078.49
T2	34.97	41.63	33.75	167.18	163.555	15.00	452.07	130.56	1038.69
T3	07.94	41.63	33.75	167.18	178.82	15.00	393.22	130.56	968.20

4.5 Crop Yield

Table:6 represents the average yield of main product and by product. It is found that among the tillage treatments, tractor farming gave the highest grain yield (33.28 q/ha), followed by bullock farming and power tiller farming. In case of by product also tractor farming gave the highest yield (45.86 q/ha), followed by T1 and T2 respectively.

4.6 Total Energy Inflow-Outflow pattern

Total energy inflow is obtained by the summation of energy under different sources for a particular treatment combination. Details of input and output energy obtained for each treatment combination is shown in Table: 7. From that Table it is noted that maximum energy output (107909.6 MJ/ha) was obtained from tractor farming (T3), whereas it was minimum (82930.5 MJ/ha) in the case of power tiller farming (T2).

4.7 Output-Input Energy Ratio

Total output-input energy ratio obtained in different treatment under power tiller as the source of power is minimum (5.56), where as tractor farming evolved a maximum ratio of 7.74. The calculation of output-input ratios for main products, by products and total product are given in Table: 7. Bar-diagram: 4. represents output-input ratios for T1, T2 and T3 . The result indicates that tractor farming is energy efficient since it evolved the maximum output-input ratio and hence tractor with

Table 6. Operation wise energy requirements for the cultivation of paddy under different tillage treatments for field preparation, K.C.A.E.T., Tavanur, 1992.

Treat-ments	Average values of energy requirements of various operation (MJ/ha)											Average yield of crop (q/ha)		Average specific energy of crop (MJ/q)	
	Tillage/ puddling	Nursary prepa-ration	Nursary uprooting and transportation	Bund forming and trimming	Trans-planting	Ferti-lizer appli-cation	Gap filling	Harve-sting	Trans-portation	Thresh-ing	Average total	Main product	By-product	Main product	By-product
T1	1195.99	308.08	328.20	81.60	328.14	29.40	32.36	798.20	150.80	1132.50	4385.27	30.60	37.56	143.30	116.94
T2	1892.15	308.08	328.20	81.60	288.20	29.40	32.36	737.31	150.80	1132.50	4920.60	27.50	32.97	178.93	149.24
T3	1032.94	308.08	328.20	81.60	318.13	29.40	32.36	620.15	150.80	1132.50	4034.16	33.28	45.86	121.22	87.97

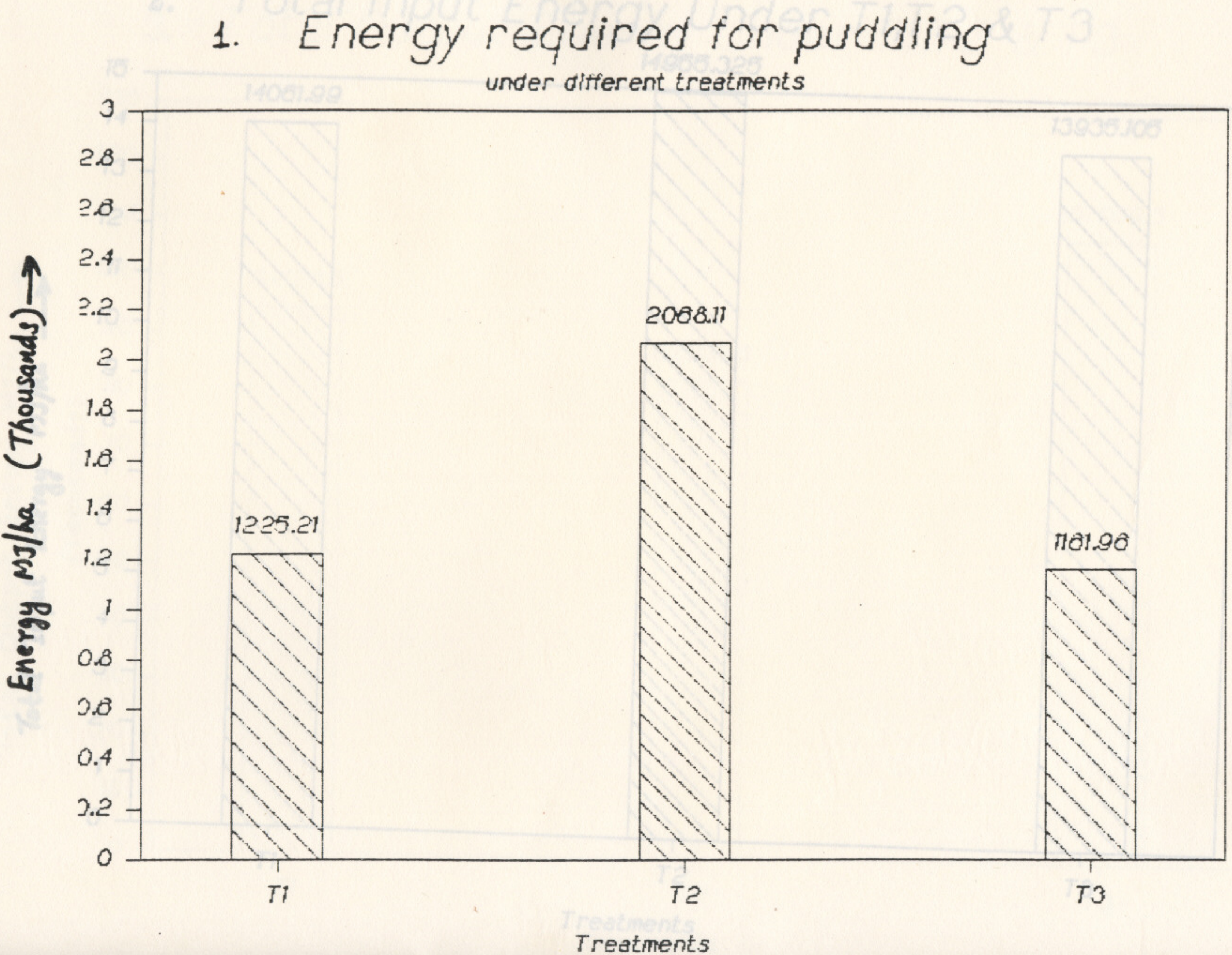
TABLE.7. Output-input energy ratio for the cultivation of paddy under differnt tillage treatments for field preparation.

Parameters	T1	T2	T3
A. INPUTS			
a. Field operations	4358.43	4953.71	4034.21
b. Seed	1140	1140	1140
c. Chemical, fertilizer & Machinery	8688.04	8834.78	8760.99
d. Total inputs	14186.47	14928.49	13935.2
B. OUTPUTS			
a. Main product	46506.3	41743.00	50579.9
b. By-product	46917.2	41187.5	57329.7
c. Total products	93423.5	82930.5	107909.6
C. OUTPUT-INPUT ENERGY RATIO			
a. Main product	3.28	2.80	3.63
b. By product	3.31	2.76	4.11
c. Total product	6.59	5.56	7.74

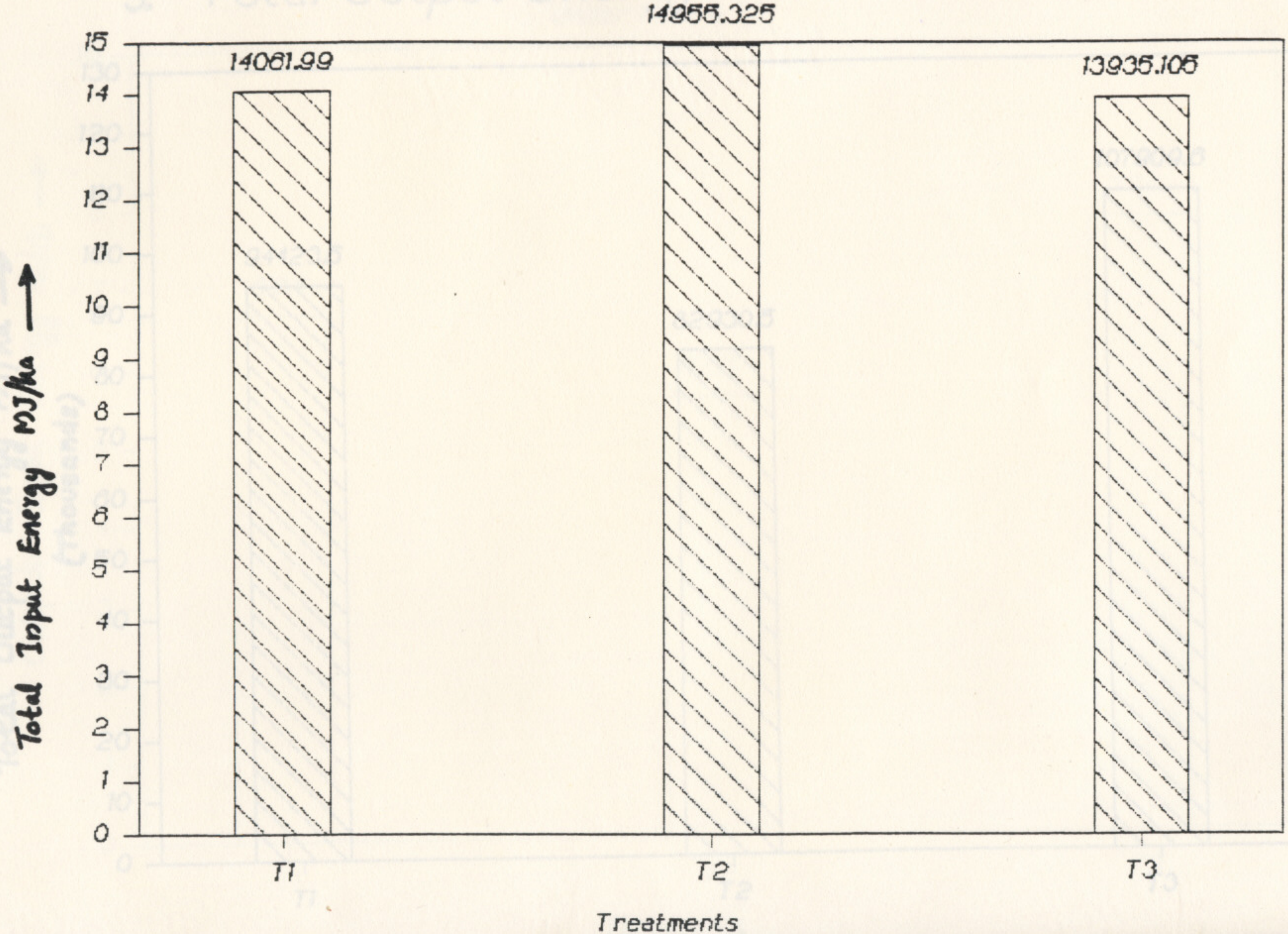
TABLE.7. Output-input energy ratio for the cultivation of paddy under differnt tillage treatments for field preparation.

Parameters	T1	T2	T3
A. INPUTS			
a. Field operations	4358.43	4953.71	4034.21
b. Seed	1140	1140	1140
c. Chemical, fertilizer & Machinery	8688.04	8834.78	8760.99
d. Total inputs	14186.47	14928.49	13935.2
B. OUTPUTS			
a. Main product	46506.3	41743.00	50579.9
b. By-product	46917.2	41187.5	57329.7
c. Total products	93423.5	82930.5	107909.6
C. OUTPUT-INPUT ENERGY RATIO			
a. Main product	3.28	2.80	3.63
b. By product	3.31	2.76	4.11
c. Total product	6.59	5.56	7.74

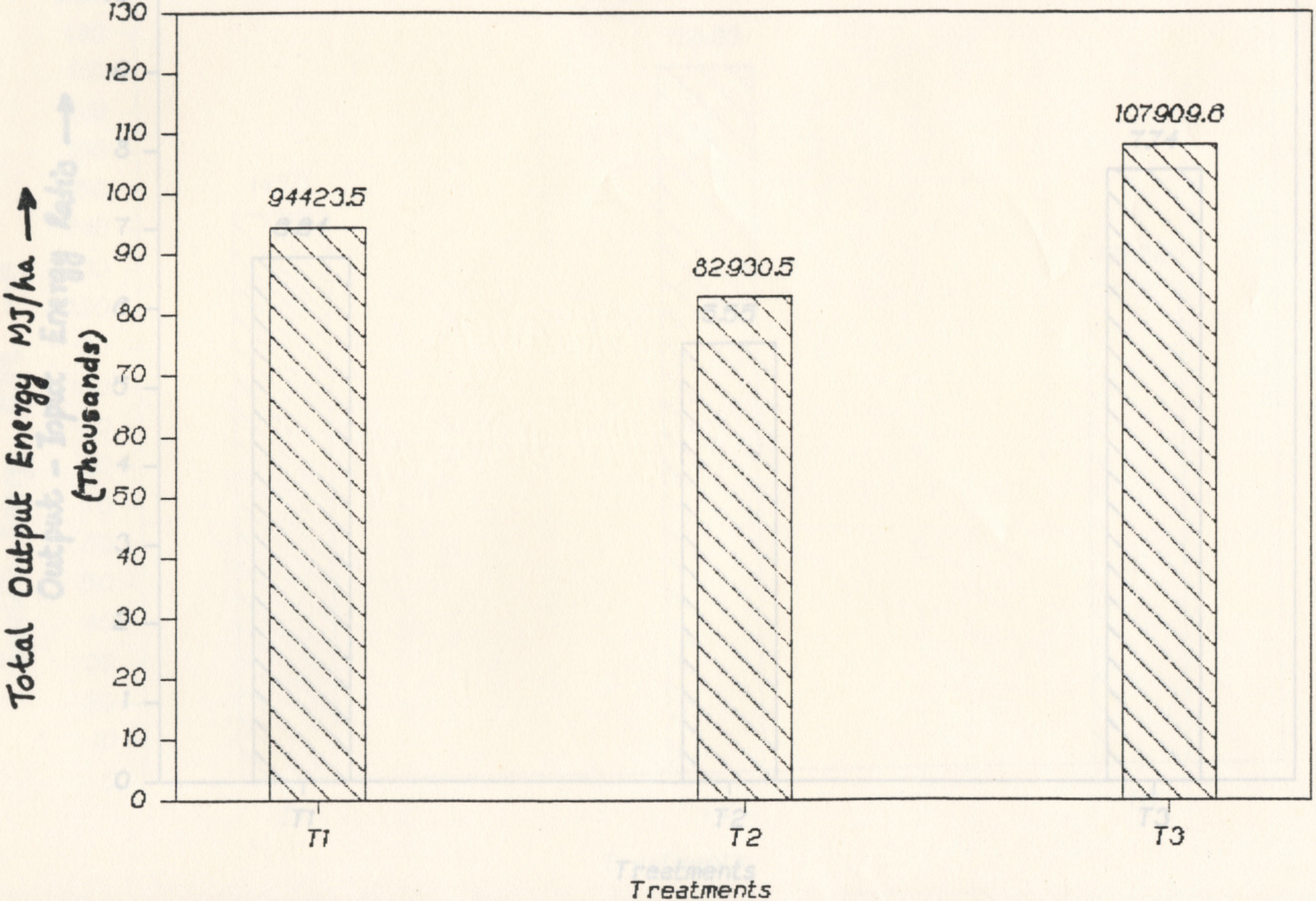
BAR DIAGRAMS



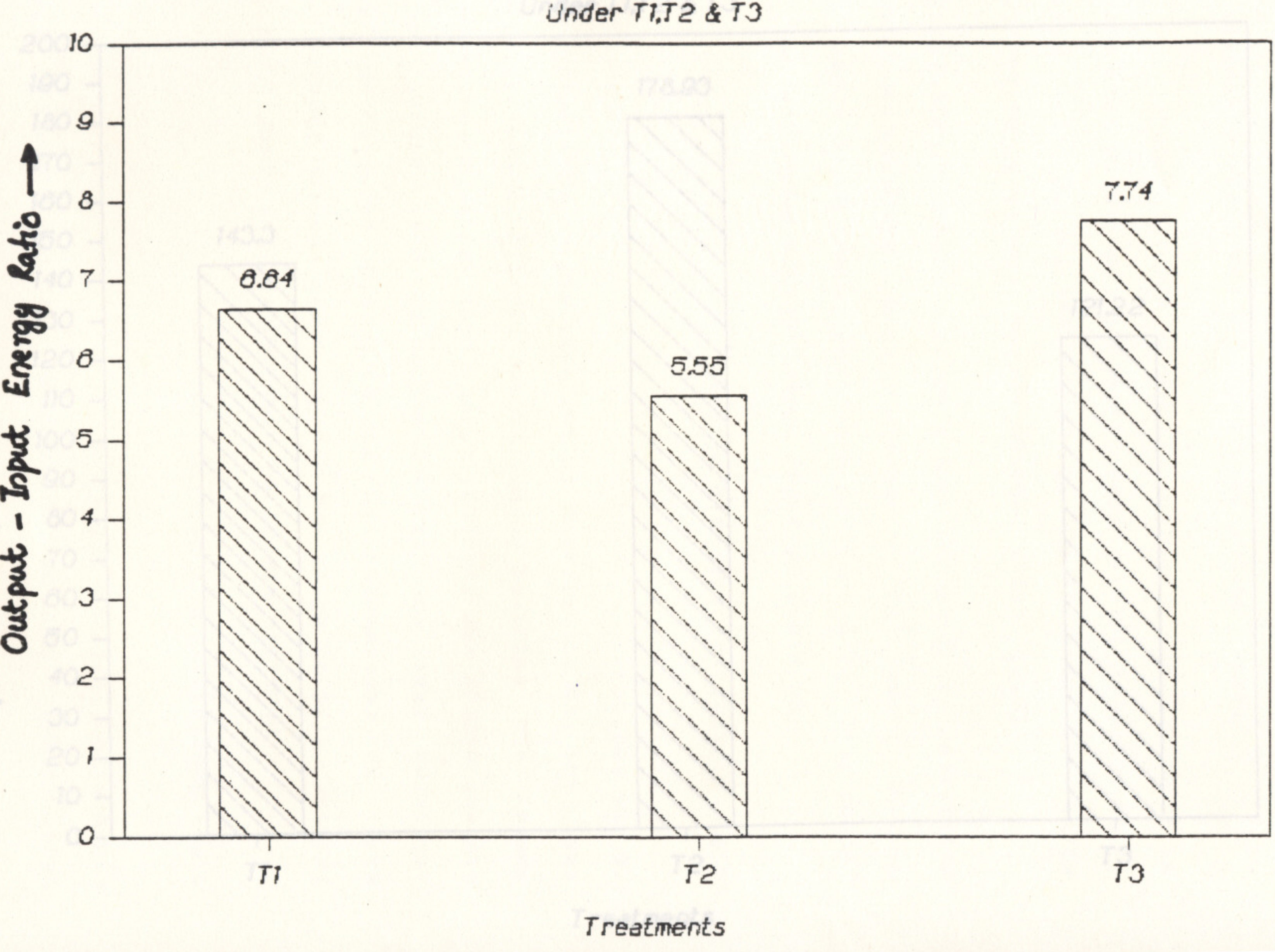
2. Total Input Energy Under T1,T2 & T3



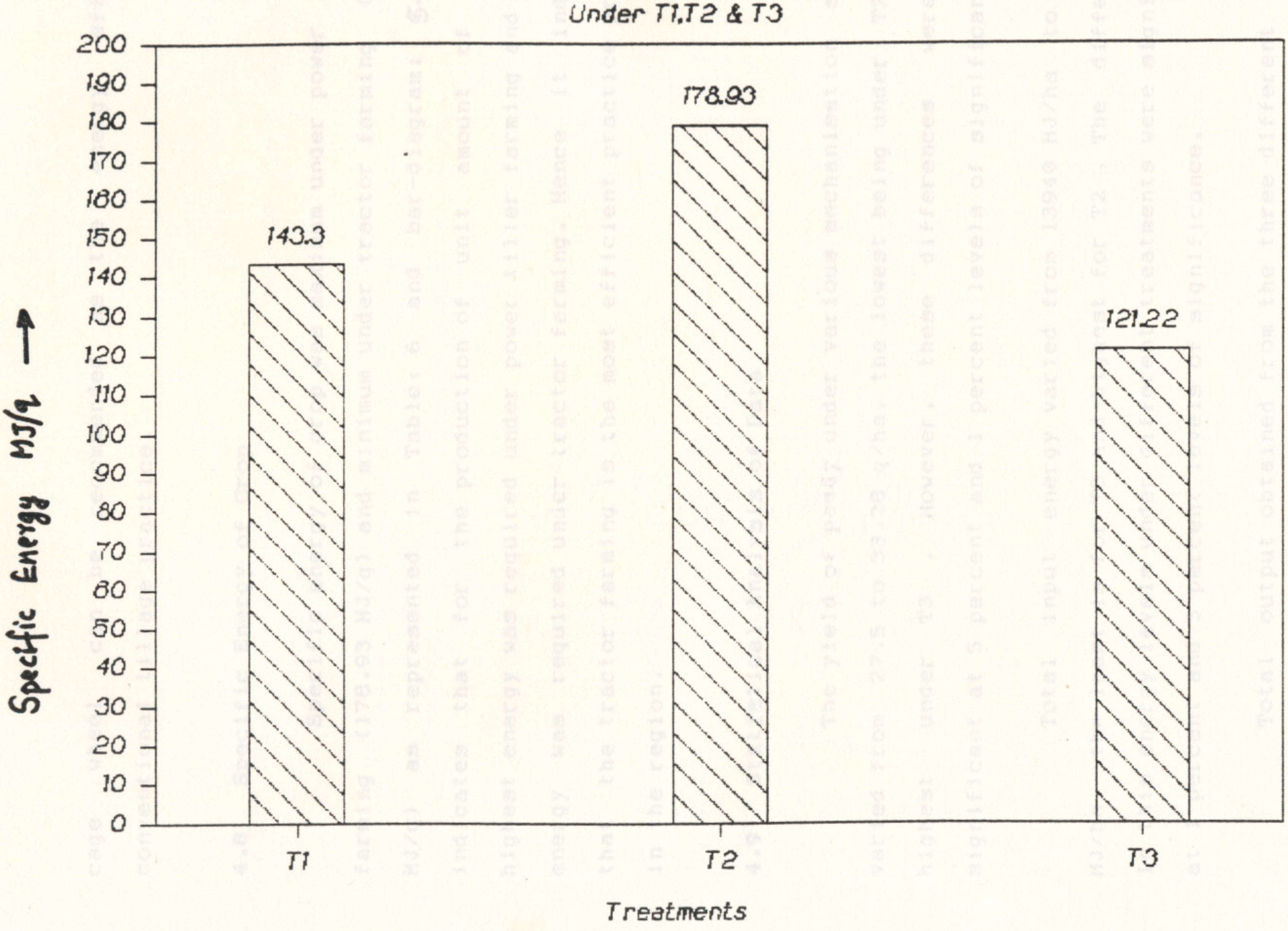
3. Total Output Energy Under T1,T2 & T3



4. Total Output - Input Energy Ratio



5. Specific Energy of Crop under T1,T2&T3



cage wheel can be recommended as the energy efficient conventional tillage practice.

4.8 Specific Energy of Crop

Specific energy of crop was maximum under power tiller farming (178.93 MJ/q) and minimum under tractor farming (121.22 MJ/q) as represented in Table: 6 and bar-diagram: 5. This indicates that for the production of unit amount of paddy, highest energy was required under power tiller farming and least energy was required under tractor farming. Hence it indicates that the tractor farming is the most efficient practice prevalent in the region.

4.9 Statistical Analysis of Data

The yield of paddy under various mechanisation systems varied from 27.5 to 33.28 q/ha, the lowest being under T2 and highest under T3 . However, these differences were not significant at 5 percent and 1 percent levels of significance.

Total input energy varied from 13940 MJ/ha to 14930 MJ/ha, the least is for T3 and highest for T2 . The differences in this energy levels under different treatments were significant at 1 percent and 5 percent levels of significance.

Total output obtained from the three different levels were found to be significant at 1 percent and 5 percent levels of significance.

TABLE.8. Statistical analysis of energy data of field experiments

Sl.No.	Parameters	Level of significance	
		P = 0.05	P = 0.01
1.	Total input energy	S	S
2.	Crop yield	N.S.	N.S.
3.	Total output energy	S	S
4.	Output-input energy ratio	S	S

Total output- input energy ratios under the three treatments were found to be varying between 5.56 and 7.74 for T3 and T2 respectively. Statistical analysis showed that these differences were significant at 1 and 5 percent levels of significance.

The detailed procedure for analysis of variance are given in Appendix III and results were given in Table: 8.

From the analysis of results obtained from the experiments, it is seen that tractor farming consumed least energy and evolved higher output energy in respect of the other two tillage practices. Hence, it should be recommended as the most energy efficient tillage practice for virippu cultivation of paddy rather than the power tiller and bullock farming systems.

SUMMARY

Paddy is a major crop of Kerala. The introduction of high yielding varieties of paddy requires application of advanced technology, higher level of commercial energy inputs through fertilizer and chemicals and timeliness of various field operations for higher productivity. Thus, the use of efficient farm power and machinery system became more relevent and important to achieve timeliness of field operations for higher agricultural production. The conventional method of cultivation carried out by the local farmers need also to be analysed from the point of view of judicious use of available energy resources through energy audit for different field operations in the crop production system.

Keeping the above point in view, the field experiments were conducted at the Instructional Farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur during the year 1992.

The field experiments conducted with three different levels of tillage under bullock, power tiller and tractor as the sources of power, for the cultivation of paddy in virippu season. The statistical design adopted for conducting the experiment was randomised block design (RBD) with four replecations. The plot size selected were of 0.1 ha, 0.1 ha and 0.2 ha under bullock, power tiller and tractor farming. Red Thriveni was selected as the crop variety. The various field observations recorded include operation time, fuel consumption, crop yield etc. The

computation of energy values were done following the procedure detailed in Chapter III.

The results of experiment, have been presented and discussed under Chapter IV. The salient findings of the experiment are summerised below;

1. The total energy required for the cultivation of virippu paddy was found to be minimum (13935.20 MJ/ha) and under treatment T3 (Tractor with cage wheel x 4) as against maximum energy (14928.49 MJ/ha) in case of T2 (Power tiller with cage wheel x 4).

2. Operation wise, field preparation consumed maximum energy(1892.15 MJ/ha) in case of power tiller farming. Least energy was consumed by tractor farming (1032.94 MJ/ha). Tansplanting consumed a maximum energy (328.14 MJ/ha) under bullock farming and least for power tiller farming (288.20 MJ/ha). Threshing required a constant input energy of 1132.50 MJ/ha under the different treatments.

3. Crop yield was found to be maximum (33.28 q/ha) under tractor farming and least for power farming (27.50 q/ha).

4. Tractor farming gave the highest output-input ratio of 7.74, followed by bullock farming (6.59) and power tiller farming (5.56). This shows that tractor farming is the most energy efficient tillage practice for the cultivation of virippu paddy.

5. Specific energy of the crop was maximum under power tiller farming (178.93 MJ/q) and minimum under tractor farming

(121.22 MJ /q) which indicates that tractor farming is the best method for maximum production paddy with minimum energy requirement.

6. The statistical analysis of crop yield data of paddy indicated that crop yield obtained from tractor farming will not vary significantly to respect of the two farming systems. The F- test reveals that the effect of input energy, output energy and output-input energy ratios were significantly at 1 percent and 5 percent levels of significance. Hence, it is concluded that tractor farming emerged as the most efficient farming system comparing with bullock and power tiller farming systems.

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APPENDIX I

Details of the experiment

1. Location : 'B' block in the instructional farm of KCAET,Tavanur

2. Crop : Virippu-paddy

   Variety : Thriveni

3. Year of experiment : 1992

4. Source of power : Bullock, power tiller (KUBOTA,12 hp) and tractor (HMT, 35 hp)

5. Implement treatments for tillage :

   a) Bullock drawn Desi ploughing x 5 + levelling x 1

   b) Power tiller with cage wheel x 4

   c) Tractor with cage wheel x 4

   They were designated as T1 , T2 and T3 respectively

6. No. of replications: 4

7. Plot sizes:

   a) For bullock plot - 0.1 ha

   b) For power tiller plot - 0.1 ha

   c) For tractor plot - 0.2 ha

8. Experimental design: Randomised block design

9. Observations made:

   a) Labour and energy inputs through each operations in the production of paddy

   b) Operation time

   c) Crop yield

   d) Energy consumed for each operations and total energy

   e) Specific energy of the crop

   f) Output-Input ratio

APPENDIX II

Equivalents for direct and indirect sources of energy

Particulars	Unit	Equivalent energy (MJ)	Ramarks
A. INPUTS			
1. Human labour			
a) Adult man	Man-hr	1.96	
b) Woman	Woman-hr	1.57	1 adult women = 0.8 adult man
c) Child	Child-hr	0.98	1 child = 0.5 adult man
2. Animals			
a) Bullocks	Pair-hr	10.10	Body weight 350-450 kg
b) He-buffaloes	-do-	15.15	He-buffalo = 1.5 medium bullocks
3.Diesel	Litre	56.31	It includes the cost of lubricants
4.Petrol	-do-	48.53	-do-
5.Electricity	kWhr	11.93	
6.Mechinery			
a) Electric motor	kg	64.80	Distribute the weight of the machinery equally over the total life span of the machinery (hrs).
b) Farm machinery excluding self propelled machines	kg	62.70	
7.Chemical and fertilizers			
a) Nitrogen	kg	60.60	Estimate the quantity of
b) P O	kg	11.10	P O and K O in the chemical fertilizer

c) K O	kg	06.70	. Then compute the amount of energy input from chemical fertilizer
8. Seed			
a) Output of crop production system and it is not processed			Same as that of output of crop production system
B. OUTPUT			
1. Main products			
a) Cereal crops, such as: oats, paddy, wheat	kg	14.70	The main product is grain
2. By products			
a) Straw, vines, etc.	kg	12.50	Dry mass

Assumptions for indirect energy and cost

Life of power unit	= 10000 hours
Life of thresher (7.5 hp)	= 2500 hours
Life of tillage machine	= 2500 hours
Life of motor (5 hp)	= 10000 hours
Life of power tiller	= 8000 hours
Life of pump	= 5000 hours
Weight of Desi plough	= 12 kg
Weight of Leveller	= 09 kg
Weight of cage wheels(Power Tiller)	= 44 kg
Weight of cage wheels(Tractor)	= 202 kg
Weight of Thresher	= 2000 kg
Weight of Tractor	= 1725 kg
Weight of Power Tiller	= 485 kg
Weight of KUBOTA engine	= 145 kg

APPENDIX III

Randomised Block Design (RBD)

Randomised block experiment is a term that stems from agric. research in which several 'variables' or 'treatments' are applied to different blocks of land for replecation or repetition, of the experimental effects, such as yields of different varieties of paddy, or the quality of different makes of fertilizers. The blocks are formed in such a way that each contains as many plots as there are treatments to be tested, and one plot from each is randomly selected for each treatment. Let there be four treatments (A,B,C,D) in six blocks of four plots. The arrangement on the field might be as shown below.

I		II		III	
A	D	B	C	C	A
C	B	A	D	D	B
C	D	B	D	B	D
B	A	A	C	A	B

The analysis of variance table for a randomised block design will in general have the following form.

ANALYSIS OF VARIANCE TABLE

Source of variation	SS	DF	MS	F observed	F 1%	F 5%
Column treatments	SSC	(c-1)	MSE	MSC/MSE		
Row treatme-nts(Block)	SSR	(r-1)	MSR	MSR/MSE		
Remainder (Error)	SSE	(r-1)(c-1)	MSE	--		
Total	SST	rc-1				

where,

SSC = variation between column means

SSR = variation between row means

SSE = variation within or for errors

SST = total variation

MSC = SSC/(c-1), mean square between column means

MSR = SSR/(r-1), mean square between row means

MSE = SSE/(r-1)(c-1)

c = No. of column treatments, and

r = No. of row treatments.

By comparing the treatment mean square with the remainder mean square, we can decide by an F-test whether the treatments have any effect, regardless of whether there is a significant variation from block to block. F-ratios at 5% and 1% levels of significance are available from a standard table and compared with the computed F-ratios.

APPENDIX IV

PLOTWISE DATA UNDER T1, T2 AND T3.

1. Yield of paddy (q)

Treatments	Replications			
	1	2	3	4
T1	39.30	31.87	20.86	30.40
T2	30.00	25.86	31.63	22.40
T3	38.00	42.27	26.69	26.16

2. Total input energy (MJ/ha)

Treatments	Replications			
	1	2	3	4
T1	14139.85	14246.60	14150.67	14203.32
T2	14971.39	15003.41	14906.12	14835.31
T3	13900.72	13942.99	13963.11	13933.92

3. Total output energy (1000 x MJ/ha)

Treatments	Replications			
	1	2	3	4
T1	132.98	91.92	59.22	89.57
T2	105.80	75.18	85.45	65.29
T3	144.34	114.74	83.34	89.21

4. Output-input energy ratios

Treatments	Replications			
	1	2	3	4
T1	9.41	6.45	4.19	6.31
T2	7.07	5.01	5.73	4.40
T3	10.38	8.23	5.97	6.40

APPENDIX V

Energy parameters supplied by various sources.

Operations		Human (hr/ha)	Animal (hr/ha)	Diesel (l/ha)	Seed (kg/ha)	Fertilizer		
						N	P	K
Nursary	T1	33.75	--	17.25	75.00	3.13	--	--
Prepa-	T2	33.75	--	--	75.00	3.13	--	--
ration	T3	33.75	--	--	75.00	3.13	--	--
Tillage/	T1	99.20	99.20	--	--	--	--	--
Puddling	T2	34.97	--	33.00	--	--	--	--
	T3	07.94	--	17.25	--	--	--	--
Bund	T1	41.63	--	--	--	--	--	--
forming	T2	41.63	--	--	--	--	--	--
	T3	41.63	--	--	--	--	--	--
Nursary preparat-	T1	167.18	--	--	--	--	--	--
ion and transpor-	T2	167.18	--	--	--	--	--	--
tation	T3	167.18	--	--	--	--	--	--
Trans-	T1	83.93	--	--	--	--	--	--
plant-	T2	163.55	--	--	--	--	--	--
ing	T3	178.82	--	--	--	--	--	--
Fertili-	T1	15.00	--	--	--	75.0	75.0	175.0
zer	T2	15.00	--	--	--	--	--	--
	T3	15.00	--	--	--	--	--	--
Harvest-	T1	407.24	--	--	--	--	--	--
ing and	T2	452.07	--	--	--	--	--	--
transpo- rtation	T3	393.32	--	--	--	--	--	--
Thresh-	T1	130.56	--	15.63	--	--	--	--
ing	T2	130.56	--	15.63	--	--	--	--
	T3	130.56	--	15.63	--	--	--	--

STUDY OF ENERGY INFLOW-OUTFLOW PATTERN IN PADDY CULTIVATION WITH SPECIFIC REFERENCE TO TILLAGE TREATMENTS

BY

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ABSTRACT OF PROJECT REPORT

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Kelappaji College of Agricultural Engineering & Technology

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ABSTRACT

Considering the judicious use of available energy on the farm for the production of paddy, three conventional tillage practices prevalent in Kerala State namely, bullock operated Desi plough together with wooden plank levelling, power tiller operated cage wheel and tractor operated cage wheel were tested to find out the most energy efficient tillage practice. Energy inflow-outflow pattern of these three treatment practices were studied and hence computation of output-input energy ratio and specific energy of the crop under each treatment were done. This study revealed that tractor farming is the most energy efficient tillage practice to be followed in virippu cultivation of paddy.