ECONOMICS OF ENERGY USE FOR AGRICULTURE IN MARATHWADA REGION OF MAHARASHTRA

By
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B.Sc. (Agriculture)

DISSERTATION
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2001

Dedicated to

MY Beloved

Aai, Aba

&

Bapu

CANDIDATES DECLARATION

I hereby, declare that the dissertation

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Parbhani

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CERTIFICATE - I

This is to certify that the dissertation entitled **"Economics of Energy Use for Agriculture in Marathwada Region of Maharashtra"** submitted by **Shri. Patil Mahendra Madhukar** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE* in *Agricultural Economics* is record of original and bonafide research work carried out by him under my guidance and supervision. It is of sufficiently high standard to warrant its presentation for the award of the said degree. No part of the dissertation has been submitted anywhere for other degree of any University or Institutions.

PARBHANI
Date : 30/6/2001

(H.N.Patil)
Research Guide

CERTIFICATE II

This is to certify that the dissertation entitled **"Economics Of Energy Use For Agriculture In Marathwada Region Of Maharashtra"** submitted by **Shri Patil Mahendra Madhukar** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirements for the degree of *MASTER OF SCIENCE* (Agriculture) in the subject of *Agricultural Economics* has been approved by students advisory committee after oral examination in collaboration with External Examiner.

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(Patil M.M.)

LIST OF ABBREVIATION

J	=	Joule
MJ	=	mega joule
TJ	=	tera joule
GJ	=	giga joule
KWh	=	kilowatt hour
Km	=	kilometer
Km^2	=	kilometer square
ha	=	hectare
ha^{-1}	=	per hectare
mm	=	milimeter
kg	=	kilogram
q	=	quintal
t	=	tonnes

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INTRODUCTION

CHAPTER I

INTRODUCTION

In a present age nothing can be done without energy and the level of energy consumption has become symbol status of the society, firm or industry of the nation. So energy according to the law of physics is defined as 'capacity to do work'. Here the agricultural energy means different inputs are to be used in agricultural operations to do work which are in the form of direct or indirect source of energy (Singh *et al,* 1988).

Energy - agriculture relationship are becoming more and more important with the intensification of agriculture, which is considered to be the only means of raising agricultural output in land scarce economics. The intensification led growth in agriculture would obviously demand more of energy in the form of fertilisers, diesel, pesticides and electricity that are non-renewable in nature. Prior to the introduction of green revolution technologies during the midsixties, energy requirements of Indian agriculture were largely met from traditional, renewable sources. Since then, the use of non-renewable energy input has increased substainally both in irrigated and in rainfed agriculture, and at present about half of energy used in agriculture comes form non-renewable sources (Singh *et al*, 1998). During the year, 1992, In India energy use in agriculture in the form of diesel energy, electricity, animals energy and human energy was 299, 4080, 1059 and 1434 $MJha^{-1}$, respectively.

One of the major constraints to agricultural production and productivity is the inadequacy of farm power and energy. The average farm power availability needs to be increased from the current 1.15 $kWha^{-1}$ to at least 2.00 $kWha^{-1}$ to assure timliness and quality in field operation, practise heavy field operations like sub-soiling, deep ploughing and handle produce and by-products efficiently, process them for value addition, income and employment. Total farm power availability has increased from 0.25 $KWha^{-1}$ in 1951 with animals power contributing 97.4 per cent, to 1.15 $KWha^{-1}$ in 1997 with animal sources contributing only 22.7 per cent, mechanical sources 43.5 per cent and electrical 33.8 per cent (Anonymous, 1999). The availability of draft animals is reducing. Thus shortfalls have to be met mostly through electro-mechanical power sources. Farm power sources will be utilized efficiently only if we have matching, energy efficient, versatil, study user friendly and affordable implements and machines.

Agriculture is basically an energy conversion process. It is both a producer and consumer of energy. The process involves the conservation of solar energy into biomass by way of photosynthesis. Modern agriculture enhances production of biomass by increasing photosynthesis through better plant type and use of irrigation water, fertiliser, pesticides and other growth promoting inputs. Areas with higher agricultural productivity use very high levels of non-renewable commercial energies as compared to area which have low levels of agricultural productivity (Singh et al., 1994).

Punjab Agriculture has achieved a transformation of unprecedented dimension and agriculture development in the state may be characterised as nothing short of revolution energy needs of Punjab agriculture are steadily increasing under the influence of modern technology. The advent of new technology has gone a long way in substituting capital for labour, yet the scope of complete specialisation is limited due to sub-division and fragmentation of holding. Even the more use of existing and new energy can lead to increase in agricultural productivity and human employment.

In view of scarcity of non-renewable energy resources, economic and environmental consequences of increasing use of energy in agriculture and other economic activities are widely debated. Given the current energy situation many observers feel that, energy intensive agriculture may not be sustainable in the long run not only because of fear of decline in energy supply but also due to adverse impacts of many energy based input such as fertilisers and pesticides on agro-ecology.

With the introduction of new farm technology the prospects of increasing productivity per hectare have brightened. The short duration high yielding varieties has helped not only in attaining higher physical productivity but also in increasing the intensity of cropping and realise greater output per unit area and time for which an approach is envisaged known as multiple cropping programme. The intended objective, however, could be successfully attained only through in the adoption of package of improved practices as also timely completion of various farm operations. It is in this context that, the farm power act as one of the most determinants for successful execution of multiple cropping programme.

Energy can be calcified on the basis of different categories viz..

1. Direct source of energy

The direct source of energy is that which release the energy directly like bullock, human labour, stationary and mobile mechanical or electrical power units such as diesel engines, electric motor, power tiller and tractors.

The direct energy are further classified as renewable and non renewable source of energy depending upon replenishment.

i. Renewable direct source of energy

In this category, the energy sources, which are direct in nature but can be subsequently replenished are grouped like human, animal, solar and wined energy ,fuel wood , agricultural wastes etc.

ii. Non renewable direct source of energy

In this category, direct energy source which is not renewable are classified coal and fossil fuels.

2. Indirect sources of energy

These are energies which do not release energy directly but release it by conversion process which are seed, manure, chemical fertilizer and machinery.

i Renewable indirect source of energy

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

ii Non renewable indirect sources of energy

The energy sources which are not replenished come under this category which are chemical fertilizer and machinery.

3. On the basis of comparative economic value

i Non-commercial energy

Each and every energy source bear some economic value. The energy sources which are available cheaply are called as non-commercial source of energy. Which are Human labour, bullock, fuelwood, agricultural wastes, farmyard manure etc.

i Commercial energy

The energy sources like petroleum products viz. diesel, kerosene, oil and electricity, which are capital intensive exemplify commercial source of energy.

Since agriculture is the primary sector of the Indian economy and one of the major claimantals of energy for various operations done on the field and beyond. Agriculture is a user of energy. The level of production in agriculture and productivity of crops depends upon energy inputs consumed during various farm operations of crops include material inputs viz; Seed, fertilizer, manures, mechanical energy along with human and bullock labour hours spend on executing the production process.

Under Vidarbha region of Maharashtra State the wheat crop consumed 17134.79 $MJha^{-1}$ of commercial energy component and 2433.84 $MJha^{-1}$ non-commercial energy component (Adhaoo, 1989).

Agriculture becomes a major cause of reduction in energy supply where agricultural land is created by cutting down forests. The world dose not have too much more land to exploit for agriculture operations simply because ecological and social cost of expanding crop area into existing forest land would be unsustainable high. Therefore, major focus has been on greater use of energy source such as fertilizer, pesticides, water, machinery etc.

Agriculture is basically a seasonal industry and, therefore, demand for energy fluctuates depends on change in season. During certain month of year agriculture demands large quantities of energy for different agricultural operations despite the rapid increase in mechanization several operations viz. digging, plantation weeding and harvesting are performed largely by manual workers providing 43000 tera Joule (TJ) of human energy and 80 million draught animal providing 81000 TJ of animal energy. In the aggregate of these two sources provide 0.298 $kwha^{-1}$ of farm power (Pachauri,1998).

The process of development stimulates the demand for energy and accelerates the depletion of our resources. But agricultural scene has undergone a big transformation after the green revolution. Not only the cropping intensity and irrigated area had increased but all major farming inputs including energy saw a big jump. The total commercial energy input to Punjab agriculture jumped from 32408 x 10^6MJ to 176236x 10^6MJ during the period 1970-71 to 1994-95 (Singh and Singh,1998).

Energy requirements of crop vary according to the type of farming system, level of technology, crop to be raised and most of the other factors. But an Indian agriculture is characterized by very wide diversity of technology employed. There are still vast area covered by traditional agriculture. Which leads to uneconomic and insufficient use of available energy due to lack of knowledge. This lack of knowledge regarding the energy use pattern of various crops and sequences under rural India including Marathwada region.

Under the circumstances it becomes essentially imperative on the part of the planners and technologist to give increasing attention to more efficient utilisation of energy in production agriculture. Keeping these fact in view, the present study was conducted in cluster of three villages, viz. Nandapur, Babhulgaon and Ghaygoan in central Maharahstra plateau zone and western Maharashtra dry zone in Marathwada region of Maharasthra state with the following specific objectives.

1. To examine pattern of direct and indirect energy use in agriculture
2. To estimate energy use for major crops grown by the farmers
3. To workout per hectare energy use in physical and monetary terms.
4. To estimate energy consumption in crop production.

Scope of study

The important aspects of the study lies in appraising the farmers about energy cost and returns from crop production and economical energy use for agriculture in Marathwada region of Maharashtra state.

The increasing demand for food with increase in population and the changing energy use habits of the rural people emphasize the need for energy oriented research. The study will provide more information about use of available resources and its efficiency in crop production. The study will also help the farmers in knowing whether there is any scope for reorganisation of resources so as to maximise profit by combining cheaper alternatives to keep down the cost of energy use and thereby improving economic efficiency. The findings of the present study would shade light on ecological and environmental conservation of natural energy resources.

Further, the findings would also be useful to the planners for advance planning to bridge the gap between demand and supply of energy for agricultural production in the study area.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Review of literature related to a research topic is a necessary step in conducted of any scientific research. It helps in formulation the framework of the study, deciding objectives and methodology appropriate to the situation under which research is to be carried out. It also helps to compare results of such studies and reasoning thereof. The literature published having direct or indirect bearing on the objectives of the present investigation are reviewed in the following sections.

2.1 Pattern of direct and indirect energy use in agriculture

2.2 Cropwise energy use

2.3 Per unit area energy use in physical and monetary terms.

2.4 Energy consumption in crop production

2.1 Pattern of direct and indirect energy use in agriculture

Singh and Singh (1976) reported on levels and pattern of energy consumption in an agriculturally advanced area of Uttar Pradesh. The information used for these study was procured from survey conducted in five purposively selected villages. The 25 farmers representing, small, medium and large were selected randomly form these five villages. Further, they were reclassified into bullock and tractor operated farms. They attempted to estimate the energy use patterns and its cost on bullock and tractor operated farms in their study area. They revealed that, tillage operation consumed bulk energy in crop production and irrigation and threshing also consumed too sizeable amount of energy used. Energy used in tractor operated farm was more than double of that used on the bullock farms and that energy supplied through mechanical sources. Acquisition of mechanical sources of farm power on the tractor farms helped in timely accomplishment of farm operation and realisation of higher cropping intensity which helps in the attainment of greater returns per unit of area and energy cost.

Bhatia and Dutta (1986) studied on impact of energy use an farm income in Amritsar district of Punjab. The multistage random sampling technique with block as primary unit of sampling and operational holding as the ultimate unit of the study was used. In analysing the data Cobb-Douglas production function was used. The marginal value product (MVP) of chemical energy use on of small farm was the highest among all other energy used that was Re.0.410781/ MJ. The ratio of MVP to the acquisition cost was 3.3563 for chemical energy and 2.7859 for mechanical energy, indicated that farm income could be increased by intensive use of these sources of energy in place of human and bullock energy. In case of large sized farm income could be increased by more use of chemical energy but farmer can increase more of their income by employing more of human energy than that of mechanical energy as the ratio of acquisition cost was greater than unity and higher than that of mechanical energy.

Singh et al. (1988) studied level and pattern of energy consumption of sugarcane in eastern Uttar Pradesh. The survey was carried out on 70 marginal, 38 small, 24 medium and 18 large farms. Data were tabulated on the energy used for land preparation, sowing, fertiliser and manuring, irrigation, plant protection, interculturing, post harvest operation and total energy used. The energy used was differentiated into that of human, bullock, tractor and stationary machinery. The use of total energy was highest on large farms, and that of tractor energy increased with farm size. Most of the energy was expended on the post harvest land preparation and irrigation.

Bhatia and Dutta (1989) studied impact of energy use and employment in agriculture in the Amritsar district. The multi-stage random sampling technique with block as primary unit was used. out of 15 blocks Majitha and Verka were selected at random and cultivator were divided in four groups viz., marginal, small, medium, large sized farm groups 25 per cent farmers from each category was selected. They revealed that, the number of family labour engaged in agriculture bear direct relationship with size of operational holding. However, employment bears inverse relationship. The functional relationship indicated that, incase of marginal and small farmers, human employment can be supplemented by the more use of mechanical energy whereas in the case of medium farms, the use of human labour can be increased some what with the increase due of chemical energy but in case of large farms, the use of human labour was rational and can be increased with more use of chemical as well as mechanical energy.

Szozepaniak (1991) studied on energy as production factor in agriculture in Poland. The primary energy sources are classified as object of labour, secondary sources as means of carrying work out. In agriculture, energy is derived form natural sources such as sunlight and wind, and secondary sources such as processed fuels. Human and animal power are also involved. Factors influencing energy demand include the supply and quality of production equipment, seasonal operation of machinery, cultivation techniques, structure of production domestic and service requirement. Better use of free sources such as solar power, biogass and biomass production, and better utilisation of organic residues. As well as involving science and technology, there need to be appropriate economic incentives to encourage agricultural producers to adopt energy saving methods.

Bhatia *et al.* (1992) studied on energy use pattern in Punjab agriculture. They analysed the sample from 15 villages. Estimates were made of the energy requirements of different farm sizes and in different zones were determined. They also evaluated the factor responsible for variation in the energy consumption level in agriculture and the yield energy output-input ratio of different crops.

Thakur and Mishra (1993) studied energy requirements and energy gap for production of major crops in Madhya pradesh. The study is based on sample of 100 farmers from 12 villages in 12 districts of vie major crop zones. The crop zones covered under study were i) rice zone ii) rice wheat zone iii) wheat zone iv) sorghum-wheat zone and v) cotton-sorghum zone. Energy gap was estimated by computing difference between recommended levels of energy for crop production and actual energy used. They revealed that, the energy gap will have to be minimised, if the productivity level of crops are intended to be pushed up to narrow down the yield gap or the yield sacrifice for want of required energy inputs in production of various crops. The total energy requirement for each zone depend upon the acrage under the crop. Paddy required the highest 41180 TJ in rice, zone wheat required the higher 6980TJ in rice-wheat zone, the total energy requirement in wheat zone was dominated by wheat and it was 14556 TJ. In cotton-wheat zone wheat getting highest energy requirement followed by sorghum. They also estimated that the highest energy gap between recommended and actual energy consumption was estimated for paddy (34427 TJ) followed by wheat (29536TJ)

Khan and Singh (1996) studied energy inputs and crop production in western Pakistan. Patterns of energy used and their relationship with crop production were investigated on farms in the Dera Ismail Khan district of Pakistan. One year long survey of daily inputs of energy to more than 600 crop plots on 26 farms in 7 villages was carried out. These are both rainfed and irrigated farms, operated by bullocks and tractors. Irrigation was provided by either canal or tube-wells. Data on energy inputs were recorded for crop production operations to the selected farms, for human labour, bullock, electric motors, diesel engines and tractors. application of fertilser and chemicals was included and yield was recorded in tons/ha and MJ. They observed that, on per hectare basis, the use of tractor reduces the use of both human labour and bullock on farms and increases total energy consumption. Due to timely land preparation, yields of most of the corps were higher on tractor operated farms, than on bullock operated farms. Canal irrigated farms had higher cropping intensity and used more energy than rainfed farms. Energy consumption per hectare was highest on tube well irrigated farms, owing to the higher consumption of electrical or diesel energy for pumping water.

Pachauri (1998) studied economics of energy use in agriculture. He briefly reviewed the energy use in agriculture, changes in Indian agriculture and energy use. He noticed that the demand for energy fluctuates depending on changes in season. Despite the rapid increase in mechanisation that has taken place in Indian agriculture, several farm operations are performed largely by manual workers. The study revealed that in Indian agriculture about 200 million agricultural workers providing 43000TJ of human energy and 80 million draught animals providing 81000TJ of animal energy. In aggregate these two sources provide 0.298 kw/ha of farm power.

Stout *et al.* (1998) conducted a study on energy for agriculture in the twenty first century. They reviewed the use of energy in agriculture, agriculture and sustainable development, agriculture as an energy conservation process, rural energy issues, transition to sustainable energy system, energy requirement in rural areas, energy use pattern, what are the alternatives to human power, animal draft power; energy conservation and efficient use, energy policy for sustainable rural development.

Bien (1999) studied the ecological aspects of the mechanisation of fertiliser application, plant protection, soil cultivation and harvest of cultivated crops in Poland. He reported that, energy use in agriculture, mechanization of fertilisation, plant protection, sowing, harvesting, threshing foilar fertilisation, manure processing to produce fertilisers, ecological hazards heavy metal contamination in crops, spraying pesticides, precision agriculture.

Risoud (1999) carried out study on sustainable development and energy balance of farms in France. The question of whether the energy balance of a farm, in which non-renewable energy and gross product energy are considered, provides an indicator of sustainable development is addressed, on the basis of French examples it is demonstrated that, in simplifying and quantifying complexity, energy efficiency reveals farm autonomy, its utilisation of local resources and non-renewable energies. It is also suggested that, better energy efficiencies are obtained in plant protection than 20 years ago and that energy analysis useful for comparing different management sequences of a given crop or animal product, and to provide as internal assessment of the farm.

Sap *et al.* (1999) conducted study on energy saving policy in the mechanization of agricultural production in Russia. They revealed that, recent development of any energy saving policy in Russian agriculture (following trends during the energy crisis in the USA in 1973-1980). The role of VIM (All Russian Research Institute for Agricultural Mechanisation) in the development of this energy saving policy is discussed.

Saran *et al.* (1999) studied energy use pattern in Punjab agriculture. Their study was based on the data collected from 300 farms belonging to small, medium and large sized groups. The study indicated that, the use of commercial energy increased with an increase in farm size and level of technology adoption. The findings of the study suggested the need for proper management of energy inputs on all the sized group of the farm.

Uri (1999) studied the conservation tillage and the use of energy and other inputs in US agriculture. He reported that, the effectiveness of conservation tillage practices in reducing the impact of agricultural production on the environment was dependent on what happens to energy, pesticides and fertilser use as these practices are more extensively adopted. To gain some insight into this, the conservation tillage adoption decision is model. These conservation of tillage adoption decision in tow step . Procedure - the first whether or not to adopt these procedures, second the decision on the extent to which conservation of tillage should be used appropriate models of the Cragg and Heckman (dominance) type are estimated. Based on farm level data on maize production in USA. The farm on which conservation of tillage was adopted it has an above average expenditure on pesticides and below average expenditure on custom pesticide applications. Additionally, for a farm adopting no tillage production practice, an above average expenditure was made on fertiliser.

2.2 Crop wise energy use

Khandewal *et al.* (1988) studied energy consumption for production of major crops in Jabalpur. The experiments were conducted at the farm of college of Agril. Engineering, Jabalpur to assess energy through direct power sources. Three different crop rotations were taken which were paddy-wheat, soybean-wheat and paddy-berseem. They analysed energy for different farm operations and concluded that, irrigation consumed the maximum direct energy for wheat and berseem followed by seedbed preparation under both the systems of tractor and bullock farming. For paddy maximum energy consuming operation was tillage followed by threshing. However, weeding was proved to be the most energy, time and cost consuming operation for soybean.

Singh et al. (1988) conducted study on energy requirement for wheat production in Kandi region of Punjab. A survey was conducted for two years to determine the energy requirement for raising wheat crop. Fifty two farmers were selected for study from all categories. Mean grain yield in 1984-85 was 612 $kgha^{-1}$ when the crop was partially irrigated. Output input ratio was increased to 3.3 in 1985-86 was 2.8 in 1984-85. They revealed that, even meeting some of the irrigation requirement of these region could increase grain yield more than three times. Thus, creating irrigation facilities in these region will definitely increase the yield significantly.

Turn et al. (1988) carried out study on energy use in cotton production in china. They revealed that, energy requirement for production of one hectare cotton in Yucheng country, china, were determined in terms of total energy use and energy use ration in MJ energy used/kg cotton produced. Inputs were quantified as direct energy, ancillary energy that used to produce pesticides, fertiliser, embodied energy that is durable equipment, farm structures, labour and animal power. Ancillary energy requirements, at more than 90 per cent were the largest components of cotton production. Strategies for reducing energy use are discussed.

Adhaoo (1989) studied energy use in irrigated wheat production under partially mechanised cultivation in Vidarbha region of Maharasthra. For wheat production commercial energy component was 87.56 per cent and non-commercial energy component was 12.44 per cent. Irrigation as single activity alone consumed 48 per cent and fertiliser application as another important activity including material and labour energy consumed 42.26 per cent commercial energy. The farm operations such as sowing, interculturing, harvesting were major energy consuming activities with 27.4, 19.88 and 17.10 per cent respectively, under non-commercial energy output input ratio of energy considering only grain yield was 1.75 and including other biomass it was 2.13.

Tsatsarelis (1991) estimated Energy requirements for cotton production in Central Greece. The amount of energy used in cotton production as practised by farmers in central Greece was calculated to examine means of reducing energy inputs and securring greater energy efficiency. Energy used was calculated from the unit operations involved, machinery, chemicals and other inputs. Total energy was calculated to be 82600 $MJha^{-1}$ with irrigation and fertilisers as major inputs. Cotton yield was 1024 kg/ha^{-1} lint and 2176 $kgha^{-1}$ seed. The study revealed that, a production system with reduced energy requirement was established based on reduced irrigation and fertilisers inputs and on better, machinery management. With this system, saving in energy of 11500 MJ ha^{-1} may be achievable, without yield losses.

Gill et al. (1992) studied energy requirements in crop rotation : a study of potato and wheat. They conducted study at a research farm of Punjab Agricultural University, Ludhiana. Energy requirements for different field operations as well as the total energy required for the production of potato and wheat were determined. The study included three energy systems, namely draught power and two type of tractors. The draught power system was found to use the least energy. The use of tractor drawn implements increased the total energy demand but it reduced share of human energy. In all the systems maximum energy was required for digging and collecting potato and harvesting and threshing wheat. The total energy for the production of potato was found to be 27619, 28883 and 29886 $MJha^{-1}$ under bullock, tractor T_1, and tractor T_2 energy system, respectively. These figures for wheat were 12700, 13780 and 13066 $MJha^{-1}$, respectively. Seed, chemicals and fertilisers contributed the major share of total energy in Potato-Wheat rotation.

Mittal et al. (1992) reported on energetics of wheat production in two selected village of Uttar Pradesh in India. A study was made to assess the energy requirements of wheat production under two different agro-climatic conditions of Uttar pradesh. They concluded that, the total energy needs for cultivating wheat was higher in village cluster eco-system of khamaria, representing the Tarai area in comparison to the village cluster of Jaipur Bisha. However, the output input energy ratio and the specific energy that was energy input for producing unit weight of grain, were the same in both selected village.

Singh and Mushtaq (1992) worked on energy inputs in irrigated wheat crop in Pakistan. Energy inputs in the production of an irrigated wheat crop were studied on farms utilising bullock and tractor power using irrigation water from tubewells, canal or both, in the Faisalbad district of Punjab, Pakistan. The total energy input on tractor farm with tubewell, canal and canal plus tubewell irrigation were 18, 16.4 and 16.6 $MJha^{-1}$ and on bullock farm 16.3, 12.9 and 13.6 $MJha^{-1}$, respectively. They found that, the contribution of fertiliser, fuel and electrical energy inputs to be much higher as compared to other energy inputs. The wheat yield varied from 2.7 to 3.7 tha^{-1} and 24 to 2 tha^{-1} on tractor and bullock farms, respectively. The energy inputs were highest on tubewell irrigated farm followed by canal plus tubewell irrigated and canal irrigated farms.

Gill et al. (1993) studied energy required in sugarcane (planted and ratoon) cultivation in Punjab. This study included three energy systems, namely, bullock, tractor E1 and Tractor E2. The investigation revealed that, total energy for field operations was maximum for tractor E2 system and it was lowest for bullock system. In all the energy system, irrigation required the maximum energy as compared to any other field operation. The field operations required 2726, 2853 and 2971 MJ ha^{-1} for planted crop of sugarcane and 3131, 3250 and 3250 MJ ha^{-1} for ratoon crop under bullock, tractor E1 and tractor E2 system, respectively. The maximum energy was drawn from mechanical power sources in all the systems.

Singh et al. (1994) studied energy inputs and crop yield relationships for rice in Punjab. For their study data concerning energy inputs and rice yields for 20 g farmers from three villages in Punjab, India were collected over two years and analysed. Relationships between crop yields and tillage, irrigation, fertiliser and pre-harvest or total energy inputs were determined.

2.3 Per unit area energy use in physical and monetary terms

Bhatia and Dutta (1986) studied on, impact of energy use on farm income in Amritsar district of Punjab. The multi-stage random sampling technique with block as primary unit of sampling and operational holding as the ultimate unit of the study was used. In anlaysing the data Cobb-Douglas production function was used. The marginal value production (MVP) of chemical energy incase of small farm was highest among all other energy used i.e. Rs.0.410731/mega joules. The ratio of MVP to the acquistion cost was 3.35628 for chemical energy and 2.7859 for mechanical energy, indicating that, farm income could be increased by intensive use of these sources of energy in place of human and bullock energy. In case of large sized farms income could be increased by more use of chemical energy but farmers can increase more of their income by employing more of human energy than mechanical energy as the ratio of acquisition cost is greater than unity and higher than that of mechanical energy.

Singh and Subbarayan (1986) conducted study on optimum use of energy input on different size group of farms in Meerut district of Uttar Pradesh. Multistage random sampling technique was used for the selection of farmers. The study revealed that, the farmers have to forgo very little in terms of net returns (monetary) if they have to adopt energy maximising plans. The energy maximising plans are very much consistent with net returns maximising plan. So the planners can give emphaiss for energy maximising plans which will be readily acceptable to the farmers, since these plans can give higher monetary returns than those under the existing plans and was almost consistent with the net returns optimisation plan.

Singh and Singh (1992) worked on energy input Vs crop yield relationship to four major crops of northern India. Th data were used form 500 crop plots belonging to 24 farmers in Northern India were statistically analaysed to establish mathematical relationship between energy input and crop yields of wheat, sugarcane and maize. For all three crops, yield seemed to be linearly correlated with total energy input. wheat yield showed a highly significant linear relationship with the total energy input applied before the crop matures. sugarcane yield was found to correlate with field operations energy input only. Fertiliser energy input was found to affect wheat and maize yield more than irrigation energy which was most influential on sugarcane. In general, crop yields did not show any direct relation to tillage energy.

Singh (1993) conducted study on measurement of energy use in agriculture in Punjab. Historically, energy utilisation efficiency has been measured using energy ratio and energy productivity. Both these measures have their limitation. He was reported a new measure of energy productivity, namely value of product per unit of energy inputs was proposed in his study to measure energy utilisation all the macro level. It provides a midway approach to net energy analysis. This measure will enable comparison of the efficiency of different agriculture system, agricultural regions, farm size classes, countries. Comparisons over time of the changes within an agricultural system are also possible, It will help in identifying region of comparative advantage for various agricultural activities and may also aid policy formulation for the location of agriculture and agricultural development.

Agarwal *et al.* (1997) conducted experiment on effect of irrigation and fertility on effect of irrigation and fertility on productivity, economics and energy out put of linseed cultivars. They conducted field trial at Jabalpur, Madhya Pradesh in Winter some linseed cultivars were grown without irrigation, or some grown irrigated at 30 or 30 to 60 days after sowing and were given no fertilizer, 30 kg N + 15 kg P_2O_5 + 10kg K_2O/ha or double these NPK rates yield, net returns and energy output were highest with two irrigation and higher NPK rate.

Saini *et al.* (1998) studied on Energy management for sustainability of hill agriculture. The study was conducted in Kangra valley of Himachal Pradesh using data from 80 farms. This peper examined the existing energy input-output pattern of important cropping systems of the study area, estimates the energy requirements of important cropping systems at improved levels of technology and maximises the net energy and net returns through optimal allocation of inputs on different categories of farms. the systematic energy optimising management model of a linear programing type was employed to generate two each of energy efficient and returns efficient plans. The study concludes that, the farmers have to compromise very little in terms of net returns if they are to adopt energy optimised plans. Since the energy optimised plans showed saving of energy intensive inputs like, chemical, fertilizers, human labours and traction power to a large extent as compared to that of returns optimised plans, implying thereby that farmers in hills are more energy conscious in using wisely and judiciously.

Subrahmanyam *et al.* (1998) Conducted studies on energy use and its efficiency in Andhara Pradesh agriculture. They examined the major changes brought about in agriculture sector of Andhra Pradesh in terms of irrigation, cropping pattern and land holding distribution and implications of each of them on energy use. The analysis was based on data collected from 495 cultivating households across 20 districts. Output and inputs are converted into energy units. The agriculture Sector of the State has attained a low growth rate of 2.1 percent resulting from low irrigation growth of 1.1 percent. The cropping pattern has shifted towards Paddy and Sugarcane among irrigated crops and cotton and groundnut among dry crops. Paddy and cotton have high energy consumption of about 20 G.J. per ha. While paddy consumes more energy for irrigation, cotton consumes more for plant protection and soil nutrients. The responsiveness of output to increases in traditional and modern inputs studied by using a Cobb. Douglas production function. It was found that a 1 percent increase in traditional inputs increases output by 0.64 percent whereas a 1 percent increase in modern inputs contributes a 0.37 percent increase in output . The low contribution of modern inputs may be due to ground water irrigation which produces output at high energy cost.

Dobriecevic *et al.* (1999), conducted a study on Energy potential of bio mass agriculture in Croatia. Due to growing population and increases in yield, world production and processing of agricultural products are also growing. Production and processing of high quality agricultural products require a lot of energy.

According to statistical data from 1995, 83,500 MG a of biogas can be produced per year and animal unit. Biogas of pruned branches of fruit tree and vines amounts to 16300 t stones and shells that remain from fruit processing have the energy of 27.7 TJ. There are 79,000 t of biomass from Wheat and barley Straw; Maize ears and stems, that have 11.1 TJ of energy. The biomass of rapeseed, Sunflower, Soybean and bean stacks have 340 TJ of energy.

Niedziolka (1999) studied Energy and economic analysis of maize grain production technology. In his paper he presented the results of a study on the evaluation of labour, energy and financial inputs with regard to the output obtained on maize growing family farms in Poland. The analysis shows the portability of maize production being due to energy use and economic efficiency. Positive production effects creates good opportunities to extend the acreage of maize and increase the profitability of family farms.

Niedriolka (1999), Studied on an energetic and economical estimation of maize grain production in family farm. He presented result of study of expenditure of labour, energy and finances as well as the production. effects connected with maize production for grain in family farm in Poland. A high level of profitability of maize grain is found for the farm examined. An index of energetic effectiveness, depending on Soil class and previous crop, was 1.4-1.9 , While index of economic effectiveness ranged between 1.7 and 2.3 . It is concluded that Poland has both natural, technology and economic potential for increasing the production of fodder grain of maize, Which could reduce imports and improve the profitability of family farms.

2.4 Energy consumption in crop production

Sanghi and Blase (1976) studied on, an economic analysis of energy requirements of alternative farming system for small farmer. They analysed alternative farming system for a small farmer, in their entirety for energy intensiveness, resource use and economic returns. They revealed that, the energy requirements for field operations and irrigation, at least for the crops not having heavy water requirements, can be met by Basic System. The Basic system was able to supply the input requirements with the exception of chemical fertilizer and seed for a higher level of food production. The basic system maximizes the use of the farm's biological energy resources . Such system assures a small farmer a relatively high level of income with a minimum of risk and capital requirements.

Senapati (1976) reported on energy consumption and agricultural development in Punjab and Haryana. He analysed the changes in the pattern of energy consumption and also shows the relationship between changes in the energy consumption and changes in cropping intensity yield and production and to investigate into the Social cost of such energy consumption in relation to the value of the total output. In his study he analysed the trends in consumption of commercial energy.

Kis (1987), Studied Energy consumption in agriculture. Since 1980, the energy consumed by Hungarian agriculture has decreased 5.6% despite increases in propitiation. The shares of energy inputs in total energy consumption have also changed favorable with the production of electric, gas, oil, petrol falling from 86.3% to 71.9% over the last 7 years. However, the traditional areas of energy saving are becoming exhausted. In future, further improvement will have to be achieved by applying up-to-date methods, motivating the working population, utilizing biomass for fuel and by researching new energy theology development.

Kis (1987) worked on Energy consumption in agriculture in Hungare. Since 1980, the energy consumed by Hungarian agriculture has decreased 5.6 percent despite. increases in production. The shares of energy inputs in total energy consumption have also changed favourably also the traditional areas of energy saving are becoming exhausted. In future, further improvement will have to be achieved by applying up-to-date methods , motivating the working population, utilizing biomass for fuel and by researching new energy technology developments.

Bonny (1988) examined energy consumption in agriculture in 1985 and trends over the last 10 years. He indicated from the analysis based on recent statistical information and on survey result that due to increasing energy costs over the period under review have forced many French farmers to adopt their farming techniques to reduction in energy use, and have led to stabilization in overall energy consumption and the search for cheaper, alternative Source of energy. In 1985 energy consumption in agriculture was significant, representing around 12 percent of inputs. Since them the trend has been downward and enormous energy saving have been made.

Adhaoo (1990) studied on optimization of energy inputs for crop production in India. Linear, programming technique was used in India to study energy consumption for different size of farms and different crops and to investigate how net returns could be maximized using available energy resources without creating and imbalance in production. In a study it was found that, bullock energy contributes 33-94 to 40-53 percent of the total energy input. The most energy consuming crops were hybrid cotton and jowar small farmers were better managed than medium and large farms. By using optimal plan indicated that, net returns could be increased on small, medium and large farms by 33,8.22 and 16.44 percent, respectively.

Ivanov (1990) reported on Fuel and energy analysis of existing and planned machine combinations for cultivating and harvesting wheat in Bulgaria. He evaluated Energy consumption when wheat followed a cereal predecessor was 18534 $MJha^{-1}$ exceeding energy consumption after row crops by 10.3 percent. in the case of direct sowing, energy consumption is reduced by an average 3 to 13 percent. Planned machine combinations should ensure a fuel saving of approximately 2.2 $kgha^{-1}$.

Chellappan *et al.* (1994) Studied Energy use in crop production system in two different farm situations. They examined energy use in the production of Sorghum by 15 farmers employing traditional and 15 employing innovative technologies averaged 3103 and 10246 MJh^{-1}, respectively, and the energy input : output ratio was 13.23 and 23.78. They concluded that, although the energy inputs on mechanized farms were high the resulting high productivity more than compensated for this.

Singh *et al.* (1998) studied the economic analysis of energy use in Punjab agriculture. In Punjab agriculture, total energy use as well as energy use on per ha. basis increased considerably as agricultural development Proceeded in the state. The increase in electricity use was much sharper than for other sources. The study examined the energy and agriculture growth nexus in Punjab state in an historical as well as contemporary perspective. Rice and wheat emerged as major energy consuming crops of the state. They concludes that, energy has played a major role in the agriculture development of the state. Energy policy, especially that on mode of providing subsidies requires a fresh look. Since agricultural development has reached a plateau in the state with almost no scope of change in net sown area, cropping intensity, irrigated area cropping pattern in the future, the requirement of energy will be determined by the behavior of the farmers reflected in the technological path adopted them sustained efforts are needed to look for an economically suitable alternative to paddy which is largely responsible for power and groundwater consumption. A shift of 20 percent of the area from paddy will considerable reduced the pressure of electricity demand. Since the paddy crop alone consumed three froths of the total electricity in the agricultural sector.

Singh *et al* (1998) studied the energy demand for crop production in rained areas in Soybean belt of Madhya Pradesh based on the primary data collected from 108 cultivator households. They reported that, the intensification led growth in agriculture to meet the increasing demand for food will demand more commercial energy in the form of fertilizers, diesel fuel, pesticides and electricity. The level, pattern and efficiency of energy use in rainfed crops and possibilities of substitution between different energy input using farm level data. Wheat was the most energy intensive crop followed by Soybean and chickpea. The energy use was very low in coarse cereals and *kharif* pulses. The crop that are more remunerative where observed to consume more energy per unit of output. The current input output price structure favours the use of commercial energy would increase with the shift in cropping pattern towards commercial crops and fine cerals. Technological intervention appears to be the only option to minimize the use of commercial energy.

Stakic *et al.* (1998) Studied on optimization of energy consumption in agriculture production in Yugoslavia. A method for optimizing agricultural production was developed, with the aim of energy and material saving as well as better organization of work in agricultural system. optimization is carried out by changing production plans, by using new technologies by recycling waste materials. A simple model, SIMPLEX, consisting of set of linear equations and constants was used for solving the system. A mathematical model using computer software was developed for carrying out system optimization.

Cestmir and Svatos (1999), studied the Modeling of energy flow in plant production in agriculture. They prescribed a model of energy flows in biomass production. The energy necessary for the production of fertilizer and other energy. As an output energy was considered in this model to be that included in the final product. It was concluded that energy every agricultural product contains more energy they was used in its production, and that in addition it contributes to landscape creation and protection.

Halberg *et al.* (1999) conducted experiments on energy consumption using different farming methods the energy consumption per hectare for intensively and organically grown crops on sandy, dry sandy and clay soil in Denmark and for dairy farms. He concluded that although the consumption of diesel fuel per hectare was similar for intensive and organic farming system, the energy consumption per kg grain and the feed unit consumed per kg meat or milk are lower for organic system due to high indirect energy costs in intensive farming cost are higher on dry sand soils irrespective of farming system so provided a low level of fertilizers maintained, conventional farming methods may be more cost effective. than organic method on this type of soil.

Stefanek and Banaj (1999) conducted experiment on Energy consumption at ploughing by a share. plough in Croatia In his experiment ploughing depth, plough construction and equipment, working method, soil and the preceding crop are significant factors affecting energy consumption during ploughing using a plough share. During investigation it was determined that an increase in the power unit ploughing speed of 1 km/h resulted in an increase average power. consumption of 6.71 per cent. soil compaction and texture were directly related to power consumption. The higher the soil compaction, the higher the energy consumption.

Ivanov (1999) studied the Investigation of the theoretical model for optimum levels of the energy expenditure in grain production. In his study the theoretical model of optimum levels of energy consumption in grain production in different production conditions. The marginal possible value of the coefficient of energy efficiency. Which gives a physical since to the therotical model, was established. it was established that the multiplying effect of Solar energy in grain crops is highest at an optimum level of energy expenditure and moderate energy return levels. The maximum value of energy difference in grain crops is equal to the sum of the maximum value of the multiplying of effect of solar energy and a constant value of C. It was established that in order for the basic equation of the energy difference to have a maximum value at current value of energy expenditures, it is necessary that the maximum possible energy returns of grain crops at a respective level of energy expenditures are bigger than value C.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

Salient features of Marathwada region

Location

In Marathwada region comprises eight district viz. Aurangabad, Jalna, Parbhani, Nanded, Beed, Osmanabad, Latur and Hingoli. The total geographical area of this region is 64813 km^2 out of which 11,041 km^2 is Parbhani district and 1008 km^2 in Aurangabad district. Area under selected villages, Ghayagaon, Nandapur and Babhulgaon is 16.81, 8.55 and 8.01km^2 respectively. Parbhani and Aurangabad district are situated in $18^0 45'$ to $20^0 01'$ and 19^0 to 20^0 the north latitude, respectively.

Soil

In Marathwada region soil is mostly fertile, medium black soil, but soil in Aurangabad district is coarse shallow soil.

Climate

The climate of Marathwada region is pleasent and aggriable cool and warm during greater part of the year. The maximum temperature in Parbhani and Aurangabad district in 1996-97 was 42.6°C and 40°C, minimum temperature was 7.0°C and 10.4°C in month of December, respectively. The rainfall is not uniformly distributed during monsoon. The average rainfall in Parbhani and Aurangabad district is 854 mm and 726 mm, respectively.

3.1.1 Population

The total population in Parbhani district was 21.17 lakhs and 22.14 lakhs in Aurangabad district. Rural population was 4.77 and 7.25 lakhs in Parbhani and Aurangabad district, respectively. Population in selected villages was 8100, 3227 and 5590 in Ghayagaon, Nandapur and Babhulgaon, respectively.

3.1.5 Cropping pattern

Nearly half of the cultivable area of Aurangabad and Parbhani district is generally cropped under kharif crops. Sorghum, pearl millet wheat are the most important corps are grown, groundnut, rice, pulses, safflower, sunflower, cotton and sugarcane are also grown. Total cropped area of the Parbhani and Aurangabad district is 12.07 lakh and 9.27 lakh, respectively. in which, area under cotton is 3.26 and 1.10, lakhs sugarcane is 1.16 and 0.15 lakh, kharif sorghum is 2.02 and 0.38 lakh, wheat is 0.48 and 0.31 lakh, respectively in Parbhani and Aurangabad districts. The present study is based on secondary data collected under. 'All India Co-ordinated projects on "Energy requirement in Agricultural sector implemented at College of Agricultural Engineering, Parbhani However, sampling procedure adopted in the project for selection of sample was as under.

3.2 Sampling design

To select sample multistage stratified random sampling design was adopted. The first strata of the sample comprised selection of the district, second selection of tehsils, third selection of village's fourth and final selection of the farmers.

3.2.1 Selection of district

Parbhani and Aurangabad districts were selected for present study to represent of their respective agroclimatic zones. Parbhani district which come under Central Maharashtra plateau zone and Aurangabad district comes under in Western Maharasthra dry zone.

3.2.2 Selection of tehsils

On the basis of respective agroclimatic zones that is central Maharashtra plateau zone and Western Maharasthra dry zone. Parbhani, Basmat and Vaijpur tehsils were selected for present study.

3.2.3 Selection of village

One village was selected from each selected tehsils on the basis of the agro-climatic zones, considering the co-operation of the farmers, easy approach, non-urban effect, representatives of the locality. To meet the objectives finalised as per the technical programme, Energy requirement in agricultural sector, given to Marathwada Agricultural University, Parbhani centre. Three village were selected for energy audit viz. Nandapur and Babhulgaon from Parbhani district and Ghyagaon from Aurangabad

3.2.4 Selection of farmers

The farmers of selected villages were classified into different categories based on their land holding as marginal farmers (upto 0.99 ha) small farmers (1.00 to 1.99 ha), medium (2.01 to 3.99 ha) and large (4.00 and above) The sixteen farmers were selected form each sample village. Thus, from three selected villages, size of sub sample for each category was sixteen farmers of wheat, sugarcane and cotton. But for kharif sorghum sixteen farmers were selected from each sample village. Thus, from two selected villages, size of sub-sample for each category was sixteen farmers. Thus, for present study final sample consisted of 176 farmers. The above type of stratified random sampling is known as disproportionate stratified random sampling in which different strata are having equal sample size. This type of stratified sampling method has greater advantage over proportionate random sampling method with regards to inter-strata comparison because, in which arithmetic mean are calculated on the basis of equal sample size and analysis of variance, source are also more as compared to proportionate random sampling (Agnihotri, 1980).

The distribution of the sample is shown in table 3.1

Table 3.1 Distribution of sub sample

Category of farmer	Pre stratified size of land holding in hectare	Size of sub sample			
		Wheat	Sugarcane	Cotton	Kharif sorghum
Marginal	0 - 99	12	12	12	08
Small	1 - 1.99	12	12	12	08
Medium	2 - 3.99	12	12	12	08
Large	above 4	12	12	12	08
	Total	**48**	**48**	**48**	**32**

The Cropwise distribution of the sample is presented in table 3.2

Category of farmers	*prestratified size of land holding (ha)*	*size of sub sample*
Wheat		
1. Marginal	0.00 - 0.99	12
2. Small	1.00 - 1.99	12
3. Medium	2.00 - 3.99	12
4. Large	4.00 and above	12
Sugarcane		
1. Marginal	0.00 - 0.99	12
2. Small	1.00 - 1.99	12
3. Medium	2.00 - 3.99	12
4. Large	4.00 and above	12
Cotton		
1. Marginal	0.00 - 0.99	12
2. Small	1.00 - 1.99	12
3. Medium	2.00 - 3.99	12
4. Large	4.00 and above	12
Kharif sorghum		
1. Marginal	0.00 - 0.99	08
2. Small	1.00 - 1.99	08
3. Medium	2.00 - 3.99	08
4. Large	4.00 and above	08

3.2.5 Collection of data

In the project data were collected by cost accounting method. The present study is based on secondary cross sectional data pertaining to an agricultural year 1996-97.

3.3 Analytical techniques

To analyse the data simple tabular analysis tools viz. means, frequencies, percentages, ratio etc. were employed to arrive at meaningful conclusions. In addition to this functional analysis was also performed to give further statistical treatment to the data by fitting linear and Cobb-Douglas production functions.

3.3.1 Tabular analysis

Tabular analysis comprise of arithmetic mean, percentage, frequencies ratio etc. For drawing valid conclusion and to determine energy cost and returns from crop production.

3.3.2 Cobb-Douglas production function

On the basis of goodness of fit (R^2) Cobb-Douglas production function (log linear) was used to determine the resource. productivity and resource use efficiency of agricultural energy in production of kharif sorghum, wheat, cotton and sugarcane. The data were therefore, subjected to functional analysis by using the following form of equation

$$Y = a.xi^{b1} . x2^{b2} .... xn^{bn} \ ei$$

In this functional form 'Y' is the dependent variable, xi are independent variables, 'a' is the constant representing intercept of the production function and bi are the regression coefficients obtained from this function directly represents the elasticity of production which remain constant through out the relevant ranges of inputs. The sum of coefficient that is bi indicates the nature of returns to scale. This function can easily be transformed into linear form by making logarithmic transformation. After logarithmic transformation, this functions

For fitting production function in four major corps viz. kharif sorghum, wheat, cotton and sugarcane, by considering the problem of multicollinearity refers to situation where because of strong inter-relationship among independent variables.

It becomes difficult to disentangle their separate effect on the dependent variables. Some of independent variables are not important just because standard errors are high. It might be due to the present of multicollinearlity.

The main consequences of multicollinearirty are (a) the sampling variances of estimated coefficients increases as degree of collinearity increases between the explanatory variables, (b) estimated coefficients may became very sensitive to small change in data, that is addition or deletion of few observations produce a drastic change in some of estimates of coefficients. This result in non-significant of regression coefficient. Some time it so happens that more of regression are significant but value of R^2 is very high, the remedies suggested for problem of multicollinearity includes (a) getting more data (b) using extraneous estimates(c) ridge regression (d) dropping of variables and (e) using principle components.

For cotton and sugarcane the equation fitted was of following formula

$$Y = aX1^{b1} . X2^{b2} . X3^{b3} . X4^{b4} . X5^{b5}$$

Where,

Y = Gross energies in MJ

a = intercept of production function

bi = regression coefficient of respective resource variables (i = 1,2,3,4,5)

For kharif sorghum and wheat crops the equation fitted was following formula.

$$Y = aX1^{bi} . X2^{b2} . X3^{b3} . X4^{b4} . X5^{b5} . X6^{b6} . X7^{b7}$$

Where,

Y = Gross energies in MJ

a = intercept of production function

bi = regression coefficient of respective variables

(i = 1,2,3,5,6,7)

X1 = Human energy

X2 = Bullock energy

X3 = Mechanical energy

X4 = Energy from seed

X5 = Energy from fertilizers

X6 = Energy from manure

X7 = Energy from irrigation

In second type the equation fitted was of following formula

$$Y = aX1^{b1} . X2^{b2} . X3^{b3} . X4^{b4} . X5^{b5}$$

Y = gross yield in kg

a = intercept of production function

bi = regression coefficient of respective resource variable (i=1,2,3,4,5)

X1 = Human energy

X2 = Bullock energy

X3 = Mechanical energy

X4 = chemical energy

X5 = Energy from seed.

'F' value was tested at k and n-k-1 degrees of freedom that is explanatory or independent (k) and number of observation or number of farmers (n). R^2 is coefficient of multiple determination. Intercept (a) is the mean of yield or gross energy obtained in the absence of selected variables and regression coefficient (bi) are coefficients of independent variables. Regression coefficients were tested for significance by applying 't' test at n-k-1 degree of freedom as under

$$t_{n-k-1} = \frac{b}{SE}$$

Where,

b = regression coefficient of particular variable

SE = Standard error of that variable

3.3.3 Resource use efficiency

Marginal value productivity of resource indicates the addition of the gross energy or yield for unit increase in the i^{th} resource with all other resources are fixed at their geometric mean levels. The MVP of different input factors can be worked out by following formula.

$$MVP = b \cdot \frac{\bar{Y}}{\bar{X}} \cdot PY$$

MVP = Marginal value products

b = regression coefficient of particular independent variable

$\bar{Y}$ = geometric mean of dependent variable

$\bar{X}$ = geometric mean of independent variable

PY = price of dependent variable

3.4 Terms and concepts used

3.4.1 General information

Equivalents for direct and indirect sources of energy

Particulars	Unit	Equivalent energy MJ	Remarks
1	2	3	4
A. Input			
1. Human labour			
i. Adult mean	Man hour	1.96	
ii. Woman	woman-hour	1.57	1 adult women = 0.8 adult man
iii. child	Child-hour	0.98	1 child = 0.5 adult man
2. Animals			
a. Bullocks			
i. large	pair hours	14.05	Body weight above 450 kg
ii. medium	pair hours	10.10	Body weight 35-45 kg
3. Diesel	litre	56.31	It includes cost of lubricant
4. Petrol	litre	48.23	It includes cost of lubricant
5. Electricity	kwh	11.93	-
Machinery			
i. Electric motor	Kg	64.80	Distribution the weight of the machinery equally over the total life span of the machinery (in hours). find the use of machinery (hours) for the particulars operation in a crop.
ii primemovers other than electric motor (including self propelled machines	Kg	64.80	
Farm machinery			
7. Chemical fertilisers			
i Nitrogenous	kg	60.60	Estimated quantity of nitrogen, P2O5 and K2o in the chemical fertiliser. Then computed the amount of energy input from chemical fertiliser
8. Farm yard manure	kg (Dry mass)	0.3	--

1	2	3	4
9. Chemical i superior chemicals	kg	120	chemical requiring dilution at the time of application
ii Inferior chemicals	kg	10.0	Gypsum and any other chemical not requiring dilution, at the time of application
10. Seed a. output main product	-		Same as output of crop production system
i Cereal crops such as wheat, maize, sorghum, bajra, paddy oat barley	kg (dry mass)	14.7	The main output is grains
ii Sugarcane	kg (hundred mass)	5.3	-
iii Fibre crops, cotton sunhemp, jute, sunflex etc	kg (dry mass)	11.8	main product is fibre
b. By products			
i. Straw, vines etc	Kg dry mass	12.5	--
ii. wood, fruit vines, plant wood, etc	kg dry mass	18.0	--
iii. Cotton seed	kg dry mass	25.0	--
iv. Sugarcane leaves and tops	kg dry mass	16.1	--

Gross energies (y)

Physical product are not used as a dependent variable because it is not possible to aggregate them. So, in order ot quantity the production arable, gross energy is calculated by converting the physical products into the energy by multiplying the yield of different crops with their respective energy coefficients. Total energies are treated as dependent variable.

3. Human energy (x1)

The labour input should be recorded in term of work hours of men, women and children employed for different farm operations. Labour was measured in terms of adult manday of eight hours. it included family labour, permanent and casually hired labour, one adult women equal to 0.8 adult man and one children equal to 0.5 adult man. By converting the working hour into energy by multiplying with their respective energy coefficients.

4 Bullock energy (x2)

Bullock pair hours in field operations were calculated and converted into energy terms

4. Mechanical energy (x1)

This includes tractor hours, other machine hours and irrigation that is how long motor runs. Moreover, this includes operations done through machinery etc. Machine hours calculated were converted to energy term by multiplying their respective energy coefficient.

6. Chemical energy (x4)

It includes the use of fertiliser, pesticides, insecticides, manure etc. These were converted into energy terms by multiplying their respective coefficients.

7. **Energy from seed (x5)**

The physical quantities of seed is multiplying by their respective energy coefficients.

8. **Energy from different inputs**

Physical quantity of input is converted into energy by multiplying their respective energy coefficients.

3.4.2 Cost items

The following items of cost were considered

1. Hired human labour
2. Hired bullock labour
3. Tractor
4. Seeds
5. Fertilisers
6. Farm yard manure
7. Chemicals
8. Electricity charges
9. Diesel
10. Petrol
11. Threshing
12. Transportation
13. Depreciation on electric motor
14. Depreciation on power sprayer.

3.4.3 Measurement and evaluation of cost items

1. Hired human labour

Hired human labour was measured in man day. On manday consist with eight hours. Labour cost was evaluated at the rate of Rs. 30 for per day per male and Rs. 20 for per day per female. Female labour was converted into mandays Multiplying by 0.8 factor to number of females.

2. Hired bullock labour

Hired bullock labour was measured in bullock pair day. One bullock pair day consist with eight hours. Cost of bullock labour was evaluated at the rate of Rs. 100 per day per bullock pair

3. Hired charges of tractor

Hired charges of tractor were evaluated Rs. 125 for per working hours.

4. Seeds

Cost of seeds was evaluated Rs. 180 per 3 kg for kharif sorghum, Rs 900 quintal for wheat Rs. 250 per kg for cotton and Rs. 650 per tonnes for sugarcane.

5. Fertilisers

Urea was charged at the rate of Rs.180 per 50 kg, single super phosphate was Rs. 120 per 50 kg and murrate of potesh was Rs. 210 per 50 kg.

6. Farm yard mannure

Farm yard mannure was charged at the rate of rs. 40 per quintal

7. Chemicals

Endosulfan was charged at the rate of Rs. 190 per litere, Monocrotophos Rs. 210 per litre and spark Rs. 425 per litre.

8. Electricity charges

Electricity charges as Rs. 1.10 per unit

9. Diesel

Diesel was charged at the rate of Rs. 11.70 per litre.

10 Petrol

Petrol was charged at the rate of Rs. 28 per litre.

11. Threshing

Charges of threshing was at the rate of Rs. 15 per quintal grain yield.

11 Transportation

Charges of transportation was at the rate of Rs. 100 per ton of agricultural produce upto 15 km

12 Depreciation on Electric motor

It was calculated at the rate of 10 per cent on the value of electric motor.

13 **Depreciation on power sprayer**

It was calculated at rate of 10 per cent on the value of power sprayer

3.4.4 Measures of income

a) Gross income

It referred to the sum of the values of main produce and by produce from the crop production. It is also known as total receipt or return of the crop production.

b) Output-input ration

It is the ratio of output (gross income) to input.

Thus methodology chapter which was divided into four part like salient features of Marathwada region, particularly in Aurangabad in Parbhani district, sampling design, analytical techniques as well as terms and concepts for convenience of the study has been tried to present in comprehensive form.

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

In the earlier chapter the objectives, concepts, past studies and design of the study are presented. The data were analysed with respect to the objectives. The results of the analysis are presented and discussed in this chapter in the following sections.

4.1 Energy requirement

4.2 Energy consumption (physical and monetary)

4.3 Total energy consumption (per hectare)

4.4 Functional analysis

4.1 Energy requirement

4.1.1 Kharif sorghum

The per hectare, sourcewise energy requirement for kharif sorghum production is given in Table 4.1

The Table 4.1 reveals that, at an overall level, on an average per hectare total energy consumption for production of kharif sorghum on the sample farms was estimated at 7085.82 MJ. In this, share of commercial and non commercial energy was estimated at 56.72 and 42.28 per cent, respectively. This implied that, commercial energy played major role in kharif sorghum production.

Table 4.1 Energy requirements from various energy sources for raising kharif Sorghum crop

Energy sources	Energy requirement (MJha^{-1})				
	Marginal	Small	Medium	Large	Overall
I. Commercial	454.53	486.16	349.66	407.66	425.50
i. Direct non renewable	(6.16)	(6.72)	(5.12)	(5.70)	(5.99)
(Diesel, Electricity)					
ii. Indirect non-renewable	3503.37	3598.24	3329.17	3599.25	3507.43
(Chemicals, fertilsiers,	(47.50)	(49.73)	(50.61)	(50.35)	(49.50)
machineries)					
iii. Energy from seed	85.25	81.37	89.12	92.50	87.06
	(1.16)	(1.12)	(1.35)	(1.22)	(1.23)
Total commercial energy	4043.15	4165.77	3767.95	4099.40	4018.99
	(54.82)	(57.57)	(57.28)	(57.35)	(56.72)
II. Non-commercial energy	2865.92	2516.55	2416.05	2561.54	2591.17
i. Direct renewable	(38.86)	(34.78)	(36.78)	(35.81)	(36.57)
(Human, Animal)					
ii. Indirect renewable	465.87	553.37	394.37	489.00	475.66
(Farmyard manure)	(6.32)	(7.65)	(5.99)	(6.84)	(6.76)
Total non-commercial energy	3331.79	3069.92	2810.42	3050.54	3066.83
	(45.18)	(42.43)	(42.72)	(42.65)	(43.28)
Total energy consumption	7374.94	7235.69	6578.37	7149.94	7085.82
	(100)	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total energy consumption

Within commercial energy contribution of indirect non renewable was the highest and it was 50.73 per cent. Whereas share of direct non-renewable energy was very small i.e. 5.99 per cent.

Of the total non commercial energy i.e. 3066.83 MJ, consumption of direct renewable alone was to the tune of 36.57 per cent to the total consumption of energy for sorghum production. Rest 6.71 per cent was contribution indirect

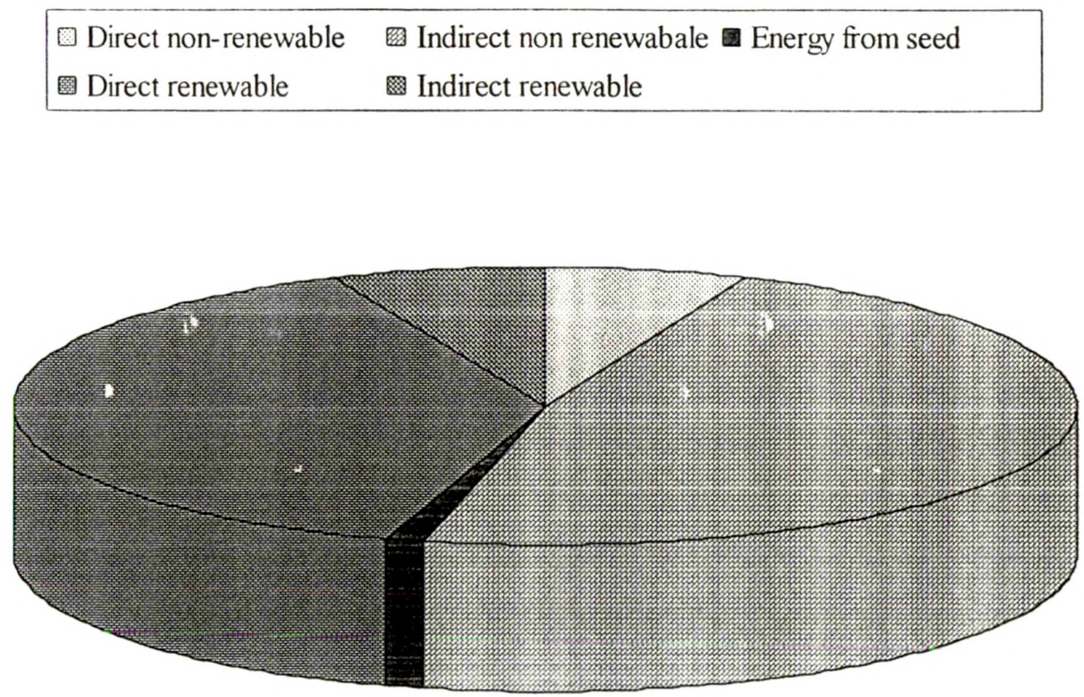

Fig 1. Energy requirement from various energy sources for raising kharif sorghum crop

renewable. The similar sourcewise consumption of energy for kharif sorghum production was observed on different sized group of farms also.

The consumption of total energy was found to be the highest on marginal farms i.e. 7374.94.03 $MJha^{-1}$ and the lowest was on medium sized farms (6678.37 $MJha^{-1}$). Higher energy consumption on marginal sized farms was attributed to higher consumption of direct renewable energy. This was due to non-economical size of land holding.

Foregoing analysis brought out that, commercial energy use had an edge over that of non-commercial energy. Whereas, within commercial energy use of indirect non-renewable was much more not only this, indirect non-renewable commercial energy dominated total energy consumption scenario on the sample farms.

4.1.2 Wheat crop

The per hectare sourcewise energy consumption on different size group of farms for wheat crop is presented in Table 4.2.

A glance on the Table 4.2 indicates that, at an overall level on an average, per hectare total consumption of energy for wheat production was worked out to be 9304.72 MJ. Breakup of the total energy consumption into its components viz. commercial and non-commercial was 73.77 and 26.24 per cent, respectively.

Table 4.2 Energy requirements from various energy sources for raising Wheat crop

Energy sources	Energy requirement ($MJha^{-1}$)				
	Marginal	Small	Medium	Large	Overall
I. Commerical	346.79	1280.29	792.95	1744.54	1017.94
i. Direct non renewable (Diesel, Electricity)	(4.62)	(12.96)	(8.64)	(14.87)	(10.94)
ii. Indirect non-renewale (Chemicals, fertilsiers, machineryies)	3688.86	4698.01	3960.08	5986.99	4583.46
	(49.14)	(47.54)	(48.78)	(51.12)	(49.26)
iii. Energy from seed	1133.25	1273.33	1270.58	1330.91	1252.02
	(15.09)	(12.89)	(15.65)	(11.36)	(13.46)
Total commercial energy	5168.90	7251.63	5933.41	9059.44	6853.42
	(68.85)	(73.39)	(73.09)	(77.35)	(73.66)
II. Non-commercial energy	2213.56	2492.97	2041.47	2414.31	2290.56
i. Direct renewable (Human, Animal)	(29.49)	(25.24)	(25.14)	(20.61)	(24.61
ii. Indirect renewable	124.83	135.80	143.41	238.83	160.72
(Farmyard manure)	(1.66)	(1.37)	(1.77)	(2.04)	(1.73)
Total non-commercial energy	2338.39	2628.77	2184.88	2653.14	2451.30
	(31.15)	(26.61)	(26.91)	(22.65)	(26.34)
Total energy consumption	7507.29	9880.40	8118.29	11712.58	9304.72
	(100)	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total energy consumption

In commercial energy, contribution of indirect non-renewable source was the higher as compared to that of direct non renewable. the shares of direct and indirect source of energy were estimated at 10.94 and 62.72 per cent to the total consumption of energy. While, in case of non commercial energy contribution of direct and indirect sources accounted for 20.61 and 2.04 per cent respectively. This implied that, role of indirect renewable non-

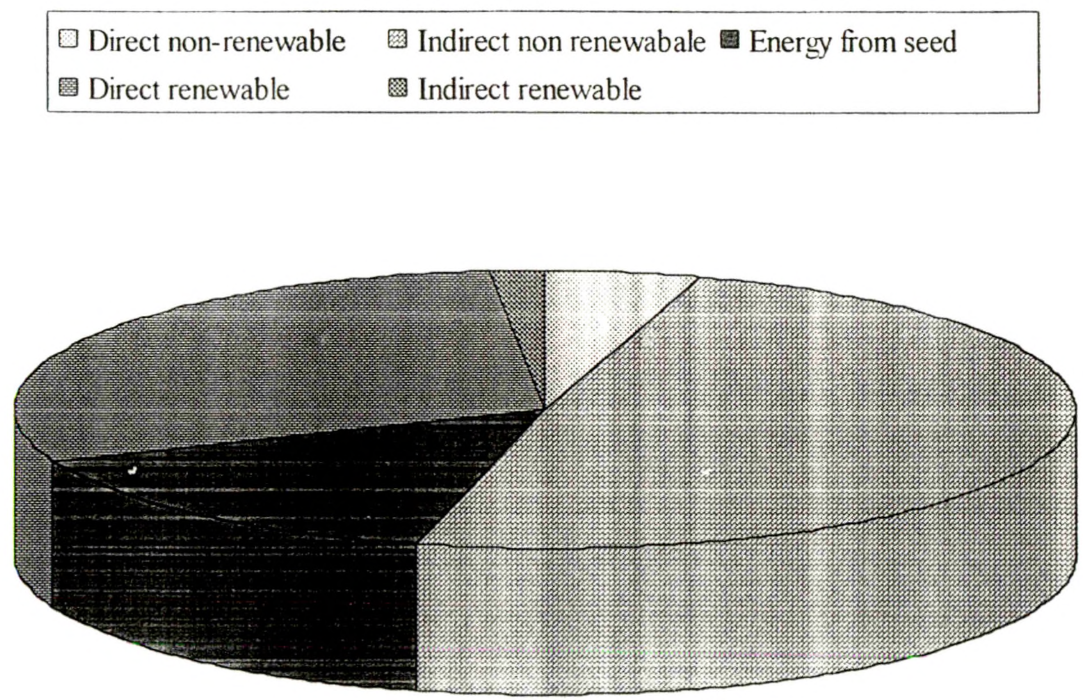

Fig 2. Energy requirement from various energy sources for raising Wheat c rop

commercial energy in wheat production was negligible. The similar trend was noticed in consumption of energy supplied through different sources on the various sized group of the farms.

In wheat production, the highest energy consumption was observed on large sized farms i.e. 11712.58 $MJha^{-1}$ and the lowest was on marginal sized farms i.e. 7507.29 $MJha^{-1}$. This indicated that, almost there was positive relationship between size of holding and energy consumption for wheat crop with an exception of medium sized farms wherein energy consumption was bit lower as compared to small sized farms.

The above findings clearly indicated that, commercial source of energy played major role in wheat production on the sample farms in general. Further, it was observed that there was positive relationship between size of land holding and energy consumption.

4.1.3 Cotton crop

The per hectare sourcewise consumption of energy for cotton production on different size of land holdings is shown in Table 4.3.

The table 4.3 shows that at an overall level on an average per hectare total consumption of energy for cotton production was estimated at 11890.92 MJ. In this commercial and non-commercial sources accounted for 59.99 and 40.01 per cent of the total energy consumption.

Table 4.3 Energy requirements from various energy sources for raising cotton crop

Energy sources	Energy requirement (MJha^{-1})				
	Marginal	Small	Medium	Large	Overall
I Commercial	628.41	860.18	737.83	1629.18	964.90
i Direct non renewable	(5.28)	(6.05)	(6.69)	(15.67)	(8.12)
(Diesel, Electricity)					
ii. Indirect non-renewable	6386.65	8189.32	5267.74	4584.6	6106.96
(Chemicals, fertlisers,	(53.65)	(57.56)	(47.74)	(44.07)	(51.36)
machinaries)					
iii. Energy from seed	65.20	61.04	61.25	62.66	61.20
	(0.55)	(0.43)	(0.55)	(0.60)	(0.51)
Total commercial energy	7080.26	9110.54	6066.62	6275.94	7133.06
	(59.48)	(64.04)	(54.98)	(60.34)	(59.99)
II. Non-commercial energy	4149.50	4436.07	4292.91	3428.99	4076.74
i. Direct renewable	(34.85)	(31.18)	(38.91)	(32.97)	(34.28)
(Human, Animal)					
ii. Indirect renewable	674.54	680.16	674.25	695.51	681.12
(Farmyard manure)	(5.67)	(4.78)	(6.11)	(6.69)	(5.73)
Total non-commercial energy	4824.04	5116.23	4967.16	4124.50	4757.86
	(40.52)	(32.96)	(45.02)	(39.66)	(40.01)
Total energy consumption	11904.30	14226.77	11033.98	10400.44	11890.92
	(100)	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total energy consumption

Further, breakup of commercial energy into direct non-renewable and indirect non-renewable sources was estimated at 8.12 and 51.87 per cent of the total energy consumption. Whereas, distribution of non-commercial energy into direct renewable and indirect renewable was 34.28 and 5.73 per cent of the total energy consumption. The similar trend in sourcewise energy consumption for production of cotton crop on the different sized group of farms was witnessed.

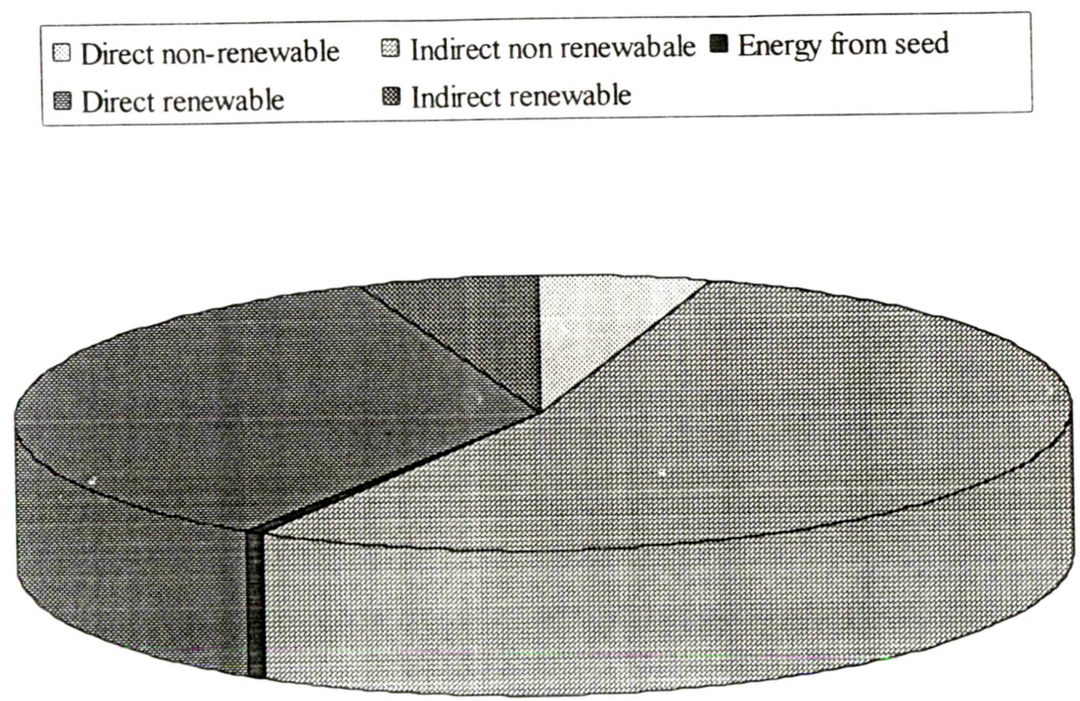

Fig 3. Energy requirement from various energy sources for raising Cotton c rop

The highest energy consumption was observed on the small farms (i.e.14226.77 $MJha^{-1}$) and the lowest on large sized farms (10400.44 $MJha^{-1}$). This shows inverse relationship between energy consumption and size of land holding.

Forgoing analysis leads to conclude that, commercial source of energy had an edge over that of non-commercial source of energy. Further, it may be concluded that the size of land and energy consumption are inversely related barring an exception marginal sized farms.

4.1.4 Sugarcane

The per hectare sourcewise energy consumption for sugarcane crop on different size of farms is furnished in Table 4.4

The Table 4.4 reveals that, at an overall level, on an average per hectare total energy consumption production of sugarcane crop was worked out to be 58775.30 MJ. In this share of commercial and non-commercial energy was estimated at 91.17 and 8.83er cent respectively.

While, in non-commercial source of energy the share of direct renewable and indirect renewable was estimated at 6.62 and 2.21 per cent, respectively. The similar trend exhibited on different size of farms also.

Table 4.4 Energy requirements from various energy sources for raising sugarcane crop

Energy sources		Energy requirement ($MJha^{-1}$)			
	Marginal	Small	Medium	Large	Overall
I. Commercial	2321.18	3880.55	1482.26	4990.09	3167.52
i. Direct non renewable (Diesel, Electricity)	(3.65)	(6.21)	(2.96)	(8.470	(5.39)
ii. Indirect non-renewable	15070.33	11655.45	11266.99	10197.11	12048.47
(Chemicals, fertilsiers, machineryies)	(23.69)	(18.63)	(22.53)	(17.31)	(20.50)
iii. Energy from seed	40422.00	40689.00	33992.83	38678.36	38370.55
	(63.54)	(65.05)	(67.95)	(65.14)	(65.28)
Total commercial energy	57813.51	56225.00	46742.08	53565.70	53586.34
	(90.88)	(89.89)	(93.44)	(90.92)	(91.17)
II. Non-commercial energy	4429.29	4719.87	2432.96	3979.87	3890.49
i. Direct renewable (Human, Animal)	(6.96)	(7.54)	(4.87)	(6.76)	(6.62)
ii. Indirect renewable	1372.41	1605.66	848.00	1367.00	1298.27
(Farmyard manure)	(2.16)	(2.57)	(1.69)	(2.32)	(2.21)
iii. Total non-commerical energy	5801.70	6325.53	3280.96	5346.87	5188.76
	(9.12)	(10.11)	(6.56)	(9.08)	(8.83)
Total energy consumption	63615.21	62550.53	50023.04	58912.43	58775.30
	(100)	(100)	(100)	(100)	(100)

Figures in parentheses are percentages to the total energy consumption

The highest energy consumption was recorded on marginal size farms (63615.21 MJ) and the lowest was on medium sized farms (50023.04 MJ)

Foregoing analysis revealed that, the commercial energy played a major role in sugarcane production as compared to that non-commercial.

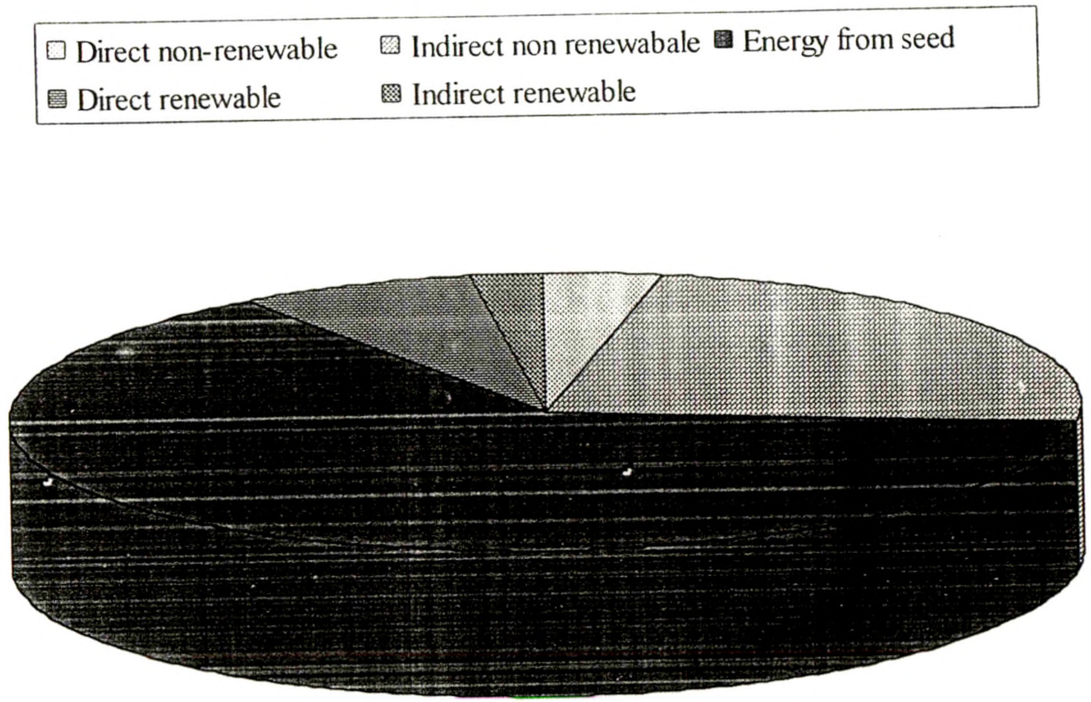

Fig 4. Energy requirement from various energy sources for raising Sugarcane c rop

4.2 Energy consumption (Physical/ Monetary)

One of the objectives of present study was to estimate energy use in terms of Physical and monetary. Accordingly an attempt was made to estimate energy use for production of Kharif Sorghum, Wheat, Cotton and Sugar cane crops grown in Marathwada region of Maharashtra State. The crop wise energy used in physical and monetary terms is presented and discussed in this section.

4.2.1 Kharif Sorghum

The per hectare operation wise energy consumption in physical and monetary terms for Kharif, sorghum production is given in Table 4.5

4.2.1.1 Physical Terms

The Table 4.5 reveals that, on an average per hectare total energy consumption for performing various operations of sorghum production was estimated at 3243.83 MJ. In this contribution of manual, bullock and mechanical power was 33.38, 46.50 and 20.12 percent, respectively.

The above findings indicated that in production of kharif sorghum use of animal power dominated over human and mechanical power. Use of mechanical power for production of kharif sorghum was found to be on lower side because, this was rainfed crop without involving irrigation and plant protection

Table 4.5 Per hectare energy consumption and energy cost for Kharif sorghum production in Marathwada Region

Operation	Manual Power		Bullock Power		Mechanical power		Total	
	Energy MJha^{-1}	Cost Rs.	Energy MJha^{-1}	Cost Rs.	Energy MJha^{-1}	Cost Rs.	Energy MJ ha^{-1}	Cost Rs.
I. Land Preparation	112.35	214.95	793.95	705.75	130.59	125.00	1036.20	1045.70
	(3.46)	(4.72)	(24.45)	(15.48)	(4.03)	(2.74)	(31.94)	(22.94
II. Sowing	61.71	118.07	208.92	185.87	-	-	270.63	303.94
	(1.90)	(2.59)	(6.44)	(4.08)			(8.34)	(6.67)
III. Fertigation & Manuring	23.88	44.73	-	-	-	-	23.38	44.73
	(0.72)	(0.98)					(0.72)	(0.98)
IV. Irrigation	27.63	52.86	-	-	1573.11	628.16	184.74	681.02
	(0.85)	(1.16)			(4.85)	(13.78)	(5.70)	(14.94)
V. Interculture	309.84	592.80	249.25	221.75	-	-	559.09	814.55
	(9.55)	(13.00)	(7.69)	(4.87)			(17.24)	(17.87)
VI. Harvesting	311..72	596.40	-	-	-	-	311.72	596.40
	(9.61)	(13.08)					(9.61)	(17.87)
VII.Threshing	69.78	133.51	-	-	334.62	235.65	404.40	369.92
	(2.15)	(2.93)			(10.32)	(5.16)	(12.47)	(8.09)
VIII. Transportation	33.75	64.57	256..83	228.50	30.34	157.10	320.92	450.17
	(1.04)	(1.42)	(7.91)	(5.00)	(0.94)	(3.45)	(9.89)	(9.87)
IX. Post harvest activities	132.75	253.58	-	-	-	-	132.75	253.58
	(4.09)	(5.56)					94.090	95.560
Total	**1082.91**	**2071.47**	**1508.26**	**1341.87**	**652.66**	**1145.91**	**3243.91**	**4559.25**
	(33.38)	**(45.43)**	**(46.50)**	**(29.43)**	**(20.12)**	**(25.13)**	**(100)**	**(100)**

(Figures in parentheses are the percentages to the total energy and total cost) measures. Hence, use of machine power was low. Similarly, on smaller extent tractor was used for ploughing even majority of respondents performed ploughing on their farms with the help of animal draft. However, almost cent per cent farmers made use of mechanical threshers for threshing operation and some of the farmers had given protective irrigation to their crop during prolonged dry spell. This was done by the farmers having irrigation facility. For transportation also mechanical power was being used by large sized farmers.

Manual power was used at every stage of crop production and almost every crop production operation as well as pre-sowing and post harvesting operations also consumed manual power. Among all the operations , harvesting absorbed or consumed the highest energy 311.72 $MJha^{-1}$ (9.61 per cent). This was closely followed by interculturing 309.84 MJ ha^{-1} (9.55 per cent). While, least energy was consumed in application of chemical fertilizers and manures i.e. 23.38 MJ/ ha^{-1} (0.72 per cent).

in animal power, the highest energy consumption was recorded for land preparation or preparatory tillage operations (793.26 MJ/ha^{-1}) such as ploughing clod crushing, harrowing etc. Land preparation consumed 24.45 per cent of the total consumption of energy for Sorghum production. The next important operation involving bullock power was transportation which

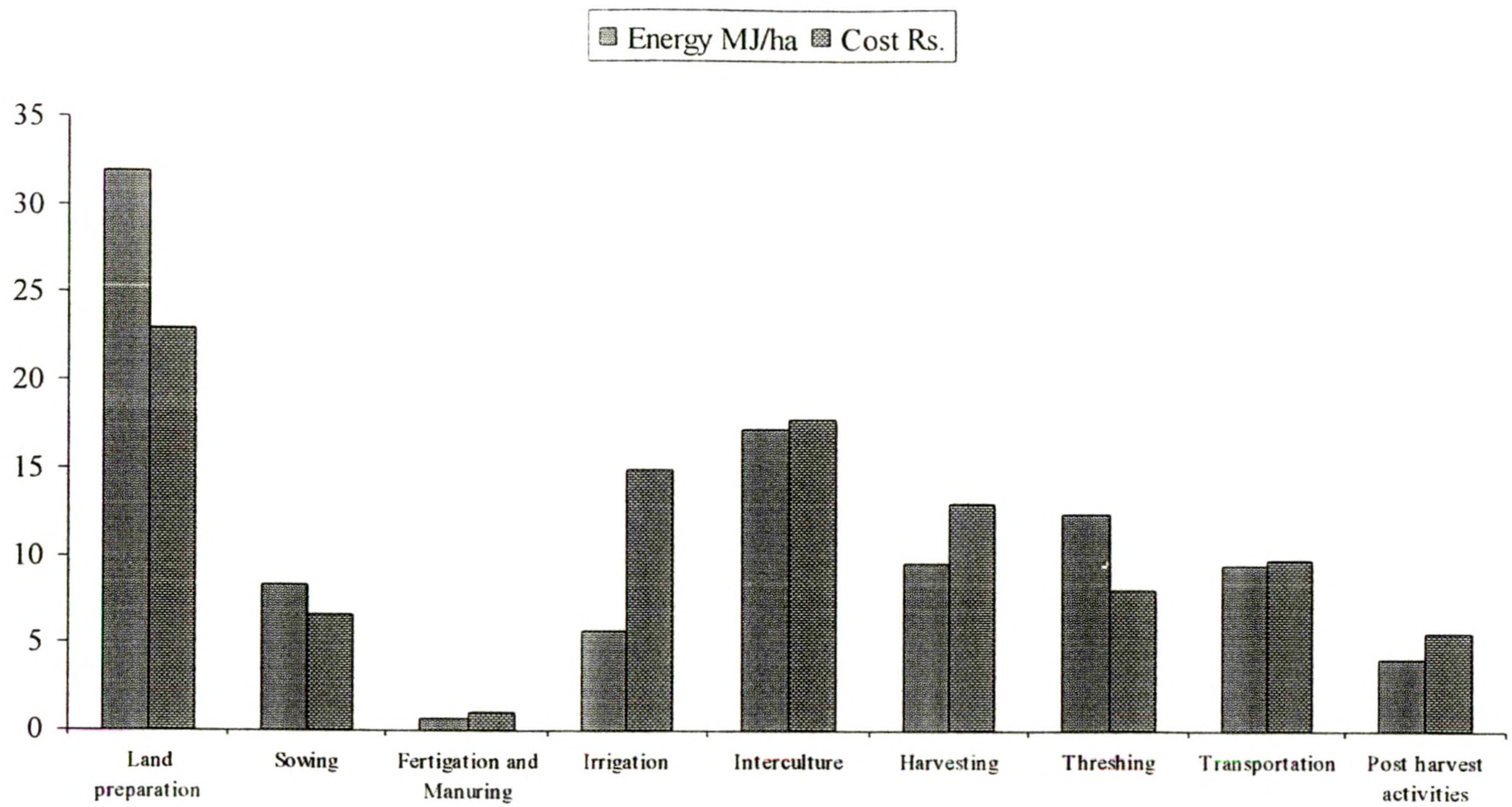

Fig 5. Per hectare consumption and energy cost for kharif sorghum production in Marathwada region

consumed energy 256.83 MJ ha^{-1} (7.91 per cent). This was closely followed by sowing operation which consumed 208.92 MJ ha^{-1} (6.44 per cent).

Foregoing analysis revealed that, animal power played major role in sorghum production in the study area as compared to manual and mechanically power.

4.2.1.2 Monetary Terms

Further Table 4.5 reveals that, the total monetary budget involved in meeting energy bill in terms direct payments for hired services as well as imputted value of owned resource together involved the total budget of Rs. 4559.25 ha^{-1} for performing various crop operations through manual, bullock and mechanical power.

As far as energy consumption in monetary terms was concerned the highest budget was spent to meet out wage bill of human labour and it accounted for 45.43 per cent of the total energy bill. This was followed by bullock power (29.43 per cent) and mechanical power (25.13 per cent), respectively. The study revealed that, human power is costlier as compared to bullock and mechanical power. As against this among three contributors of energy bullock power was found to be cheaper as compared to manual and mechanical power.

4.2.2 Wheat

The per hectare operationwise energy use in physical and monetary terms for wheat production is presented in Table 4.6.

4.2.2.1 Physical Terms :

It is seen from the Table 4.6 that, on an average per hectare total energy use for wheat production was worked out to be 35.48.86 MJ.

The sourcewise energy use revealed that, the use of bullock power (35.88 per cent) was the highest followed by mechanical (35.46 percent) and manual power (28.66 per cent) , respectively. This shows that there was more use of bullock power as compared to mechanical and manual power. However, there was very slight difference between use of bullock and mechanical power.

In manual power, the highest use was for interculturing operations i.e.269.11 MJ (7.58 per cent) and the lowest was for transportion i.e. 12.90 MJ (0.36 per cent). Land preparation, irrigation, harvesting and post harvest activities were an important items of energy consumption.

In case of bullock power, land preparation was found to be the most important activity of bullock power use and this alone consumed 20.17 per cent of the total consumption of energy for wheat production on the sample farms. While, the lowest use of bullock power was for transportation (2.59 per cent).

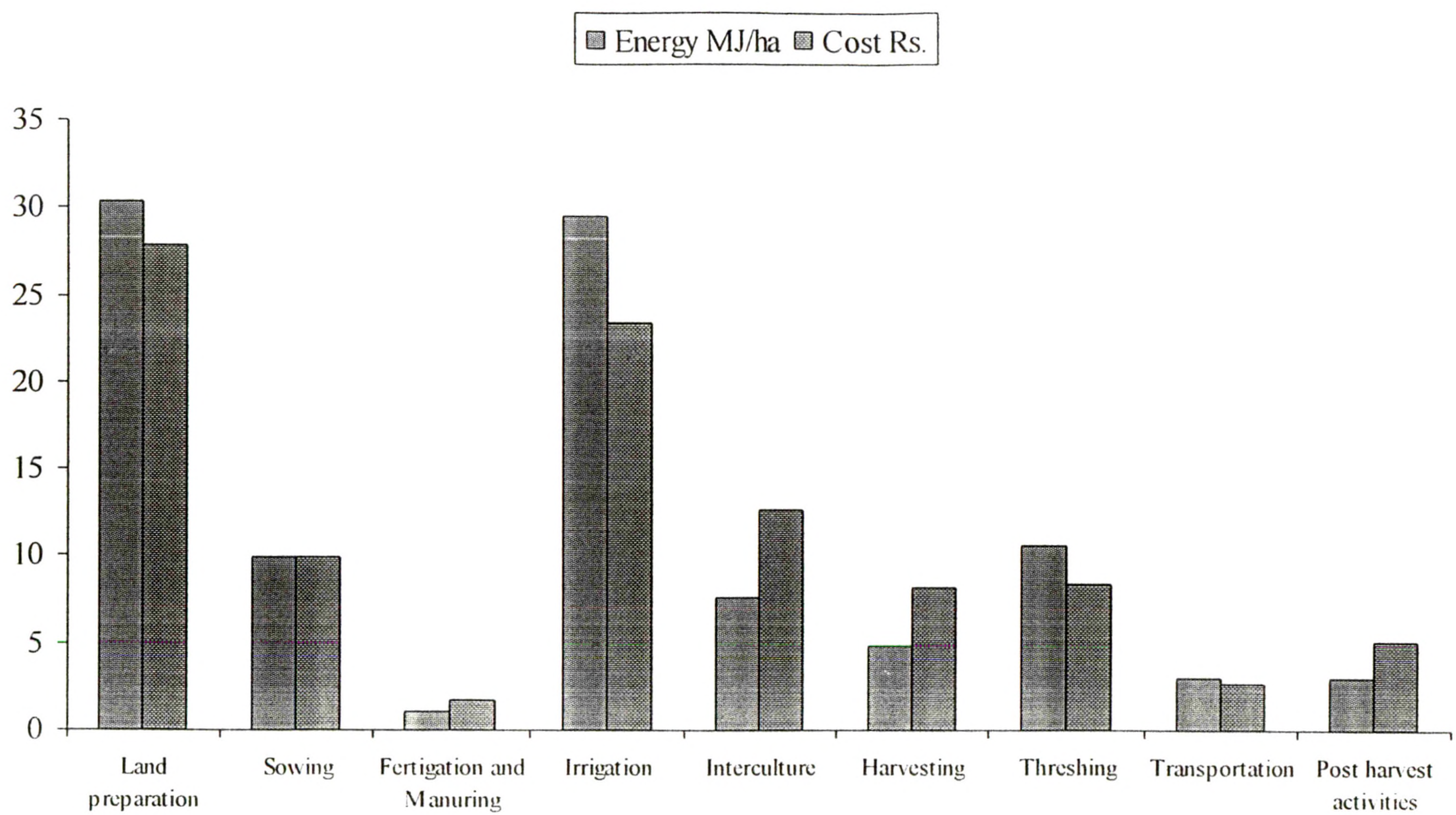

Fig 6. Per hectare consumption and energy cost for Wheat production in Marathwada region

Table 4.6 Per hectare energy consumption and energy cost for Wheat Production in Marathwada Region

Operations	Manual power		Bullock power		Mechanical powr		Total	
	Energy MJ ha^{-1}	Cost Rs.	Energy MJ ha^{-1}	Cost Rs.	Energy MJ ha^{-1}	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.
I.Land preparation	127.99 (3.60)	244.87 (6.07)	915.08 (25.78)	814.12 (20.17)	37.20 91.050	62.50 (1.55)	1080.27 (30.43)	1121.49 (27.79)
II.Sowing	84.70 (2.39)	162.05 (4.02)	266.52 (7.51)	237.11 (5.87)	-	-	351.22 (9.90)	399.16 (9.89)
III.Fertigation & Manuring	37.40 (1.05)	71.55 (1.77)	-	-	-	-	37.40 (1.05)	71.55 (1.77)
IV. Irrigation	137.53 (3.88)	263.13 (6.52)	-	-	911.22 (25.68)	683.19 (16.93)	1048.75 (29.56)	946.32 (23.45)
V Interculture	269.11 (7.58)	514.87 (12.75)	-	-	-	-	269.11 (7.58)	514.87 (12.75)
VI. Harveting	173.10 (4.88)	331.18 (8.20)	-	-	-	-	173.10 (4.88)	331.18 (8.20)
VII Thershing & Winnowing	66.97 (1.89)	128.13 (3.17)	-	-	309.86 (8.73)	212.10 (5.26)	376.83 (10.62)	340.23 (8.43)
VIII.Transportation	12.90 (0.36)	24.68 (0.61)	91.79 (2.59)	81.63 (2.02)	-	-	104.69 (2.95)	106.31 (2.63)
IX.Post harvest activities	107.49 (3.03)	205.66 (5.09)	-	-	-	-	107.49 (3.03)	205.66 (5.09)
X Total	1017.19 (28.66)	1946.12 (48.21)	1273.39 (35.88)	1132.86 (28.06)	1258.28 (35.46)	957.79 (23.73)	3548.86 (100)	4036.77 (100)

(Figure in Parentheses are percentages to the total energy and total cost)

In mechanical power, the highest use was for irrigation i.e. 911.22 MJ ha^{-1} (25.68 per cent) and the lowest was for land preparation i.e. 37.20 MJ ha^{-1} (1.05 per cent) Higher use of mechanical power for irrigation is obvious because, wheat is a irrigated crop which consumes more energy.

Foregoing analysis leads to conclude that, irrespective of source the highest was consumed by irrigation (29.56 per cent) and the lowest was for application of chemical fertilizers and organic manures (1.05 per cent).

4.2.2.2 Monetary Terms

The Table 4.6 further reveals that, the total energy bill for wheat production on the sample farms was worth Rs. 4036.77. The highest share was netted by wage bill of human or manual power (48.21 per cent) and the lowest was by mechanical power (23.73) percent.

an operation wise implicit and explicit total expenses incurred revealed that, the highest expenses were incurred on preparation of land (i.e. 27.79 per cent) followed by irrigation (23.45 per cent), interculturing operations (12.75 per cent), Sowing (9.89 per cent), Threshing and Windowing (8.43 percent), harvesting (8.20 per cent), pose harvest activities (5.09 per cent), transportation (2.63 per cent) and application of chemical fertilizer and organic manures (1.77 per cent), respectively .

4.2.3 Cotton

The per hectare operation wise energy use in physical and monetary terms for cotton production is shown in Table 4.7

4.2.3.1 Physical Terms

The Table 4.7 reveals that, at an overall level, on an average per hectare total energy used for performing various crop production operations including post harvest activities was worked out to be 5264.94 MJ. In this contribution of manual, bullock and mechanical power was accounted for 34.03,43.40,and 22.57 per cent, respectively. This indicated that, the energy use scenario was dominated by bullock power and this is attributed both preparatory and interculturing operations for providing better tilth.

An operationwise power use indicated that, the interculturing operations consumed the highest power (28.64 per cent) and the lowest was for post harvest activities (2.11 per cent). Higher use of power for interculturing operations ascribed to long duration of crop and frequent performance interculturing operations to keep crop free from weeds and pulverization of soil for braking capillary tube for moisture conservation and better aeration.

From the above findings, it is to be deduced that, bullock power use was turned out to be dominating over manual and mechanical power and interculturing operations were major consumer of energy.

Table 4.7 Per hectare energy consumption and energy cost for cotton production in Marathwada region

Operation	Manual power		Bullock power		Mechanical power		Total	
	Energy MJ ha^{-1}	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.
I.Land preparation	135.57	259.50	960.03	854.00	295.06	225.00	1390.66	1338.50
	(2.58)	(3.92)	(18.23)	(12.90)	(5.60)	(3.40)	(26.41)	(20.22)
II.Sowing	137.25	262.20	-	-	-	-	137.25	262.20
	(2.61)	(3.96)					(2.61)	(3.96)
III.Fertigation & Manuring	151.75	290.40		-	-	-	151.75	290.
	(2.88)	(4.39)					(2.88)	(4.39)
IV. Irrigation	36.26	69.37	-	-	314.09	628.82	350.35	689.19
	(0.69)	(1.05)			(5.96)	(9.49)	(6.65)	(10.54)
V Plant protection measures	278.22	532.20	1042.65	927.60	-	-	826.94	914.76
	(5.29)	(8.04)	(19.81)	(14.02)			(15.71)	(13.82)
VI. Interculture	465.06	889.80	1042.65	927.60	-	-	1507.71	1817.40
	(8.83)	(13.44)	(19.81)	(14.02)			(28.64)	(24.46)
VII Harvesting	428.24	819.30	-	-	-	-	428.24	819.30
	(8.13)	(12.38)					(8.13)	(1.38)
VIII.Transportation	48.60	92.97	282.26	75.30	30.33	98.30	361.19	266.57
	(0.92)	(1.41)	(5.36)	(1.14)	(0.58)	(1.48)	(6.86)	(4.03)
IX. Post harvest activities	110.85	212.08	-	-	-	-	110.85	212.08
	(2.11)	(3.20)					(2.11)	(3.20)
X Total	1791.80	3427.82	2284.94	1856.90	1188.2	1334.2	5264.94	6619.40
	(34.03)	(51.78)	(43.40)	(28.05)	(22.57)	(20.16)	(100)	(100)

(Figurs in parentheses are percentage to the total energy and total cost.)

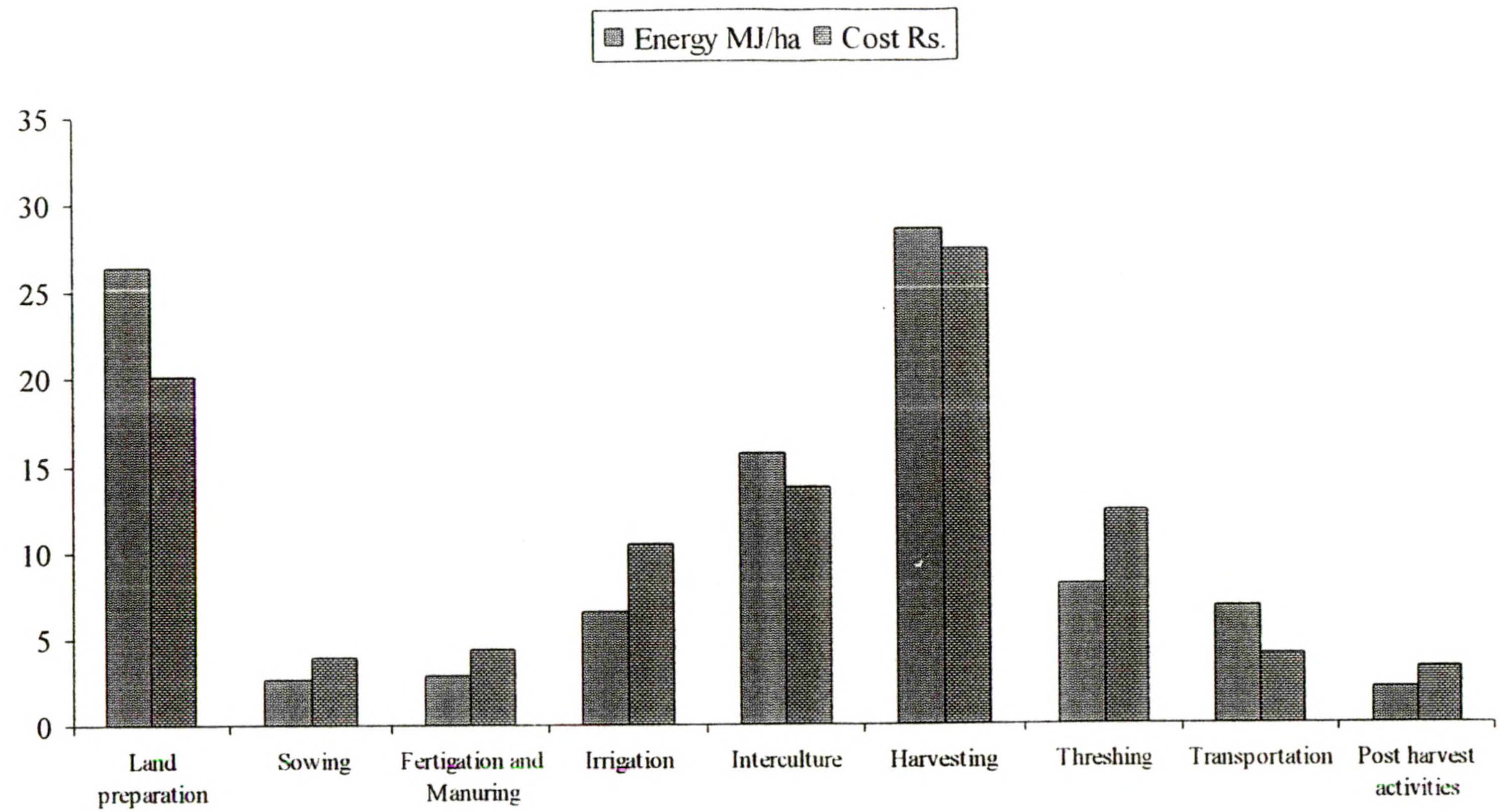

Fig 7. Per hectare consumption and energy cost for Cotton production in Marathwada region

4.2.3.2 Monetary terms

The table further reveals that, at an overall level, on an average per hectare total energy bill estimated for cotton production was Rs.6619.40. In the total energy bill directly or indirectly incurred to perform various crop production operations, the share of manual power (51.78%) was the highest and the lowest share was of mechanical power (20.16%) This indicated that, manual power was more costlier than that of bullock and mechanical power. This implied that, to reduce energy bill for cotton production, efficiency of manual labour need to be enhanced for keeping down wage bill.

Further study revealed that, the interculturing operations absorbed major energy bill (27.46%) and the lowest expenditure was incurred on post harvest activities (3.20%)

Foregoing analysis revealed that the sample farmers laid more emphasis on use of bullock power as compared to that of manual and mechanical power. Further, it may be concluded that, in physical terms as well as monetary term interculturing operations were the major consumers of energy.

4.2.4 Sugarcane

The per hectare operationwise energy use in physical and monetary terms for sugarcane production is depicted in table 4.8.

Table 4.8 Per hectare energy consumption and energy cost for Sugarcane production in Marathwada region

Operation	Manual Power		bullock Power		Mechanical Power		Total	
	Energy $MJha^{-1}$	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.	Energy $MJha^{-1}$	Cost Rs.
I.Land preparation	152.90	292.50	1033.37	919.36	-	-	1186.27	1211.86
	(2.07)	(4.27)	(14.00)	(13.43)			(16.07)	(17.70)
II.Sowing	269.93	516.30	-	-	-	-	269.93	786.23
	(3.66)	(11.48)					(3.66)	(11.48)
III.Fertigation & Manuring	65.45	125.40	-	-	-	-	65.45	125.10
	(0.89)	(1.83)					(0.89)	(1.83)
IV. Irrigation	484.12	926.40	-	-	3490.18	868.84	3974.30	1795.24
	(6.56)	(13.53)			(47.29)	(12.68)	(53.85)	(53.85)
V. Interculture	391.35	748.80	-	-	-	-	391.35	748.80
	(5.30)	(10.93)					(5.30)	(10.93)
VI. Harvesting	435.75	833.70	-	-	-	-	435.75	833.70
	(5.90)	(12.17)					(5.90)	(12.17)
VII Transportation	224.79	430.20	660.35	587.35	-	-	885.14	1017.70
	(3.04)	(6.28)	(8.95)	(8.58)			(11.99)	(14.86)
VIII.Post harvest activities	172.48	330.00	-	-	-	-	172.48	330.00
	(2.34)	(4.82)					(2.34)	(4.82)
IX Total	2196.77	4203.00	1693.72	1506.86	3490.18	868.84	7380.67	6848.63
	(29.76)	(61.37)	(22.95)	(22.00)	(47.29)	(12.68)	(100)	(100)

Figurs in parentheses are percentage to the total energy and total cost.

4.2.4.1 Physical terms

On perusal of the Table 4.8 it could be seen that, on an average an overall level, per hectare total consumption of energy for performing various operations was estimated at 7380.67 MJ. In this contribution of manual, bullock and mechanical power accounted for 29.76, 22.95 and 47.29 per cent, respectively.

An operationwise energy use revealed that, the highest energy was used for irrigation (53.85%) and the lowest for application of chemical fertilisers and organic manures (0.89%). Higher energy consumption for irrigation is attributed to long duration of crop and which is being raised as irrigated one.

In manual power use, irrigation operation had the highest contribution (6.56%) and the lowest was for application of chemical fertilisers and manures (0.89%). whereas, in bullock power use, it was the highest for land preparation (14.00%) and the lowest for transporation (8.95 %).

In respect of mechanical power use, it was used only for irrigation and its contribution was 47.29 per cent in the total energy consumption for sugarcane production.

The above findings leads to conclude that, in the three sources of energy supply mechanical power dominated the scenario of energy use for sugarcane production over that of manual and bullock power use. With regards to operationwise

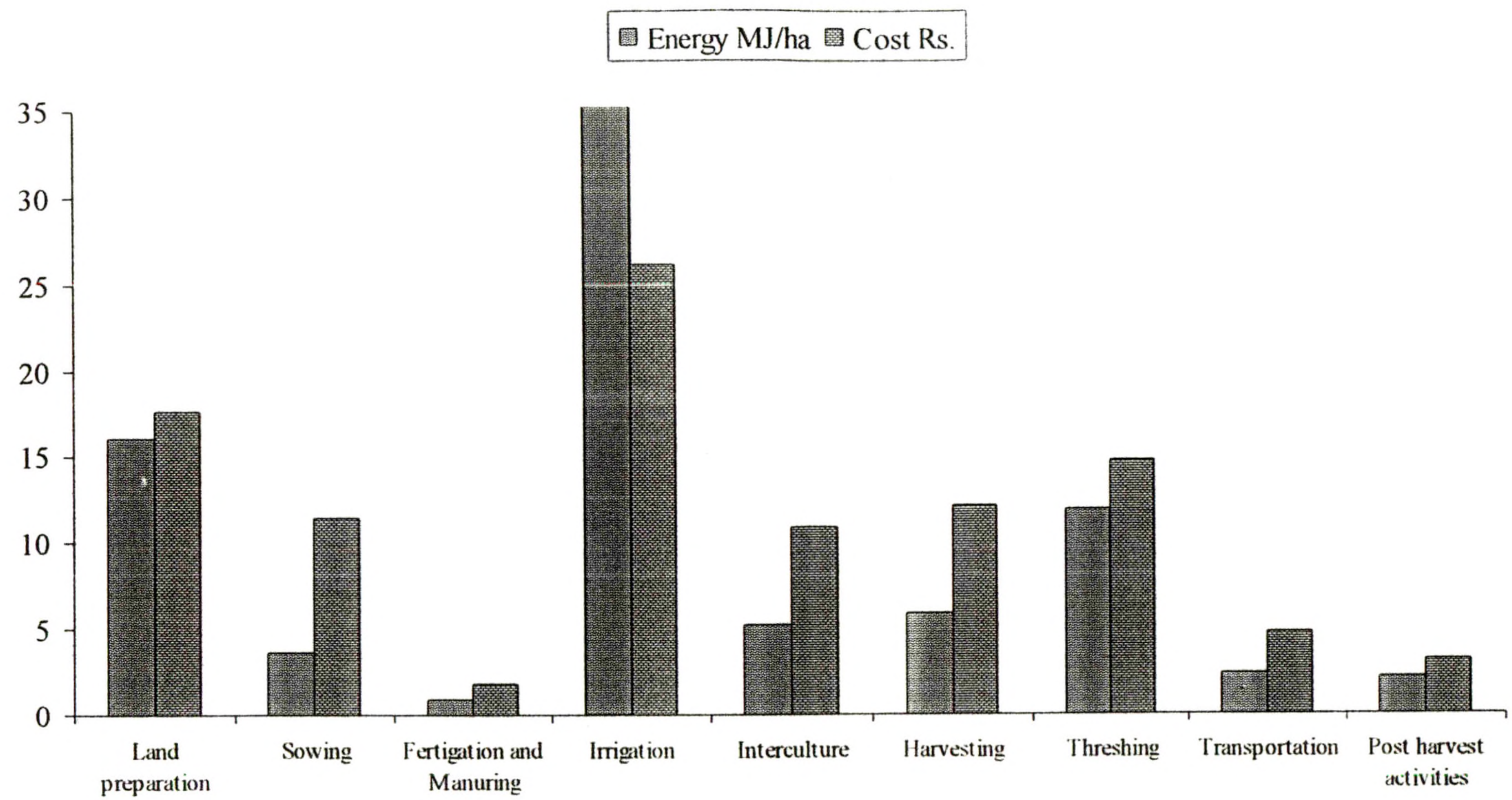

Fig 8. Per hectare consumption and energy cost for Sugarcane production in Marathwada region

energy use irrigation alone absorbed 53.85 per cent of the total energy consumed

4.2.4.2 Monetary terms

The Table 4.8 further reveals that at an overall level, on an average per hectare explicit and implicit cost energy bill to perform various operations of sugarcane production was estimated at Rs. 6848.63. In this shares of manual, bullock and mechanical energy were 61.37, 22.00 and 12.09 per cent, respectively. This implied that, human wage bill alone absorbed more than 61.00 per cent of the total energy bill to e incurred on sugarcane cultivation.

To economics sugarcane production manual energy use needs to be reduced by increasing manual use efficiency with the help of devising hand tools to perform manual operations efficiently.

An operationwise energy bill revealed that, the highest expenses were incurred in meeting energy bill of irrigation and it accounted for 26.21 per cent of the total energy Bill. While, the lowest expenses on energy consumption were incurred on application of chemical fertilisers and organic manures and it was 1.83 per cent of the total cost.

Foregoing analysis revealed that, in monetary terms manual power was found to be the most expensive source of energy for sugarcane production. While, irrigation was observed to be a major operation which is costlier.

4.3 Total energy consumption per ha

An attempt was made to estimate per hectare total energy consumption for production of Kharif sorghum, wheat, cotton and sugarcane crops and energy generated there of in Marathwada region of Maharashtra. The results of analysis of data are presented and discussed in the following section.

4.3.1 Kharif sorghum

The per hectare total energy consumption in MJ as well as monetary terms and energy generated there of is given in Table 4.9.

The Table 4.9 shows that, at an overall level, on an average per hectare total energy consumption for kharif sorghum production was estimated at 7085.82 MJ. In this share of energy supplied by chemical fertilizers (46.28 percent) was the highest, followed by animal power (21.29 percent) , manual power (15.28 per cent), mechanical power (9.21 per cent), organic manure (6.71 per cent) and seed (1.23 per cent), respectively.

The total energy generation in production of kharif sorghum was 59,568.70 MJ. In this contribution of main and by produce was 38.77 and 61.23 per cent, respectively.

Table 4.9 Per hectare energy cost and return for kharif sorghum production in Marathwada region

Sr.No.	Particulars	Energy (MJ)	Energy cost (Rs/.
I	Draft power		
i	Human	1082.91 (15.28)	2071.47 (33.11)
ii	Animal	1508.26 (21.29)	1341.87 (21.45)
iii	Mechanical	652.66 (9.21)	1145.91 (18.31)
	Total	3243.83 (45.78)	4559.25 (72.87)
II	Seed	87.06 (1.23)	355.20 (5.68)
III	Farm yard manure	475.66 (6.71)	634.21 (10.14)
IV	Fertilisers	3279.27 (46.28)	707.93 (11.31)
V	Chemicals	-	-
	Total input	7085.27 (100)	6556.59 (100)
VI	Output		
i	Main produce	23093.70 (38.77)	4524.48 (60.79)
ii	By produce	36475.00 (61.23)	2918.00 (39.21)
	Total output	59568.70	7442.48
VII	Input output ratio	8.41	1.19

Figures in parentheses are percentage to the total input and total output

Input output ratio of energy in production of kharif sorghum was estimated at 8.41 . This implied that, kharif sorghum production is efficient, conversion ratio of energy consumption into energy generation on bio-mass basis is substantial.

4.3.1.1 Energy consumption in monetary terms

The Table 4.9 further reveals that, at an overall level, on an average per hectare energy consumption in terms of money was worked out to be Rs.6256.59. As against this energy generated in monetary terms of estimated at Rs.7442.48. Input output ratio in monetary terms computed at 1.19 . This implied that expenditure incurred on energy bill implicitly and explicitly is economically viable venture through production of Kharif sorghum.

From the above findings, it may be concluded that, energy generation in production of Kharif sorghum is an efficient activity and economically viable proposition.

4.3.2 Wheat

The per hectare total energy consumption, energy bill and energy generation in wheat production is shown in Table 4.10

The Table 4.10 indicates that, at an overall level. On an average per hectare total energy consumption for production of wheat was estimated at 9304.72 MJ. In this contribution of chemical fertilizer was the highest (46.68 per cent) and the lowest was of organic manure 1.73 percent.

The total energy generated in the form of grain and straw was worked out to be 42385.80 MJ. In this share of main and by produce was estimated at 49.04 and 50.96 per cent respectively.

Input output ratio in terms of energy was computed at 4.52.

4.3.2.1 Energy consumption in monetary terms

The Table 4.10 further indicates that, the total energy bill incurred on direct and indirect form was Rs. 6039.57 .

Table 4.10 Per hectare energy cost and return for wheat production in Marathwada region

		Particulars	Energy (MJ)	Energy cost (Rs)
I		Draft power		
	i	Human	1017.19 (10.93)	1946.12 (33.12)
	ii	Animal	1273.39 (13.68)	1132.86 (18.76)
	iii	Mechanical	1258.28 (13.52)	957.79 (15.86)
		Total	3548.86 (38.13)	4036.77 (66.84)
II		Seed	1252.02 (13.46)	766.54 (12.69)
III		Farm yard manure	160.72 (1.73)	214.29 (3.55)
IV		Fertilisers	4343.12 (46.68)	1021.97 (16.92)
V		Chemicals	-	-
		Total input	9304.72 (100)	6039.57 (100)
VI		Output		
	i	Main produce	20785.80 (49.04)	9374.82 (87.85)
	ii	By produce	21600.00 (50.96)	1296.00 (12.15)
		Total output	42385.80	10670.82
VII		Input output ratio	4.52	1.77

Figures in parentheses are percentage to the total input and total output

The energy generated in monetary terms through wheat production was to the tune of Rs.10670.82 . In this contribution of main and by produce was 87.85 and 12.15 per cent respectively.

Input output ratio in monetary terms was estimated at 1.77.

Thus, foregoing analysis revealed that, wheat is efficient converse of input energy into generation of energy through output fetched. Similarly, wheat production is economical viable venture as input output ratio is greater than unity.

4.3.3 Cotton

The per hectare total energy consumption, energy bill and energy generation in cotton production is furnished in Table 4.11

Table 4.11 Per hectare energy cost and return for cotton production in Marathwada region

	Particulars	Energy (MJ)	Energy cost (Rs/.
I	**Draft power**		
i	Human	1791.80 (15.07)	342782 (29.82)
ii	Animal	2284.94 (19.21)	1856.90 (16.15)
iii	Mechanical	1188.20 (10.00)	1334.68 (11.61)
	Total	**5264.94** **(44.28)**	**6619.40** **(5.28)**
II	Seed	61.20 (0.51)	607.50 (7.89)
III	Farm yard manure	681.12)5.73)	908.16 (13.47)
IV	Fertilisers	5004.16 (42.08)	1347.48 (11.71)
V	Chemicals	879.5 (7.40)	2015.75 (17.53)
	Total input	11890.92 (100)	11498.29 (100)
VI	Output		
i	Main produce	24572.50 (40.02)	17692.20 (92.31)
ii	By produce	36825.00 (59.98)	1473.00 (7.69)
	Total output	61397.50 (100)	19165.20 (100)
VII	Input output ratio	5.17	1.67

Figures in parentheses are percentage to the total input and total output

The Table 4.11 depicts that, at an overall level, on an average per hectare total energy consumption was estimated at 11890-92 MJ. In this share of chemical fertilizer was the highest i.e. 42.08 per cent to the total energy consumption and the lowest was of seed (0.51 per cent)

An energy generated in production of cotton was worked out to be 61397.50 MJ. of this energy generated through main and by produce was estimated at 40.02 and 59.98 per cent, respectively..

Input output ratio of energy in cotton production was worked out to be 5.17.

4.3.3.1 Energy consumption in monetary terms

Further the Table 4.11 shows that, the total direct and indirect energy bill incurred in cotton production was to an extent of Rs. 11498.29. At against this, output fetched in monetary term through main and by produce was estimated at Rs. 19165.20.

Input-output ratio in monetary terms was estimated at 1.67..

The above findings leads to conclude that, cotton production is proved to be economically viable enterprise as input output ratio in monetary term is greater than unity.

4.3.4 Sugarcane

The per hectare total energy consumption, energy bill and energy generation in sugarcane production is depicted in Table 4.12.

The Table 4.12 reveals that, at on overall level, on an average per hectare total consumption of energy for sugarcane production is depicted in Table 4.12.

Table 4.12 Per hectare energy cost and return for sugarcane production in Marathwada region

	Particulars	Energy (MJ)	Energy cost (Rs/.
I	Draft power		
i	Human	2196.77	4203.00
		(3.74)	(26.90)
ii	Animal	1693.72	1506.86
		(2.88)	(9.64)
iii	Mechanical	3490.18	868.64
		(5.94)	(5.56)
	Total	7380.67	6578.50
		(12.56)	(42.1)
II	Seed	38370.55	4507.82
		(65.28)	(28.84)
III	Farm yard manure	1298.27	1731.02
		(19.95)	(11.08)
IV	Fertilisers	1725.81	2809.08
		(19.95)	(17.98)
V	Chemicals	-	-
	Total input	58775.30	15626.42
		(100)	(100)
VI	Output		
i	Main produce	378473.00	39275.50
		(49.69)	(73.36)
ii	By produce	383180.00	13900.00
		(50.31)	(26.14)
	Total output	761653.00	53175.50
		(100)	(100)
VII	Input output ratio	11.51	3.40

Figures in parentheses are percentage to the total input and total output

The table 4.12 reveals that, at an overall level, on an average per hectare total consumption of energy for sugarcane production was 58775.30 MJ. In this contribution of seed was the highest i.e. 58.01 per cent to the total energy consumption for sugarcane prodction, the lowest was that of organic manuares (2.21 per cent) .

The total energy generated in sugarcane production was estimated at 761653.00MJ . In this main and by produce accounted for 49.69 and 50.31 per cent, respectively. Whereas, input -output ratio in energy terms was estimated at 11.51 which is substantially high.

4.3.4.1 Energy consumption in monetary terms

The Table 4.12 further reveals that, the total energy bill incurred directly or indirectly on production of sugarcane was to the tune of Rs.15626.42 in lieu of this the returns obtained through main and by produce were Rs.39275.50 and Rs.13900.00 respectively. The total returns realized in sugarcane production were estimated at Rs. 53175.50.

Input output ratio in monetary terms was computed at 3.40. This is quite lucrative. This implied that, sugarcane production on the sample farms was economically viable proposition as input output ratio turned out to be greater than unity.

Thus, from the above findings it could be inferred that sugarcane crop in the study area is efficient consumer of energy and economically viable venture.

4.4 Functional analysis

In the present study two types of statistical analysis of the data were performed so as to reach meaningful conclusions from the data so collected. The first type of statistical analysis of the data comprised tabular analysis viz., mean frequencies, ratios, percentages etc. The results of said analysis are presented in earlier section. The second type of analysis of the data was done by using a tool of production function which is a part of functional analysis of the data the results emnated from functional analysis are present in this section.

In the present study an attempt was made to estimate resource use productivity of energy in production of kharif sorghum, wheat cotton and sugarcane in Marathwada region of Maharashtra State. To attain this objective the two types of production functions viz; Linear and Cobb-Douglas were fitted to the data. However, based on value of co-efficient of multiple determination i.e.. R^2 Cobb-Douglas production function turned out to be better fit. Hence, the results obtained from Cobb-Douglas production function are incorporated and presented over here.

The variables specified were human or manual energy (X_1), bullock energy (X_2), mechanical energy (X_3), chemical energy (X_4) and energy from seed (X_5).

4.4.1 Kharif sorghum

Estimates of Cobb-Douglas production function for Kharif sorghum crop are shown in Table 4.13

Table 4.13 Estimate of Cobb-Douglas production function for kharif sorghum crop

	Independent variable	Regression coefficient	standard error or Se(bi)	't' value or t (bi)
1	Human energy (X1)	1.49601	0.27103	5.5197**
2	Bullock energy (X2)	-0.15481	0.17128	-0.9039 NS
3	Mechanical energy (x3)	-0.30820	0.17925	-1.7194***
4	Energy from seed (X4)	-0.06352	0.14215	-0.4469 NS
5	Energy from fertiliser (X5)	0.52665	0.24431	2.1556*
6	Energy from manure (X6)	0.07526	0.15711	0.4790 NS
7	Energy from Irrigation	-0.35800	0.24653	-1.4522 NS

*	Significant at 5 per cent level	
**	Significant at 1 per cent level	
***	Significant at 10 per cent level	
Intercept (bo)	=	2.0958
R^2	=	0.739
'F' value	=	9.6982**
N	=	32
return to scale	=	1.2134

The Table 4.13 reveals that the Co-efficient of multiple determination i.e R^2 value is 0.739. This implied that, variation explained by the independent variables selected was to an extent of 74 per cent. Out of the seven variables selected three variable viz; human, fertilizers and organic manure energy had positive impact on production of energy in the form of sorghum grains and fodder. While, rest of the variables such as bullock, mechanical, seed and irrigation energy exerted negative influence on production of kharif sorghum main and by produce in energy form.

Only human and energy in the form of fertilizers had positive contribution towards production of sorghum and this was statistically significant. While, only mechanical energy had negatively significant effect on production energy through sorghum grains and fodder.

Though regression co-efficients of the variables of bullock, seed and irrigation energy consumption were negative they turned out to be statically non significant.

The sum of elasticities of production i.e. is 1.2134. This indicated increasing returns to scale.

4.4.1.1 Resource use efficiency of energy use in kharif sorghum production

The resource use efficiency of energy use in Kharif Sorghum Production on the sample farms was tested with the help of MVP/MC ratio and the results of the same are given in Table 4.14.

The Table 4.14 shows that, the MVP/MC ratio for human energy and energy in the form of chemical fertilizers was estimated at 3.28 and 3.48 which are greater than unity.

This implied that use of these two inputs for kharif sorghum production in energy form was efficient, therefore, there exist scope to expand further use of these inputs beyond their existing geometric mean level s of 1082.91 MJ and 3279.27 MJ, respectively. While use of mechanical energy need to be curtailed from its existing geometric mean level of 130.59 $KJha^{-1}$

On persual of the Table 4.15 it could be seen that, the co-efficient of multiple determination i..e. R^2 value is 0.40 . This implied that the variation explained by the independent input variable towards production of wheat was 40.00 per cent.

Table 4.14 Comparison of marginal value products of various input with their price in kharif sorghum crop

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input Rs/MJ	Price of input (Rs/MJ)	MVP to price ratio
Human energy	1082.91	6.27	1.91	3.28
Mechanical energy	130.59	-10.74	1.62	-6.60
Energy from fertiliser	3279.27	0.73	0.21	3.48

Note : Geometrical mean (Y) of yield was 23093.70 MJ andprice of it was Rs.0.196 MJ

The regression co-efficients of input variables viz; bullock, mechanical seed, fertilizer and irrigation energy born positive and desired sign. This indicated that these variable exerted positive influence on production of wheat. However, only contribution of bullock seed and energy in the form of fertilizer was statistically significant. As against this, contribution of human energy was negatively significant. This implied excess use of human energy in production of wheat on the sample farms.

4.4.2 Wheat

Estimates of Cobb-Douglas production function for production of wheat crop are furnished in Table 4.15

Table 4.15 Estimate Cobb-Douglas production function for wheat crop

	Independent variable	Regression coefficient	standard error or SE(bi)	't' value or t (bi)
1	Human energy (X1)	-0.53731	0.19912	-2.6984**
2	Bullock energy (X2)	0.24402	0.12432	1.9629***
3	Mechanical energy (X3)	0.08912	0.19141	0.7480
4	Energy from seed (X4)	0.51871	0.16414	3.1602**
5	Energy from fertiliser (X5)	0.37349	0.12075	3.0932**
6	Energy from irrigation (X6)	0.07453	0.05068	1.4705

** Significant at 1 per cent level

*** Significant at 5 per cent level

Intercept (bo)	=	3.9197
R^2	=	0.40
'F' value	=	4.5114
N	=	48
return to scale	=	0.7626

4.4.2.1 Resource use efficiency

The resource use efficiency in production of wheat crop is shown in Table 4.16

The Table 4.16 reveals that the MVP/MC ratio for bullock, seed and energy in the form of fertilizer was computed at 4.46, 12.24 and 3.76 respectively. This indicated efficient use of these input variables in wheat production as MVP/MC ratios were grater than unity. This implied that there exist scope for further increase in use of these input variables beyond their existing level of use.

Table 4.16 Comparison of marginal value products of various input with their price in wheat crop

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input $RsMJ^{-1}$	Price of input ($RsMJ^{-1}$)	MVP to price ratio
Humna energy	1017.19	-4.98	1.910	-2.61
Bullock energy	1273.39	3.97	0.890	4.46
Energy from seed	1252.02	7.49	0.612	12.24
Energy from fertiliser	4313.12	0.79	10.21	3.76

Note : Geometrical mean (Y) of yield was 20785.80 MJ andprice of it was Rs.0.451 MJ

4.4.3 Cotton

The table 4.17 reveals that, coefficient of multiple determination i.e. R^2 value is 0.247. This implied that, variation explained by the variables incorporated in the model is to the tune of 25 per cent. In other words contribution of human, bullock, mechanical energy and energy from seed in production of energy in the form of seed cotton is 25 per cent .

The regression co-efficients for human, mechanical and seed energy born desired sign i.e. positive thereby indicating that, contribution of these two independent variables towards generation energy in seed cotton form is positive. However, contribution of human and seed energy was statistically significant. Contribution of mechanical energy was positive but statistically it turned out to be non significant.

Table 4.17 Estimate Cobb-Douglas production function for cotton crop

	Independent variable	Regression coefficient	standard error or SE(bi)	't' value or t (bi)
1	Human energy (X1)	0.6408	0.2824	2.2686*
2	Bullock energy (X2)	-0.2182	0.2066	-1.0560
3	Mechanical energy (X3)	0.0459	0.0806	0.5697
4	Chemical energy (X4)	-0.3982	0.2139	-1.8612
5	Energy from seed (X5)	1.0704	0.36847	2.09049**

* Significant at 5 per cent level

** Significant at 1 per cent level

*** Significant at 10 per cent level

Intercept (bo)	=	4.7616
R^2	=	0.247
'F' value	=	2.7547*
N	=	48
return to scale	=	1.141

Regression co-efficients for independent variables viz; bullock and chemical energy born negative sign thereby showing that there was excess use of these inputs beyond their desired level which adversely affected production of seed cotton. However, only chemical energy turned out to be statically significant and bullock energy was found to be non significant.

The sum of elasticity of production i.e. Ɛbi is 1.14 this indicated increasing returns to scale as the value is greater than unity.

4.4.3.1 Resource use efficiency of energy use in cotton production

An attempt was made to test resource use efficiency of energy use in cotton production on the sample farms by computing MVP/MC ratio for positive and significant variables and results thereof are presented in Table 4.18.

Table 4.18 Comparison of marginal value products of various input with their price in cotton crop

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input $RsMJ^{-1}$	Price of input ($RsMJ^{-1}$)	MVP to price ratio
Human energy	1791.80	6.31	1.91	3.30
chemical energy	7093.34	-1.00	1.46	-0.68
Energy from seed	61.20	309.35	10.00	30.93

Note : Geometrical mean (Y) of yield was 24574.25 MJ and price of it was Rs.0.72 MJ

The Table 4.18 indicates that, MVP/MC ratio for human and seed energy was 3.30 and 30.93 , respectively which are greater than unity thereby indicating that human and seed energy was efficiently utilized for production of seed cotton. To maximise energy generation through seed cotton production there exist scope for further increase in use of human and seed energy beyond their existing geometric mean levels of 1791.80 MJ and

61.20 MJ, respectively. While , use of chemical energy needs to be curtailed by 7093.34 MJ from its existing geometric mean levels of use. This will help to improve efficiency of energy generation in seed cotton production.

4.4.4 Sugarcane

Estimates of Cobb-Douglas production function for sugarcane crop are furnished in Table 4.19.

Table 4.19 Estimate Cobb-Douglas production function for sugarcane crop

	Independent variable	Regression coefficient	standard error or Se(bi)	't' value or t (bi)
1	Human energy (Xi)	0.2998	0.0626	4.7884**
2	Bullock energy (X2)	0.1198	0.0682	1.7559***
3	Mechanical energy (X3)	-0.05234	0.0179	-2.9198**
4	Chemical energy (X4)	0.0779	0.0492	1.5847
5	Energy from seed (X5)	0.0561	0.0607	0.9235^{NS}

** Significant at 1 per cent level

*** Significant at 10 per cent level

Intercept (bo)	=	8.6238
R^2	=	0.676
'F' value	=	1.7498^{NS}
N	=	48
return to scale	=	0.5013

The Table 4.19 depicts that, the co-efficient of multiple determination i.e. R^2 value is 0.676. This indicates that contribution of human, bullock, mechanical and seed energy towards energy generation on cotton production farms was 68 per cent. From this it could be inferred that contribution of the independent variables selected in production function is substantial or Cobb-Douglas production function and specification of variables in the model is better fit.

The regression Co-efficients of all the independent variables excepting mechanical energy had expected sign i.e. positive. This shows that, all these variables had positive contribution towards generation of energy in the form of sugarcane. However, human and bullock energy contributed positively and significantly in sugarcane production contribution of chemical and seed energy in sugarcane production i.e. in energy form was positive but statistically it turned out to be non-significant.

The contribution of mechanical energy towards production of energy through sugarcane production was negatively significant .

4.4.4.1 **Resource Use Efficiency of Energy in Sugarcane Production**

The resource use efficiency of energy in sugarcane production was tested through MVP/MC ratio and results there of are depicted in the Table 4.20.

Table 4.20 Comparison of marginal value products of various input with their price in sugarcane crop

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input $RsMJ^{-1}$	Price of input ($RsMJ^{-1}$)	MVP to pric ratio
Human energy	2196.77	5.17	1.91	2.70
Bullock energy	1693.72	2.68	0.89	3.01
Mechanical energy	6865.19	-0.29	1.62	-0.18

Note : Geometrical mean (Y) of yield was 3778501.73 MJ and price of it was Rs.0.10 MJ

A glance on the Table 4.20 reveals that, MVP/MC ratio for input variables such as human and bullock energy was computed at 4.70 and 3.01 which are greater than unity. This implied that, use of human and bullock energy for sugarcane production in energy terms was efficient. Further, this indicates scope for expansion in use of human and bullock energy from their existing geometric mean levels of 2196.77 MJ and 1693.72 MJ, respectively. This will help in maximisation of energy production on sugarcane farms in the form of cane. However, further it was seen that, there is need to reduce energy consumption through mechanical energy from its existing geometric mean level of 6865.19 MJ.

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

In a present age nothing can be done without energy and the level of energy consumption has become status symbol of the society, firm or industry of the nation. The agriculture is the primary sector of Indian economy and one of the major claimantals of energy for various operations done on the field and beyond.

Agriculture is a user of energy. In agriculture level of production and productivity of the crops depends upon energy inputs consumed during various farm operations. The source of energy that go into the production of crops include material input such as seed, fertilizer, mannures, insecticides and mechanical energy along with human and bullock labour hours spent on executing the production process.

Agriculture becomes a major cause of reduction in energy supply where agricultural land is created by cutting down forests. The world does not have too much more land to exploit for agriculture operations simply because ecological and social cost of expanding crop area into existing forest lands would be unsustainable high. Therefore, a major focus has been on greater use of energy sources such as fertilizer, pesticides, water, machinery etc.

Agriculture is basically a seasonal industry and therefore, the demand for energy fluctuations depends on changes in seasons. During certain months of the year agriculture demands large quantities of energy for sowing, transplanting, harvesting, crushing etc. Despite the rapid increase in mechanization, several operations like digging, plantation weeding and harvesting are performed largely by manual workers. It is estimated that India has about 200 million agricultural workers providing 43000 tera joules (TJ) of human energy and 80 million draught animals providing 81000 TJ. of animal energy. In the aggregate these two sources provide 0.298 kw per ha (Kilowatt per ha) of farm power.

By realising an important role being played by an energy in various spheres of agriculture in general and crop production in particular, it is felt deemed to be undertaken the present with following specific objective.

2. To examine pattern of direct and indirect energy use in agriculture
3. To estimate energy use for major crops grown by the farmers
4. To workout per hector energy use in physical and monetary terms.
5. To estimate energy consumption in crop production.

To attain the objectives of the study for selection of the sample multistage stratified random sampling design was adopted. The present study was conducted in Marathwada region of the Maharashtra state. the Marathwada region is agroclimatically divided into two zones viz. (i) Central Maharashtra Plateau zone and (ii) Western Maharashtra dry zone. Parbhani district from former zone and Aurangabad district from later zone were selected to represent picture of the respective region. Nandapur, Babhulgaon, Atur and Ghaygaon from Parbhani, and Aurangabad districts respectively were selected purposively. Suitable sample size of the farmers will be selected randomly. The farmers will be classified into four size categories based on their land holdings.

The data were collected by cost accounting method with the help of specially designed pretested schedule. The data were analysed by employing simple statistical tools viz. means, frequencies, ratios, percentages etc. In addition to this functional analysis was also performed by fitting Cobb-Douglas production function to input and output data after conversion into energy form.

The results of an analysis of the data emanated are summerised here and conclusion thereof emerged are presented in the following section

Kharif Sorghum

Draft Power

The total draft power consumption for kharif sorghum at an overall level estimated at 3243.83MJha^{-1}. In this manual, bullock and machine power contributed 33.38, 46.50 and 20.12 per cent, respectively of the total energy consumption.

In monetary terms the total energy bill incurred on draft power for sorghum production was estimated at Rs. 4559.25. In the energy bill on account of manual, bullock and machine power accounted for 45.43, 29.43 and 25.13 per cent, respectively.

Total Energy

The total energy consumption in various forms for sorghum production at an overall level on an average was worked out to be 7085.82 MJha^{-1}. The highest energy consumption for sorghum production was recorded on marginal sized farms (i.e. 7374.94MJha^{-1}) and the lowest was on medium sized farm (6578.37 MJha^{-1}).

At an overall level, on an average per hectare total commercial and non commercial energy consumption was worked out to be 4018.99 (56.72 per cent) and 3066.83 (43.28 per cent), respectively.

Wheat

Draft Power

At an overall level on an average per hectare total draft power consumption for wheat crop was worked out to be 3548.86

MJ. In this contribution of manual, bullock and machine power was 28.60, 35.88 and 35.46 per cent of the total draft power consumption. In monetary terms the total energy bill of draft power was worked out to be Rs. 4036.77. In this share of human/manual, bullock and machine power was 48.21, 28.06 and 23.73 per cent respectively.

Total Energy

At an over all level, on an average per hectare total energy consumption was estimated at 9304.72 MJ.

The highest energy consumption for wheat production was observed on large sized farms (i.e. 11712.58 $MJha^{-1}$) and the lowest was on marginal sized farms i.e. 7507.29$MJha^{-1}$

At an overall level, in the total energy consumption share of the total commercial and non commercial energy into the total energy consumption worked out to be 73.66 and 26.34 per cent, respectively.

Cotton

Draft Power

At an overall level, on an average per hectare total draft power consumption for cotton production was estimated at 5264.94 $MJha^{-1}$. In this contribution of manual, bullock and machine power was 34.63, 43.40 and 22.57 per cent, respectively.

Total energy

At an overall level, on an average per hectare total energy consumption for cotton production was estimated at 11890.92 MJ. In this contribution of commercial and non commercial source of energy 59.99 and 40.01 per cent, respectively.

Sugarcane

Draft power

At an overall level, on an average per hectare total draft power consumption for sugarcane production was estimated at 7380.67 MJ. In this contribution of manual, bullock and machine power was worked out to be 29.76, 22.95 and 47.29 per cent, respectively.

In monetary terms, the total energy bill incurred on account of draft power was estimated at Rs. 6848.63. In this contribution of manual, bullock and machine power accounted for 61.37, 22.00 and 12.68 per cent respectively.

Total energy

At an overall level, on an average, the per hectare total energy consumption for sugarcane production was worked out to be 58775.30 MJ. In this share of total commercial and non commercial energy was 91.17 and 8.83 per cent, respectively.

On an average per hectare total energy consumption for sugarcane production was found to be the highest on marginal farms i.e. 63615.21 MJ and the lowest was on medium sized farms (50023.04).

Economics of energy use

Kharif sorghum

The per hectare total energy consumption and energy generation in kharif sorghum production was worked out to be 7083.82MJ and 59568.70 MJ. Input output ratio of energy consumption and energy generation in sorghum production was estimated at 8.41. While, energy bill incurred on sorghum production and energy generation thereof in monetary terms was to the tune of Rs. 6256.59 48 and Rs. 7442.48, respectively, input-output ratio of energy in monetary terms was computed at 1.19.

Wheat

The per hectare total energy consumption and energy generation in wheat production was estimated at 9304.72 MJ and 42385.80 MJ. Input output ratio of energy consumption and energy generation on wheat production was worked out to be 4.52 while, energy bill incurred on wheat production and energy generation thereof in monetary terms was to the tune of Rs. 6039.57 and Rs. 10670.82, respectively, input-output ratio of energy in monetary terms was estimated at 1.77.

Cotton

The per hectare total energy consumption and energy generation in cotton production was worked out to be 11890.92 MJ and 61397.50 MJ, respectively. Input-output ratio of energy consumption and energy generation in cotton production was estimated at 5.17. while, energy bill incurred on cotton production and energy generation thereof in monetary terms was to an extent of Rs. 11498.29 and Rs. 19165.20, respectively, input-output ratio of energy in monetary term was worked out to be 1.67.

Sugarcane

The per hectare energy consumption and energy generation in sugarcane production was estimated at 58775.30 MJ and 761653 MJ, respectively. Input-output ratio of energy consumption and energy generation in sugarcane production was worked out to be 11.51. While, energy bill incurred on sugarcane production and energy generation thereof in monetary terms was to the tune of Rs. 15626.42 and Rs. 53175.50 respectively, input-output ratio of energy in monetary terms was computed at 3.40.

Functional Analysis

Estimates of Cobb-Douglas production function for Kharif sorghum crop out of the seven variables selected three variable viz. human, fertilizer and organic manure energy had positive impact on production of energy in the form of sorghum grain and fodder. Variables such as bullock, mechanical, seed and irrigation energy exterted negative influence on production of kharif sorghum main and by produce in energy form, only human energy and energy in the form of fertilizer was statistically significant. MVP/MC ratio for the human energy and energy in the form of chemical fertilizer was estimated at 3.28 and 3.48. This implied that use of these two inputs for kharif sorghum production in energy form was efficient, therefore, there exist scope to expand further use of these inputs.

In case of wheat crop the input variables viz. bullock, mechanical, seed, fertilizer, and irrigation energy born positive. However, only contribution of bullock, seed and energy in the form of fertilizers was statistically significant. The MVP/MC ratio for bullock, seed, fertilizers was computed at 4.46, 12,.24 and 3.76 respectively, these are grater than unity. This implied that there exist scope for further increase in use of these input variables beyond their existing level of use

In case of cotton crop the regression coefficients for human, mechanical and seed energy born positive, however, contribution of human and seed energy was statistically significant. The MVP/MC ratio for human and seed energy was 3.30 and 30.93 respectively which are greater than unity. Therefore, exist scope for increase in use of human and seed energy beyond their existing level of use.

Incase of sugarcane impact of mechanical energy towards production of energy through sugarcane production was negatively significant. However, human and bullock energy contributed positively and significantly in sugarcane contribution. contribution of chemical and seed energy was positive but statistically it turned out to be non significant. The MVC/MC ratio for input variables such as human and bullock energy was computed at 2.70 and 3.01 respectively. Which are greater than unity. This indicates scope for expansion in use of human and bullock energy from their existing level. Further there is need to reduce energy consumption through mechanical energy from its existing level.

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APPENDIX

APPENDIX

Estimate of Cobb-Douglas production function for sugarcane crop

	Independent variable	Regression coefficient	standard error or SE(bi)	't' value or t (bi)
1	Human energy (Xi)	0.34633	0.06289	5.5177**
2	Bullock energy (X2)	0.03328	0.05466	0.60890 NS
3	Mechanical energy (X3)	-0.05311	0.01761	-3.0164**
4	Chemical energy (X4)	0.08705	0.04576	1.9023***
5	Energy from seed (X5)	0.08157	0.05867	1.3903 NS

** Significant at 1 per cent level

*** Significant at 10 per cent level

Intercept (bo) = 6.8689

R^2 = 0.684

'F' value = 18.2223**

N = 48

return to scale = 0.496

Comparison of marginal value products of various input with their price in sugarcane crop

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input Rs/MJ	Price of input (Rs/MJ)	MVP to price ratio
Human energy	2196.77	6.08	1.91	3.18
chemical energy	13018.57	0.26	0.19	1.37
Energy from seed	6865.19	-0.30	1.62	-0.19

Note : Geometrical mean (Y) of yield was 71415.42 kg and price of it was Rs.0.55/kg

Estimate of Cobb-Douglas production function for cotton crop

	Independent variable	Regression coefficient	standard error or Se(bi)	't' value or t (bi)
1	Human energy (X1)	0.18481	0.16404	1.12661 NS
2	Bullock energy (X2)	-0.02957	0.12003	-2.4638 NS
3	Mechanical energy (X3)	0.02348	0.04685	0.5012 NS
4	Chemical energy (X4)	-0.35628	0.12428	-2.8668**
5	Energy from seed (X5)	1.0473	0.21411	4.8913**

** Significant at 1 per cent level

Intercept (bo)	=	4.32471
R^2	=	0.388
'F' value	=	5.32053**
N	=	48
return to scale	=	0.8697

Comparison of marginal value products of various input with their price in cotton

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input Rs/MJ	Price of input (Rs/MJ)	MVP to price ratio
Human energy	7093.34	-0.90	1.46	-0.61
Energy from seed	61.20	303.56	10.00	30.36

Note : Geometrical mean (Y) of yield was 982.97 kg and price of it was Rs.18/kg

Estimate of Cobb-Douglas production function for kharif sorghum crop

	Independent variable	Regression coefficient	standard error or SE(bi)	't' value or t (bi)
1	Human energy (X1)	-0.19365	0.26454	-0.7321 [NS]
2	Bullock energy (X2)	0.81878	0.57904	1.4140 [NS]
3	Mechanical energy (X3)	0.55677	0.25456	2.1872*
4	Chemical energy (X4)	-0.28796	0.23124	-1.2953 [NS]
5	Energy from seed (X5)	-0.44905	0.23594	-1.9033***

** Significant at 5 per cent level

*** Significant at 10 per cent level

Intercept (bo) = 4.28684

R^2 = 0.466

'F' value = 4.54692**

N = 32

retum to scale = 0.445

Comparison of marginal value products of various input with their price in kharif sorghum

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input Rs/MJ	Price of input (Rs/MJ)	MVP to price ratio
Human energy	225.37	11.24	1.62	6.94
Energy from seed	87.06	23.39	4.08	5.73

Note : Geometrical mean (Y) of yield was 1571 kg and price of it was Rs.2.88/kg

Estimate of Cobb-Douglas production function for wheat crop

	Independent variable	Regression coefficient	standard error or SE(bi)	't' value or t (bi)
1	Human energy (X1)	-052997	0.1773	-2.9896**
2	Bullock energy (X2)	0.25815	0.11983	2.1543*
3	Mechanical energy (X3)	0.047485	0.04709	1.0083NS
4	Chemical energy (X4)	0.44555	0.10061	4.4286**
5	Energy from seed (X5)	0.47557	0.15927	2.9860**

* Significant at 5 per cent level

** Significant at 1 per cent level

Intercept (bo)	=	1.4883
R^2	=	0.439
'F' value	=	6.5731**
N	=	48
return to scale	=	0.697

Comparison of marginal value products of various input with their price in cotton

Independent variable with the unit	Geometrical mean of input (in respective unit)	MVP of the input Rs/MJ	Price of input (Rs/MJ)	MVP to price ratio
Human energy	1017.19	-4.88	-	2.55
Bullock energy	1273.39	1.91	0.89	2.15
Chemical energy	4530.36	0.95	0.19	5.29
Energy from seed	1252.02	3.59	0.61	5.88

Note : Geometrical mean (Y) of yield was 1414 kg and price of it was Rs.6.63/kg