EVALUATION OF ELECTRICAL ENERGY FOR IRRIGATION IN BANGLADESH AGRICULTURE

MD. HAFIZUDDIN

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY,

DACCA

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EVALUATION OF ELECTRICAL ENERGY FOR IRRIGATION IN BANGLADESH AGRICULTURE

A THESIS

BY

MD.HAFIZUDDIN

SUBMITTED TO

THE DEPARTMENT OF ELECTRICAL ENGINEERING, B.U.E.T., DACCA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (ELECTRICAL).

DEPARTMENT OF ELECTRICAL ENGINEERING

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY,

DACCA

JULY,1978.

C E R T I F I C A T E

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ABSTRACT

This work is concerned with the study and comparison of performances and the costs involved in irrigation systems using human muscle power, diesel power and electric power as well as combinations of these sources of energy. A survey was conducted to collect data on the various irrigation systems on two crops—rice and potato, at some selected areas of Bangladesh.

It was observed from the data on potato-irrigation that with human muscle power, average water utilized and crop production per acre are 77.6% and 92.2% respectively, but the irrigation cost is 120% of those for irrigation with diesel power. In the case of irrigation for HYV rice, the figures on average water utilized and per acre crop production decreased to 38% and 73% respectively, while the irrigation cost increased to 188%. It was also observed that with diesel power irrigation, at subsidized rates the total irrigation cost is about double of that for electric power irrigation. The average figures on water actually utilized per acre and crop-production per acre are somewhat more with electric power irrigation.

An energy model for agricultural units for Bangladesh, proposed earlier by some research workers in this area, was scrutinized and some modifications suggested. With various parameters and assumptions imposed on the model, and with farm area as the variable, farm surplus income

was calculated. Significant conclusions regarding farm surplus income--which ultimately contributes to "quality of life" of the agriculturists--were drawn depending on the sources of energy for irrigation, which has been proved to be the most important energy - related input that contributes to farm income with High Yielding Variety rice. Applying suitable and practical constraints holding for agricultural areas studied, a simple linear programming approach has been attemped to determine a practical optimum combination of various sources of irrigation energy.

Relative merits and demerits of diesel and electric irrigation, specially the question of service interruptions have been critically examined, and suggestions have been made for the progress of electrical irrigation which is likely to have the greatest impact on rural electrification programmes of Bangladesh.

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Writer.

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CHAPTER - 1.

INTRODUCTION

1.1 GENERAL

Bangladesh is a country with a population of nearly 80 million confined within an area of 14,122 Km^2, giving an average population density of 531 persons per Km^2 a figure amongst the highest in the world, About 75% of the population are cultivators. The country has a rapid increase in population-3%[1] per annum. There are 7 million small farmers possessing a farm area average 3 acres in size. About half have less than 2 acres and comprise 15% of the cultivated land area. Due to abysmal poverty, 2-3%[2] small farmers become landless a year. The country has a very low per capita income (of about 70 \$ per year.) and extreme poverty is the lot of vast majority of the population. Agriculture dominates the economy of the country. Agriculture output accounts for about 55 %[3] of the G.D.P. There is about 11% waste land. That leaves only about two-thrids of the area which is cultivable. Average food-grain deficit of the country is nearly 2.0 million tons a year.

1.2 NEED OF INCREASED AGRICULTURAL PRODUCTION

Near about 90% people of Bangladesh live in rural areas and depend on agriculture, carried out mostly in crude and primitive methods, as the only source of livelihood. Economic development of the country in a real sense could not be accomplished without effecting revolutionary changes in rural economy. An increased agricultural production is one of the important steps for improvement of the rural population.

Bangladesh has a high potential for increased agricultural production. Nature offers Bangladesh substantial agriculture resources. The soils are fairly productive and the climate is suited for year-round production. Although natural conditions are not optimal, right kind of technological advances may contribute significantly to increased production.

1.2.1 METHODS OF INCREASING PRODUCTION

There are two methods of increasing agricultural production, namely—extensive cultivation and intensive cultivation. The scope of extensive cultivation is rather limited, becuase, very little additional land is available for new cultivation. So, increase of per acre yield through intensive cultivation is the only alternative solution to fall back upon to meet the serious challenge of yearly food deficit in the country and for saving valuable foreign exchange.

1.2.2 BENIFITS OF FARM MECHANIZATION

Farm mechanisation is one of the important measures for increasing agricultural production. Farm mechanisation helps in speedy preparation of land and provides adequate supply of water and many such other advantages. Our farmers, although mostly illiterate, have established their general receptiveness to improved new technology when its usefulness is ably demonstrated. Provided with farm machineries, the farmers become as powerful as factory workers, their capacity for work increases by many times and their output of work becomes comparatively very high.

1.3. IMPORTANCE OF WATER

1.3.1 AGRICULTURE PROBLEMS

Bangladesh's agriculture is governed by the seasonal aspect. Natural precipitation is immense, but there are great variations in its seasonal and regional distribution. Over 80% [2] of the total rainfall occurs during five months from June-October and the amount of rainfall in the 7 months from April-October is about 95% of the annual total. Hence during the Rabi Season for five months from November-March, the rainfall is only 5% of the annual total. This amount is inadequate for the crop requirements during the Rabi season and largely accounts for the Rabi crop production.

In the wet season, about 70% of the flat lands are inundated by rain or river water and the only crop that can be grown on the inundated lands is rice. The growing periods of three main rice-crops-namely—Aus, Aman and Bora correspond respectively to three main seasons, namely — the hot summer months with norwesters, the rainy season and the dry winter. But even for the [redacted] main crop of Aman rice which is grown during monsoon, drought at critical periods very often causes low yield or failure. In the dry winter season, out of a total cultivable land area of 35.4 million acres, only some 7[4] million acres could be cultivated for a second crop. The major portion could not be brought under cultivation for a second crop due to lack of proper moisture content.

1.3.2 ROLE OF IRRIGATION

In view of the above facts, irrigation, both during mansoon and dry seasons, is of prime importance for the desired food production. Irrigation facilities will not only ensure the production of existing Aus and Aman season, but shall also bring more areas under food production during the Rabi season.

Five factors are essential for the increased production, namely—Availability of fund, good varieties of seeds, improved fertilizers, proper plant protection measures and Irrigation. The most vital factor contributing to high yield is the adequate and timely availability of water.

Williams and Chancellor[5] estimated crop-yield losses due to reductions in energy-related inputs, namely—fuel energy for production activities; tillage tractor power, fertilizer use, harvester capacity and irrigation water. Upon analysis of linear functions based on statistical data of crop productions in California, U.S.A, they established the fact that irrigation water reductions—had the greatest effect upon the crop-production, compared with the other inputs.

The irrigation water is necessary not only for growing crops, but also for getting a stable production. The enhanced supply of irrigation water enables improvement in cropping patterns and cropping intensity and raising the land productivity. Successful steps for irrigation can enable the farmers to undertake high yielding varieties which cannot be grown otherwise.

1.3.3 COST OF IRRIGATION

Only supply of adequate water to the farm is not the overall criterion for successful irrigation. But the supply should be in an economic way. So that cost/benefit ratio becomes minimum. Hence for economic feasibility of any irrigation scheme, it is necessary to find way to utilize adequate water with least expenditure of money (or energy). This will also attract the poor farmers to adopt modern methods of irrigation, for utilizing adequate water at minimum cost and to expand the irrigated area.

1.4 IMPORTANCE OF ENERGY STUDY

Optimum efficiency of any industrial production unit can be explained, in terms of energy, as the maximum energy output with the minimum energy input. Similarly, for an efficient irrigation scheme, the energy input to the process should be minimum. Also the cost connected to a particular source of energy, have a decisive bearing on the choice of the energy. Hence energy study is very much necessary to provide economic irrigation resulting in economic food production, and surplus income.

1.4.1 ENERGY RESOURCES FOR IRRIGATION

In our country, the total irrigated area is only 12% of the net croped land. And the area irrigated by traditional methods using human muscular energy is about 45.3% (8) of total area irrigated and which has reached almost saturation point.

Modern methods usedpower-pumps, deep tube wells, shallow tube wells and low-lift pumps which are powered mainly by Diesel-engines, whose cost of operation is increasing gradually. In contrast, the consumption of elecrical energy for irrigation-pumping is considerably low, is thus more economic.

1.5 OBJECT OF THE PRESENT STUDY

The objective of the research is to study the performances & costs of the various irrigation systems presently adopted, with various energy sources(i.e. human muscular energy, diesel and electric), it is considered desirable to compare them to determine whether it would be more economic and efficient to use electrical energy for irrigation for agricultural conditions with its specific features, constraints, limilations, and cost structures existing in our country.

Special attention has also been given to an evaluation of the technical problems involved in the operation of electrical irrigation systems in rural areas.

CHAPTER-II

ENERGY MODEL FOR AN AGRICULTURAL UNIT

2.1 INTRODUCTION

The standard of living or in a more general and over-all approach, the quality of life of a community or group of people is measured by the quantity of total energy used per capita in that community. For countries where networks for the distribution of energy is limited to only selected urban and suburban areas and where vast rural areas depend for energy on human and animal muscle power and farm and animal waste, it is not yet possible to derive reliable figures for 'energy per capita'. It is not only the quantity of electrical energy consumed per person in the fortunate electrified areas, but the total energy produced and obtained from all possible sources available and existing in the particular region or country that can be valid index in this connection.

Identification and categorization of the energy produced and utilized in various forms in rural area, can lead to develop a quantitative dynamic model for the flow of energy to facilitate study of agriculture activities.

2.2 ENERGY RESOURCES IN THE AGRICULTURAL FARM

All the various activities in the farm(including the domestic life of the agricultural family depending for its livelihood, and other necessities) can be broken up into two categories:-

i) Energy that is applied for obtaining the finished products of the farm viz-food crops and the cash crops and

ii) Energy that is consumed for making life possible in the farm-unit.

2.2.1 ANIMAL ENERGY

In typical non-mechanized farms in Bangladesh, the primary and major source of energy is that provided by animals e.g.Bullocks and Water-Buffaloes. In the absence of reliable data regarding the power provided by a bullock, in terms of horsepower or Killowatt,the energy output of Bullock working for an hour (Bullock-hour) may be taken as a unit. It is found that out of 8760 hours in a year,a Bullock cannot be effectively used for more than 1500 to 1600 hours. For the purpose of giving a numerical perspective, it may be stated that various estimates place the Bullock power as between ¼ horsepower to ½ horse power, continuous.

2.2.2 UNIT OF ANIMAL ENERGY

In order to evaluate the effectiveness of animals as a source of power to a farm as a closed (or quasiclosed) system, of production, a realistic unit of animal energy would be Bullock-hour per unit of land per year. Since also the ultimate aim of evaluating farm activities is to establish the effectiveness of the farming unit as a means of sustaining a family with its various needs, it is suggested that a more specific judgement would be possible if the animal energy applied to the farm is further modified by the number of personsdepending on the farm for their physical needs. The unit may be taken as "Bullock-hour/unit of land (acre)/Capita/year".(7)

Animal energy is applied to the agricultural unit for the following purposes:-

i) Ploughing

ii) Some irrigation(very rarely)

iii) Traction for marketting the products of the unit i.e. the cash crop and the food-crop

iv) Threshing.

2.2.3 ENERGY FEED BACK

It was observed for the purpose of setting up an energy model, that, in order to obtain mechanical energy output from farm animals, energy must also be applied to them, and the input, in this case is derived, by and large, from the outputs of the farm itself, with perhaps some supplementary animal food purchased from the cash income from the same farm. The efficiency of farm animals of Bangladesh as energy conversion devices, with type of food provided to them—is not yet known. Existence of several feed back loops in the overall energy model must thus be recognized.[7]

2.2.4 HUMAN ENERGY

Although it is possible to try to estimate, for the setting up of energy models in a farm—the efficiency of human being as energy conversion units, the attempt may not be worth while. The reason is obvious : it is precisely for replacing human muscle power that animals are introduced. However, considerable amounts of human power is used in the farm, if not for traction, then for irrigation, sowing, planting, weeding, harvesting, threshing, winnowing etc.

The application of human labour in the farm is so varied in type that it is difficult to quantify it; but, as raw power, it supplements to a major extent, animal energy in the farm. It is important to recognize that human labour in the farm is vitally important for a farm more as the concretization of skill and judgement then as raw power— significant though the later may be, considered even as animals muscle power. However for irrigation by human muscle power, it is possible to estimate realistic ranges of human muscle power in comparison with machine power, derived from either diesel engines or electric motors.

2.2.5 OTHER FORMS OF ENERGY IN THE FARM

For the setting up of an over-all energy model for agricultural units, a few other types of energy directly or indirectly active for crop growing must also be taken into account. A preliminary list for modelling purposes would include : Solar energy (providing heat and chemical energy);Chemical energy provided by animal waste which in turn is a partial output from food provided to farm animals; chemical energy provided by artificial fertilizers which are, in general, energy—intensive products of industry; rain water with stored potential energy deriving ultimately from solar energy; irrigation water provided by either muscle power or by machine power (from fossil fuel or electricity) or a combination of these. The existence of energy feedback loops at various stages can also be identified.

2.2.5.1 SOLAR ENERGY

It is well known that a great amount of energy falls on the earth from the sun : estimated to be around 900 H.P. per acre. It the last analysis all action—human and otherwise, results from this energy. Out of this, about only 1% is received by plants which they transform by photosynthesis to chemical energy. Finally only 0.2 parts per million become available as food for man and animals.

2.2.5.2 CHEMICAL ENERGY

The role of chemical energy at various stages in the operation and maintenance of the agricultural unit is evident. From the point of view of setting up of energy models for the agricultural unit, this form of energy attains its specific significance when the total muscle power — both human and animal, applied to the farm is considered as the output of certain energy conversion devices.

A number of workers in the fields of Energetics have derived figures for the efficiencies of horses and men as machine as—between 20-30%. In such calculation, metabolic rates of bodies and periods of rest have been considered. Some of theother important variables in these calculations are the digestibility of the food and the environmental temperature — the later, in view of the fact that metabolic rates in bodies is distinctly a function of temperature, and rest periods required for recuperation after hard labour are also temperature—dependant.

In the specific conditions of Bangladesh, the types and quantities of food—both in respect of digestibility, and carbohydrate or starch content—available to man and farm animals, are significantly different from those on wh-which the efficiency figures quoted above are based. For instance, in most farm areas in the Eastern region of Bangladesh, Water hyacinth plant, with a high percentage of water-content, now constitutes a considerable proportion of animal feed. The reason is not only that it is abundant in those area, but it is much cheaper than the food-crop, or even the farm-waste obtained from the agricultural unit.

With the types of animal food discussed above, and the only kind of farm-animal used in Bangladesh being Bullocks, it cannot be estimated at present, what range of efficiency for Bullocks as machine would be arrived at. The need for research, encompassing the fields of physiology, chemistry, physics and engineering is self evident in this area.

However, as human labour in the farm is more important in conjuction with skill, judgement, management, optitude and supervision, rather than as direct muscle power, the efficiency figures for a human being as a machine is not expected to be very critical. On the other hand, the chemical energy in artificial fertilizers can be easily seen to be of great significance : the energy needed from outside sources for the manufacture of these fertilizers are also to be considered for making the model to achieve a greater degree of precision. The loop in terms of energy, when animal waste is used as fertilizer, in addition to artificial fertilizer,purchased from the cash income of the farm is also to be taken into account. Also animal waste—supplementing farm—waste— when used as fuel for domestic—cooking can be considered to contribute directly not only to the main tenance of human life in the agricultural unit, but also to the determination, to a large extent, of the quality of life in that unit.

2.3 THE ENERGY MODEL, WITH SOME FEEDBACK LOOPS

With the above comments, a qualitative model as complete and realistic as possible with facts known about Bangladesh has been suggested with the forward and backward flow of energy, as seen in figure-1. While, in setting up such a model, it was remembered that energy including all losses, must balance, many facts are either not known or cannot be evaluated in terms of numerical quantities. It may be stated that the aim of agricultural units is to produce its edible, sallable or inflammable outputs, so as to secure a basic standard of living, as a minimum goal. This standard of living is commonly measured in terms of income per capita of the human beings subsisting on a particular unit. Another way of looking at the output of the unit is to determine "how much energy could have been bought (from sources outside of the unit) from the net produce of the farm, after all the energies in various forms inside the farm have been accounted for." As is also well known, energy consumption per capita is an index of the standard of living in a community. Some of the energy purchasing capability of an agricultural unit, could be reinvested in the farm—

for the purposes of artificial irrigation by power pumps, or chemical fertilizers, or even better food for the animals, etc., in an ideal situation, the farm income per capita (or energy purchasing capabilities) should increase in a faster rate than the rate of re-investment. Saturation however, would be reached at some stage, but the usefulness of the model would lie, on the one hand, in deciding the most suitable point of injection of energy, and on the other, in raising the point (or standard) of living where saturation is reached. However, it is not difficult to realize that the quality of life is not the same as "Standard of life," although the former, to a large extent is dependant on the later. As there is no agreed unit for the measurement of "quality of life," —the model can, from that ulterion concept, be left open-ended.

2.4 ENERGY MODEL FOR OPTIMIZATION OF IRRIGATION METHODS

The ultimate aim in analysing the efficiency of any industrial production unit— whether with the help of models or by any other means, is to secure optimization of the entire process, so as to acheive, in terms of energy, the maximum energy purchasing capability with the minimum application of energy. The same criterion ought to be applicable to agricultural units.

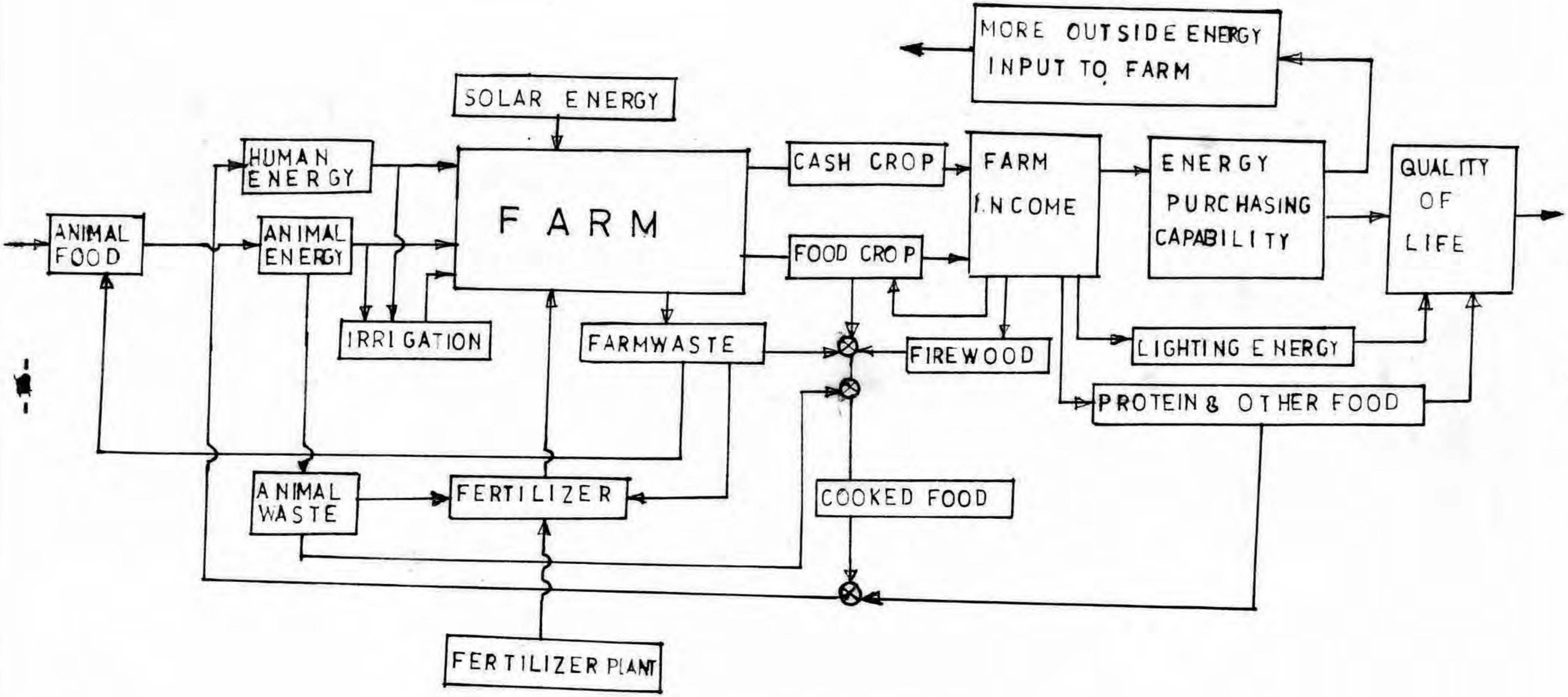
In the field of irrigation, a huge number of pumps are being used. The units require capital, spare parts, fuels, at the expense of foreign exhange. Side by side, there is a proposal from many quarters to use indigenous methods of irrigation by local donga, "dones" etc. in place of mechanical units. Analysis shows, however, efficiently used, human energy cannot replace mechanical energy. Considering all aspects, technical and otherwise, a balance may, and should be found out between the mechanical devices and human energy. It is precisely in an effort to find out the balance point that the approach through energy modelling may be of greatest use towards the optimising of the agricultural methods prevalent in Bangladesh farm. It may not be difficult to set reliable and realistic energy models for the mechanical energy devices.

2.5 NUMERICAL DATA FOR THE MODEL

The energy model can be made a precise and useful tool with appropriate quantitative data inserted at the various stages. With various relevant data used at appropriate points in the model, it will be possible to optimize the output of agricultural units, either in terms of income/capita or energy purchasing capability/capita. The latter can, in turn be invested to achieve more farm output and, therefore better quality of life,--which includes, better food and clothing, education, health, and other amenities of life, including, use of more energy, ensuring more comfort and enjoyment.

2.5.1 PRESENT STUDY

Present study is an attempt to collect the numerical data on irrigation methods with various energy sources, namely—human muscle power, diesel and electric—to be fed in the energy model.



ENERGY MODEL FOR AN AGRIGUTURAL UNIT

FIG-1

CHAPTER-III

IRRIGATION METHODS

3.1 There are various methods for lifting irrigation water to the field. They can be classified into two groups:-

A) Traditional methods and

B) Modern methods.

Traditional methods use human or animal muscular energy, to operate devices of various kinds. Area irrigated by Traditional methods in our country is 45.3%[8] of total area irrigated.

3.1.1 SWINGING BASKET :

It is used to irrigate lands near low-lying water bodies and parennial rivers. It is triangular or rectangular in shape, generally made of tin. Two men are required to lift water by swinging the basket. There are different sizes of swinging baskets. Number of operation varies from 10-16 times per minute depending on the size, level of water and capacity of men. The capacity varies from 2-3 gallons. Average discharge is about 2,500 gallons per hour.

It is used for small-scale irrigation. 31.2% of total agricultural land of our country is irrigated by this method.[8]

3.1.2 D O O N :

It is made up of three pieces of wood connected in a groove-shape. It may be also made of steel. Only one man is required to lift water. The length varies from 8-12 feet.

The depth of the groove varies from 9-12 inches. Its optimum lift is less than that of the swinging basket. Number of operation varies from 4-6 times per minute. Average capacity is 10 gallons and average discharge is 2,000 gallons per hour. 27% of total agricultural land of our country is irrigated by this method.(8)

Photo- Doon used to lift water from a Shallow Stream.

3.1.3 WATER-WHEEL:

One or two bullocks rotate in a circular path and turn the water-wheel. The water-wheel is placed in the low-lying water-bodies, where surface water is available, otherwise it is placed in a well.

The bullocks may be blind-folded and left unattended.

It is not generally used in our country.

Photo-Water Wheel turned by Bullocks.

3.2 MODERN METHODS:

Modern methods in our country use mainly mechanical power through diesel engines, electric motors at present are used to a small extent.

3.2.1 DEEP TUBE WELL:

Generally 2 cusec, 6" diameter size deep tube wells are in operation in our country. Average depth is 250'. It is operated by deep tube well turbine pumps and sunk by power rigs. Although it is designed to command an area of 300 acres, actual command area is only 50 acres[9]. Cost/unit is over Tk. 1,25,000/-. The subsidy borne by the government is Tk. 15,600/- per unit per anum.

Photo-Irrigation by Deep Tube Well.

A large group of farmers, usually numbering 40, is to be served by single unit. So it has got institutional problems as management is difficult.

About 7,000[10] deep tube wells are in operation in our country to irrigate 340,000 acres of land.

3.2.2 SHALLOW TUBE WELL:

4" diameter, ¼ to 1 cusec capacity shallow tube wells are in operation in our country. Average depth is 150ft. It is operated by centrifugal pumps and sunk by labour intensive percussion method. It can be constructed locally. Cost/unit is — Tk. 16,500/- . It can commnand an area of about 10-15 acres/cusec.

It requires smaller group of farmers—about five on the average. This reduces the institutional problems of management.

About 6,000[(10)] shallow tube wells are in operation in our country to irrigate 60,000 acres of land.

It is considered to be the most suitable for ground-water development as the water levels are not two deep and losses in the canal conveyance is low.

3.2.3 LOW-LIFT PUMP:

Small capacity (1-2 cusec) low lift pumps are used to raise water from parennial streams and ponds to irrigate fields. It is operated by centrifugal pumps. It can command an area of 7-12 acres/cusec.[(11)] It can be easily fielded and operated. It is light enough to be transported easily for short irrigation in different places during the day.

About 4000[12] pumps of 1 cusec capacity and 25,000 pumps of 2-cusec capacity are in operation in our country to cover an irrigated area of 1,40,000 acres.

It is considered to be the most effective irrigation effort in Bangladesh, provided, surface water is available.

3.2.4 <u>HAND PUMP:</u>

Manually operated hand pumps is sometimes used to irrigate fields around it with the least amount of losses. It is smaller in capacity and costs about Tk. 1000/00. There are no operating costs to the farmer except his own labour. The equipment is available in plenty with iron dealers. Hand pump can be fabricated at the village level and fixed for lifting water. It is mainly used for the supply of safe drinking water in rural areas.

CHAPTER-IV

DATA COLLECTION

4.1 METHODOLOGY

To compare the performances of various irrigation systems(i.e. Human muscular energy, diesel and electrical), it was proposed to collect data for different crops at different areas of the country. A questionnaire was prepared for this which contained items like :- (See Appendix)

i) INDIVIDUAL FAMILY :- Family members, annual income, no. of working animals, no. of agricultural implements, total land, farm crop production etc.

ii) LAND INFORMATION:- Irrigated land area, land area lacking irrigation, source of water, crop production of the irrigated land etc.

iii) ENERGY INFORMATION:- Type and capacity of the item used, Machine size, pump size, pipe diameter, number of men required, number of days of irrigation per season, number of hours of operation per month, quantity of water utilized per year, energy used per year etc.

iv) COST INFORMATION:- Direct cost (wages), indirect cost and total cost.

iv) EFFICIENCY INFORMATION:- Individual remark on the quantity of water supply and efficiency of irrigation systems.

4.2 VARIABLES OF THE STUDY

Data were collected at different areas of the country to consider the following variables:-

i) S O I L :- As the crop production depends maily on the fertility of soil, which varies with localities. Also the moisture content of soil which measures the requireement of irrigation water—varies for different localities. There may be lands which contain sufficient moisture content and irrigation water requirement is less. Some lands may depend fully on irrigation water.

ii) C R O PS:- Different crops require different quantity of irrigation water. And of all crops rice (which is the main food-crop of the country) is the most dependant on irrigation. However, survey was limited to the high yielding variety, which is mostly dependant on irrigation water and requires large supply of water for higher yield.

For a comparison, potato(which can be taken as substitute of rice) was considered, which is also dependant on irrigation water.

iii) SYSTEM OF IRRIGATION:- To compare the various systems of irrigation, it was necessary to select areas where two or more methods were adopted.

4.3 POTATO IRRIGATION

For collecting data on Potato—irrigation, the locality was slected at Munshiganj, which is the highest yielding area of potato of the country.

4.3.1 POTATO IRRIGATION BY HUMAN MUSCULAR ENERGY

Potato irrigation by human muscular energy used single or double unit swinging busket to lift water from the nearby river. Sample data were compiled and are shown in Table-I.

4.3.2 POTATO IRRIGATION BY MACHINE POWER

In the same locality, irrigation water was also provided to some fields, by a ½ cusec low-lift pump, lifting water from the river. The pump was owned by a farmer of the same locality and used on hire-basis. Sample data, were compiled, and are shown in Table-2.

4.4 HYV IRRIGATION

It was proposed to collect data on high yielding variety of rice irrigation at different areas of the country to cover all the methods i.e. Muscular power, diesel and electric.

4.4.1 HYV IRRIGATION BY MUSCULAR POWER

Data using different items e.g. swinging busket, "done" etc. were taken at different areas. Sample data were compiled, and are given in Table-3.

4.4.2 HYV IRRIGATION BY MACHINE POWER

Data were taken on high yeilding variety irrigation by machine power at two different places to compare this system with those of human muscular power and Electrical (i) One used a 2-cusec low lift pump (hired) and (ii) the other a 2-cusec low lift pump (subsidized) sample data, were compiled and are given in Tables 4 & 5.

4.4.3 HYV IRRIGATION BY ELECTRIC POWER

Data were collected on a 15 hp electric motor used to run a 2-cusec low-lift pump to lift water from a nearby canal. Sample data are given in Table-6.

TABLE-1

POTATO IRRIGATION BY HUMAN MUSCLE POWER

SL. NO.	IRRIGATED LAND AREA (ACRES)	CAPACITY OF THE SW BASKET (GLN)	NO OF MEN REQUIRED *	HOUR OF OPERATION	ENERGY USED (MAN-HR.)	QUANTITY OF WATER UTILIZED (GLN) **	TOTAL IRRIGATION COST (TK.)	CROP PRODUCTION (MD)	CROP VALUE (TK.) ***	IRRIGATION COST AS % OF CROP VALUE %
1	0.48	2.5	6	10	60	22,500	72	75	1,875	3.84
2	0.50	2.5	6	10	60	22,500	75	100	2,500	3.00
3	0.56	2.5	6	12	72	27,000	90	90	2,250	4.00
4	0.68	2.5	6	12	72	27,000	110	110	2,650	4.15
5	0.80	2.5	6	16	96	36,000	120	120	3,000	4.00
6	0.80	2.5	8	18	144	40,500	140	100	2,500	5.60
7	1.00	2.5	6	22	132	49,500	140	200	5,000	2.80
8	1.20	2.5	6	24	144	54,000	180	180	4,500	4.00
9	1.60	2.5	6	32	192	72,00	240	280	7,000	3.40
10	3.20	2.5	6	65	390	146,250	500	450	11,250	4.44

* No. of persons operating basket - 4.

No. of persons managing flow - 2.

** At the rate of 2,250 Gln/Hour.

*** Market price - Tk. 25/md.

TABLE-2

POTATO IRRIGATION BY DIESEL POWER (HIRED)

SL. NO.	IRRIGATED LAND AREA (ACRES)	MACHINE SIZE (HP)	PUMP SIZE (CUSEC)	HOUR OF OPERATION	ENERGY USED (HP-HR)	QUANTITY OF WATER UTILIZED (GLN) *	TOTAL IRRIGATION COST (TK.)	CROP PRODUCTION (MD.)	CROP VALUE (TK.)	IRRIGATION COST AS % OF CROP VALUE %
1	0.48	7	½	3	21	33,696	70	96	2,400	2.90
2	0.8	7	½	4	28	44,928	100	150	3,750	2.67
3	0.8	7	½	4	28	44,928	90	150	3,750	2.40
4	0.8	7	½	4.5	31.5	50,544	110	130	3,250	3.38
5	1.2	7	½	6	42	67,392	150	225	5,625	2.67
6	1.6	7	½	8	56	89,856	200	300	7,500	2.67
7	1.6	7	½	9	63	101,088	210	350	8,750	2.40
8	3.2	7	½	15	105	168,480	380	600	15,000	2.53
9	3.2	7	½	16	112	179,712	400	600	15,000	2.67
10	3.2	7	½	17	119	190,934	390	700	17,500	2.23

* At the rate of 11,232 Gal/hr.

TABLE-3

HYV IRRIGATION(1) BY HUMAN MUSCLE POWER

SL. NO.	IRRIGATED LAND AREA (ACRE)	CAP OF THE ITEM USED (GLN) *	NO OF MEN REQUIRED	HOUR OF OPERATION	ENERGY USED (MAN-HR.)	QUANTITY OF WATER UTILIZED (GLN X10^3)	CROP PRODUCTION (MD)	TOTAL IRRIGATION COST (TK) ***	CROP VALUE (TK. ****	IRRIGATION AS A % OF CROP VALUE %
1	0.25	2.5X2	6	75	450	337.5	15	250	1,050	23.80
2	0.32	2.5X2	6	100	600	450.0	20	350	1,400	25,00
3	0.40	2.0X2	6	150	900	600.0	25	500	1,750	28.57
4	0.50	2.5X2	6	140	840	630.0	40	450	2,800	16.07
5	0.80	2.5X2	6	200	1200	900.0	50	700	3,500	20.00
6	0.80	2.5X2	8	180	1440	810.0	55	900	4,050	22.22
7	1.00	10**	1	480	480	1,152.0	80	400	5,600	7.14
8	1.00	2.5X2	6	225	1,350	1,014.0	75	950	5,250	18.10
9	1.20	2.5X2	6	330	1,980	1,485.0	90	1200	6,300	19.05
10	1.60	2.5X2	6	450	2,700	2,025.0	140	1650	9,800	16.84

* Two units of swinging buskets of 2.5 Gln. capacity were used.

** One Done was used

*** Cost of labour = Tk. 5/per day.

**** Market price = Tk. 70/Md.

TABLE-4

HYV IRRIGATION (I) BY DIESEL POWER (HIRED)

SL. NO.	IRRIGATED LAND AREA (ACRE)	MACHINE SIZE (HP)	PUMP SIZE (CUSEC)	HOUR OF OPERATION	ENERGY USED (HP-HR).	QUANTITY OF WATER UTILIZED (GLNX10³) *	TOTAL IRRIGATION COST (TK.) **	CROP PRODUCTION (MD)	CROP VALUE (TK.)	IRRIGATION COST AS A % OF CROP VALUE %
1	0.28	16	2	15	240	674.0	100	20	1,400	7.14
2	0.32	16	2	23	368	1,033.0	160	24	1,680	9.52
3	0.40	16	2	30	480	1,348.0	200	40	2,800	7.14
4	0.56	16	2	54	864	2,426.0	280	50	3,500	8.00
5	0.80	16	2	45	720	2,022.0	400	90	6,300	6.35
6	0.80	16	2	57	912	2,561.0	420	80	5,600	7.50
7	1.60	16	2	90	1,440	3,844.0	800	180	12,600	6.35
8	1.60	16	2	120	1,920	5,391.0	850	160	11,200	7.59
9	2.00	16	2	142	2,272	6,380.0	1000	200	14,000	7.14
10	2.40	16	2	150	2,400	6,739.0	1200	270	18,900	6.35

* At the rate of 44,928 Gln/hour.

** Total irrigation cost includes-Cost of fuel (Tk.10/per Gallon), labour cost (Tk. 5/per day), Rental charge of machine etc.

TABLE - 5

HYV IRRIGATION (II) BY ELECTRIC POWER (SUBSIDIZED)

SL. NO.	IRRIGATED LAND AREA (ACRES)	ELECTRICAL MOTOR SIZE (HP)	PUMP SIZE (CUSEC)	HOUR OF OPERATION	ENERGY USED (HP-HR)	QUANTITY OF WATER UTILIZED (GAL X 10^3)	CROP PRODUCTION (MD)	CROP VALUE (TK) *	TOTAL IRRIGATION COST (TK.) **	ELECTRICAL ENERGY COST (TK) ***	[illegible] TION COST AS A % OF CROP VALUE %
1	0.5	15	2	22	330	976 £	24	1,440	80	49.00	5.56
2	0.7	15	2	30	450	1,330	37	2,220	118	67.00	5.32
3	1.0	15	2	40	600	1,772	42	2,520	150	90.00	5.95
4	1.4	15	2	54	810	2,396	50	3,000	216	120.00	7.20
5	1.6	15	2	64	960	2,838	70	4,200	240	143.50	5.71
6	2.0	15	2	80	1,200	3,544	95	5,700	300	179.00	5.26
7	2.4	15	2	96	1,440	4,255	100	6,000	360	215.00	6.00
8	2.8	15	2	112	1,680	4,960	125	7,500	420	250.00	6.67
9	3.0	15	2	120	1,800	5,320	125	7.500	450	268.00	6.00
10	3.2	15	2	128	1,920	5,675	140	8,400	480	286.00	6.96

* Market price @ Tk. 60/-per Md.

** Total irrigation cost @ Tk.150/acre includes-Security deposit. (Tk. 100/-)rental, (Tk. 600), Operation charge(Tk. 750/-) , Labour cost payment of Guard & Machine-man, repairing cost extra-payment to persons involved over the normal.

*** At the rate of Tk. 0.20 per Kwhr.

TABLE-6

HYV IRRIGATION(II) BY DIESEL POWER(SUBSIDISED)

SL. NO.	IRRIGATED LAND AREA (ACRES)	MACHINE SIZE (HP)	PUMP SIZE (CU SEC)	HOUR OF OPERATION	ENERGY USED (HP-HR)	QUANTITY OF WATER UTILIZED ($GLNX10^3$)	CROP PRODUCTION (MD.)	CROP VALUE (TK.)	TOTAL IRRIGATION COST (TK) *	COST OF DIESEL (TK) **	IRRIGATION COST OF AS A % OF CROP VALUE %
1	0.4	17	2	12	204	532	18	1,080	136	60	12.59
2	0.7	17	2	22	374	976	25	1,500	230	110	15.33
3	1.0	17	2	32	544	1,418	40	2,400	300	160	12.50
4	1.2	17	2	38	646	1,685	58	3,480	360	190	10.34
5	1.6	17	2	52	884	2,300	65	3,900	480	260	12.30
6	1,8	17	2	58	988	2,576	65	3,900	540	290	13.85
7	2.0	17	2	64	1,090	2,840	90	5,400	600	320	11.11
8	2.4	17	2	76	1.292	3,370	95	5,700	720	380	12.63
9	3.0	17	2	96	1.632	4,260	110	6,600	900	480	13.64
10	3.2	17	2	100	1,700	4,430	142	8,520	970	500	11.38

* Total irrigation cost includes-Security deposit (Tk. 100/-per m/c).Rental (Tk. 600/-per m/C). Repairing cost (Tk. 300/-per m/c), Diesel cost labour cost, payment of guard and machine-man.

** Diesel cost = Tk.10/-per gallon.

ENERGY USED vs WATER UTILIZED (POTATO)

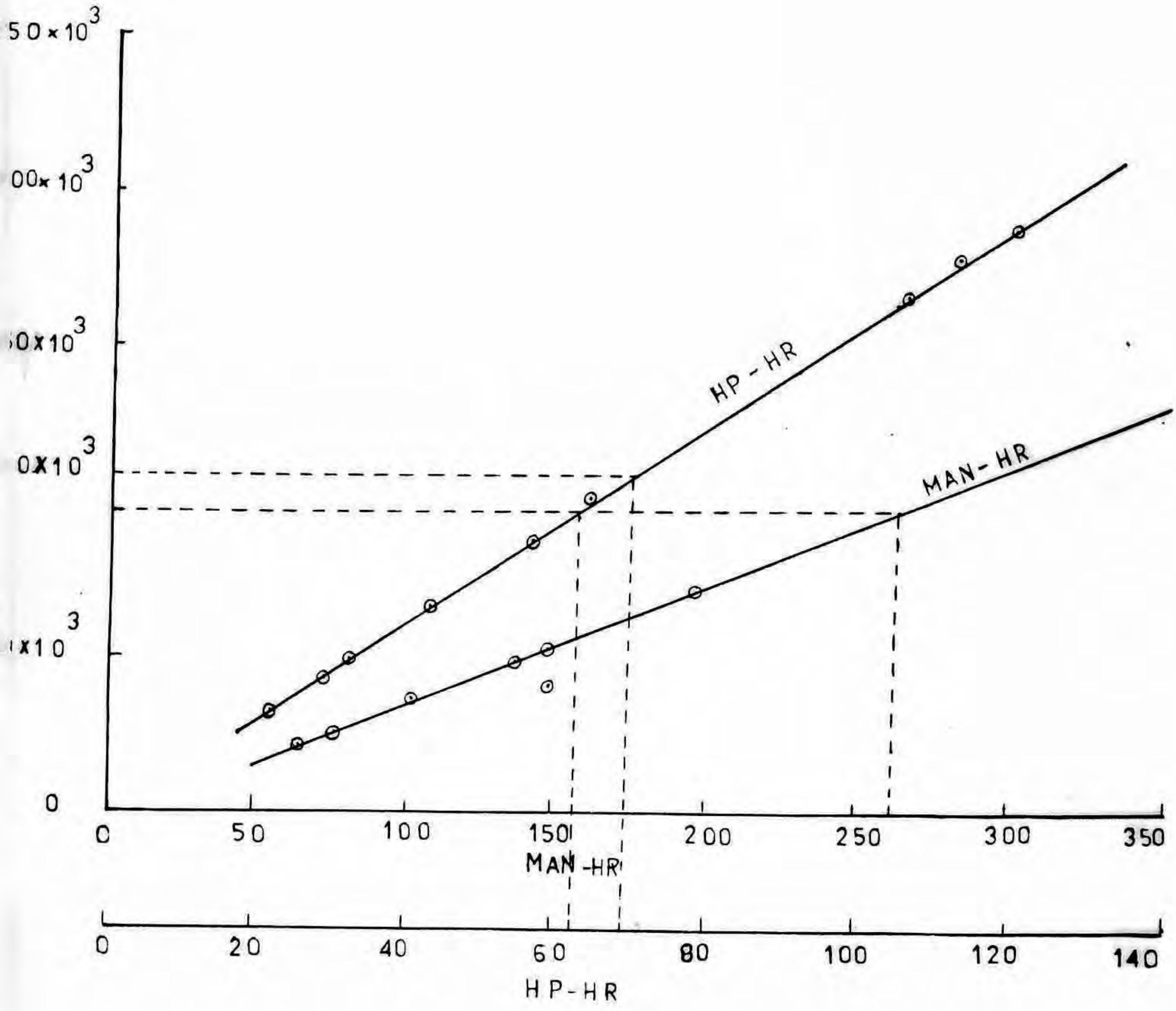


FIG.2

WATER UTILIZED VS IRRIGATION COST (POTATO)

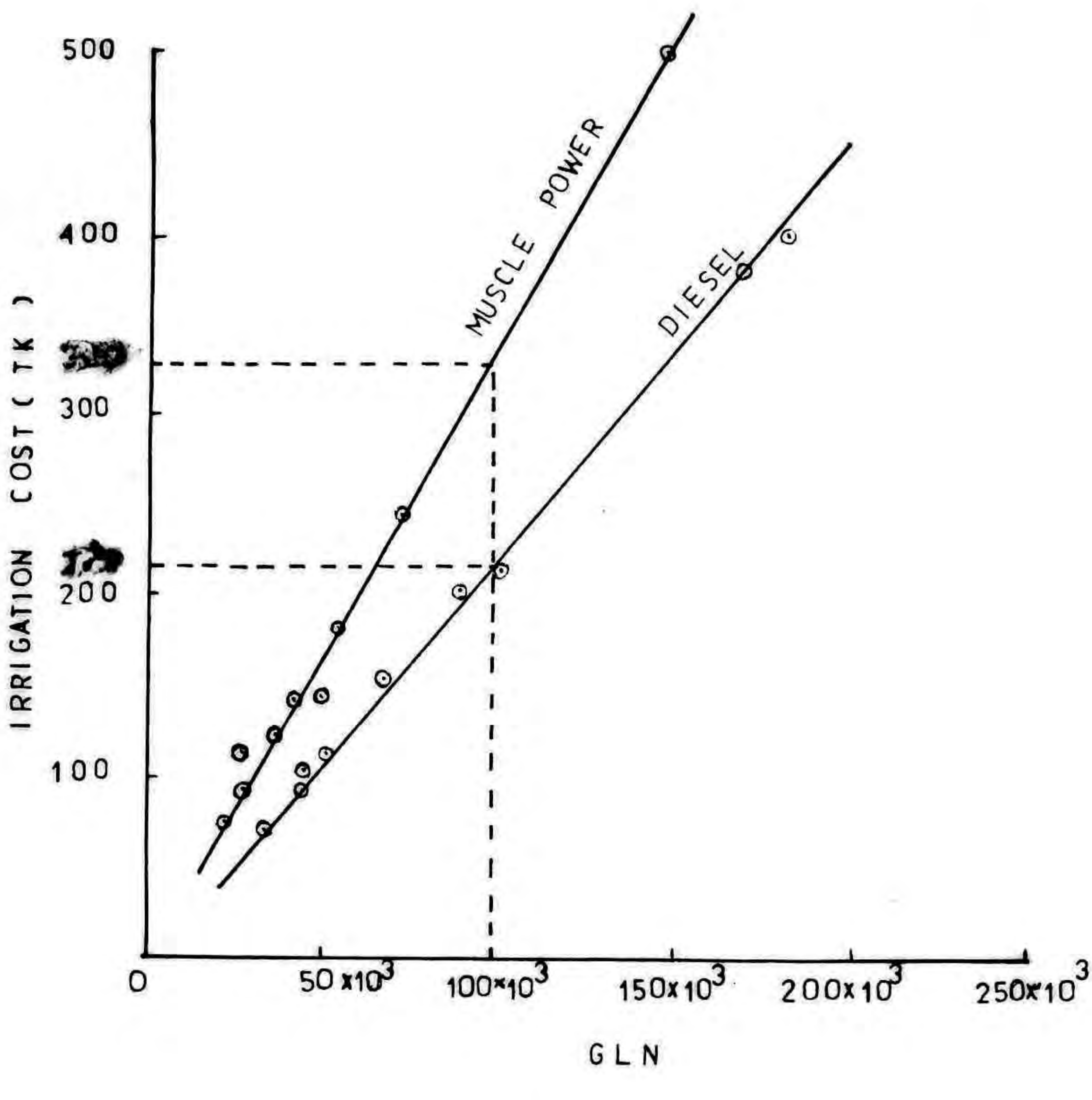


FIG - 3

LAND AREA VS IRRIGATION COST (POTATO)

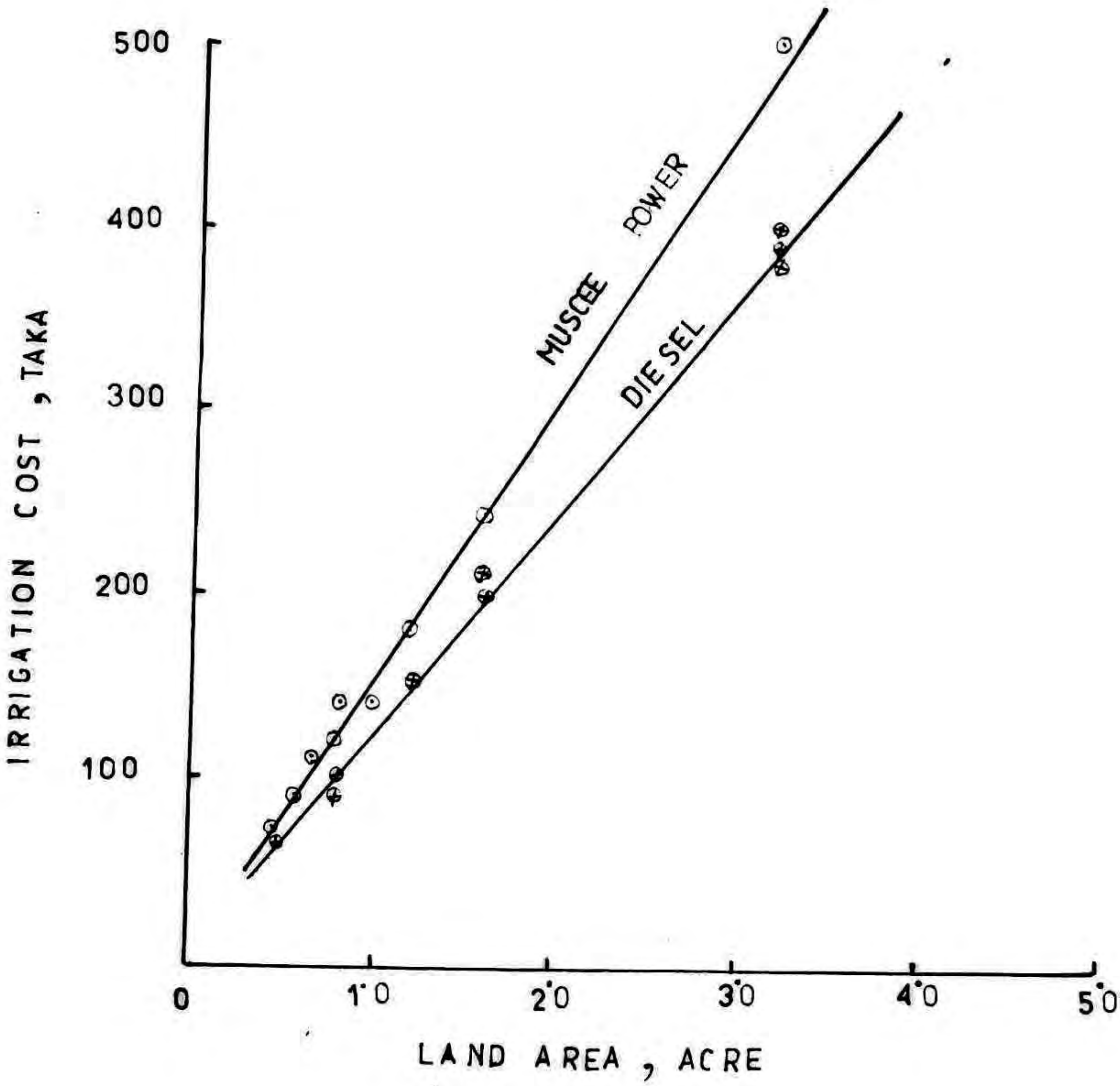


FIG-4

LAND AREA VS HOUR OF OPERATION (POTATO)

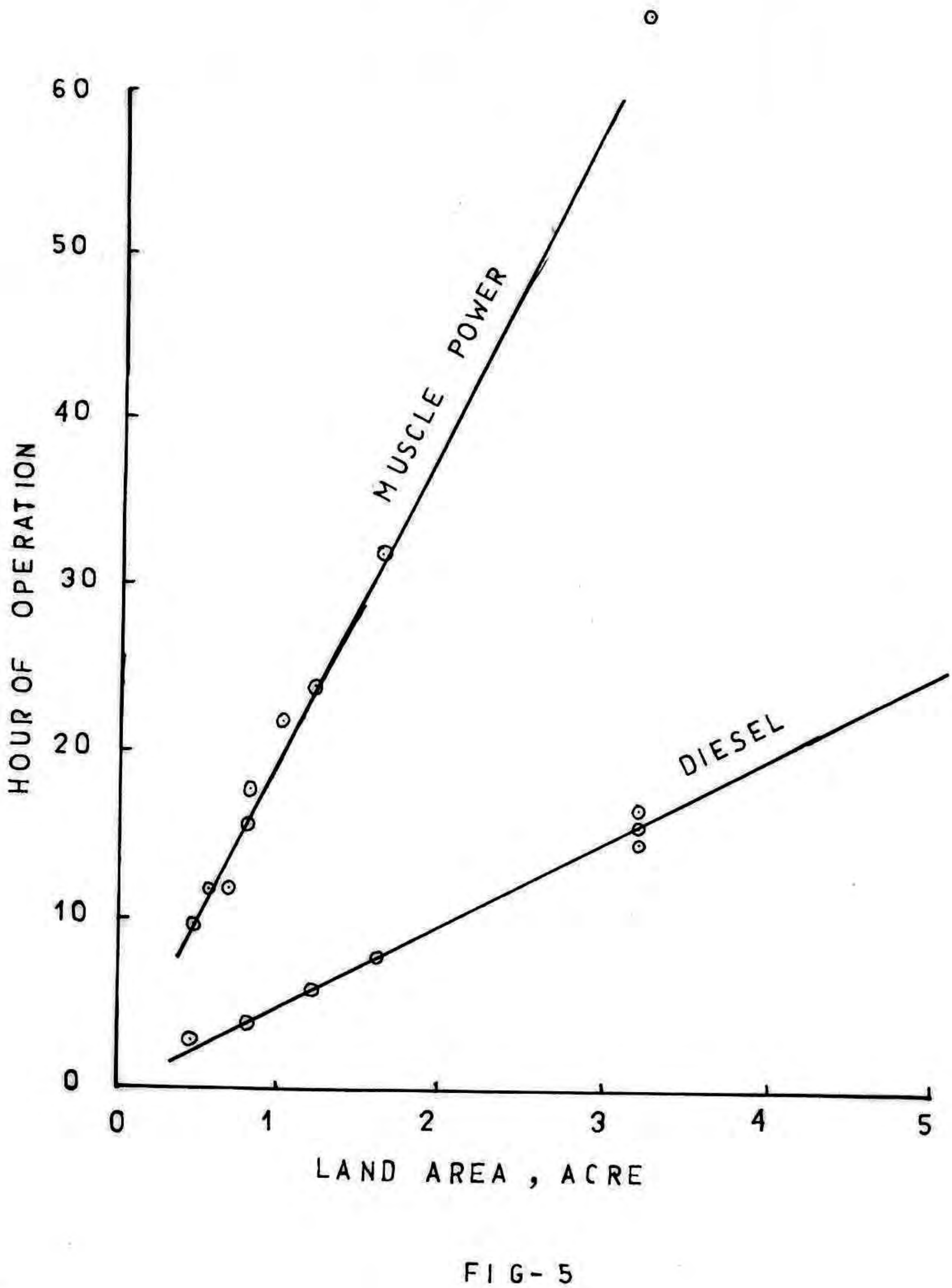


FIG-5

LAND AREA VS WATER UTILIZED (POTATO)

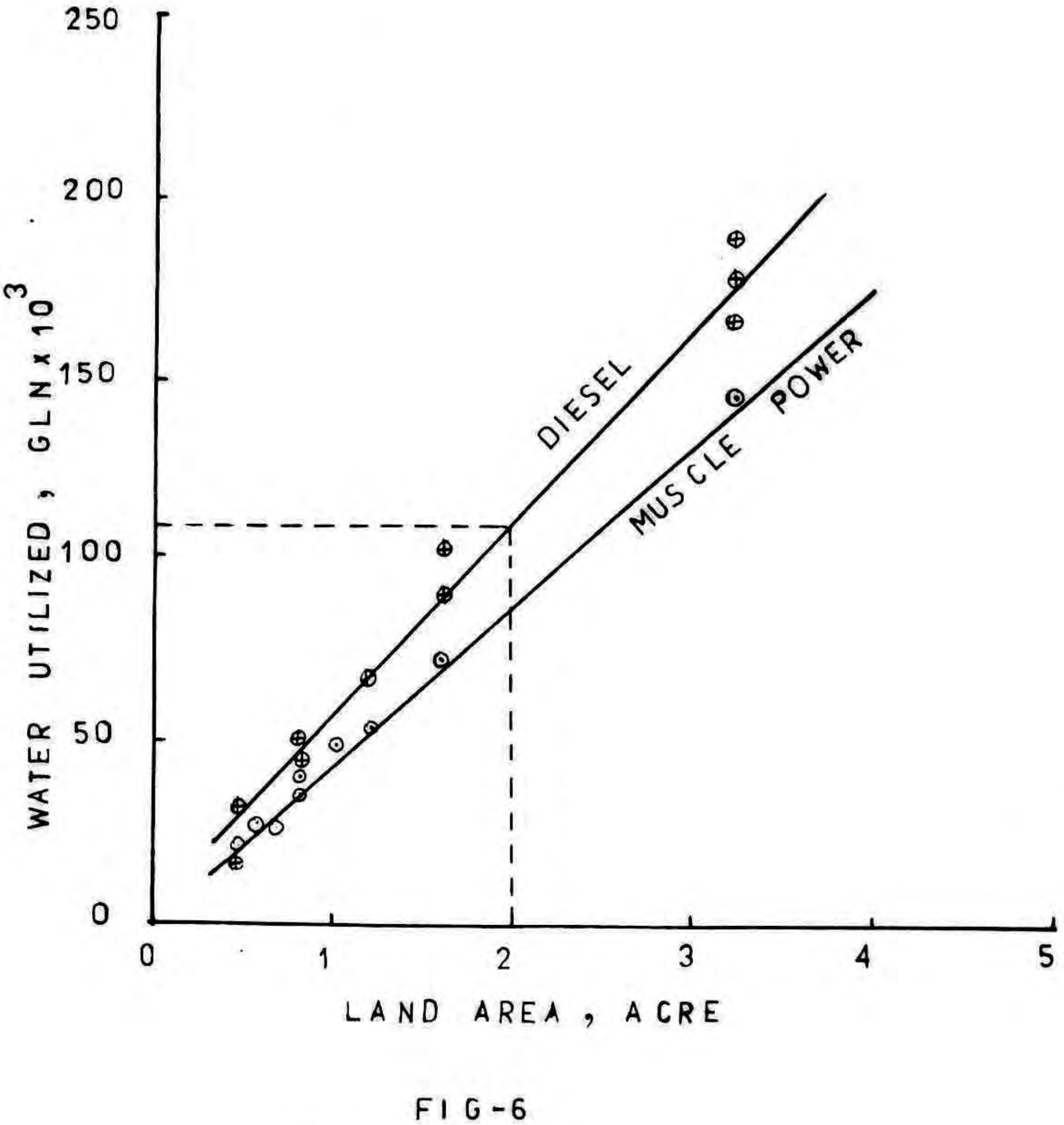


FIG-6

LAND AREA VS CROP PRODUCTION (POTATO)

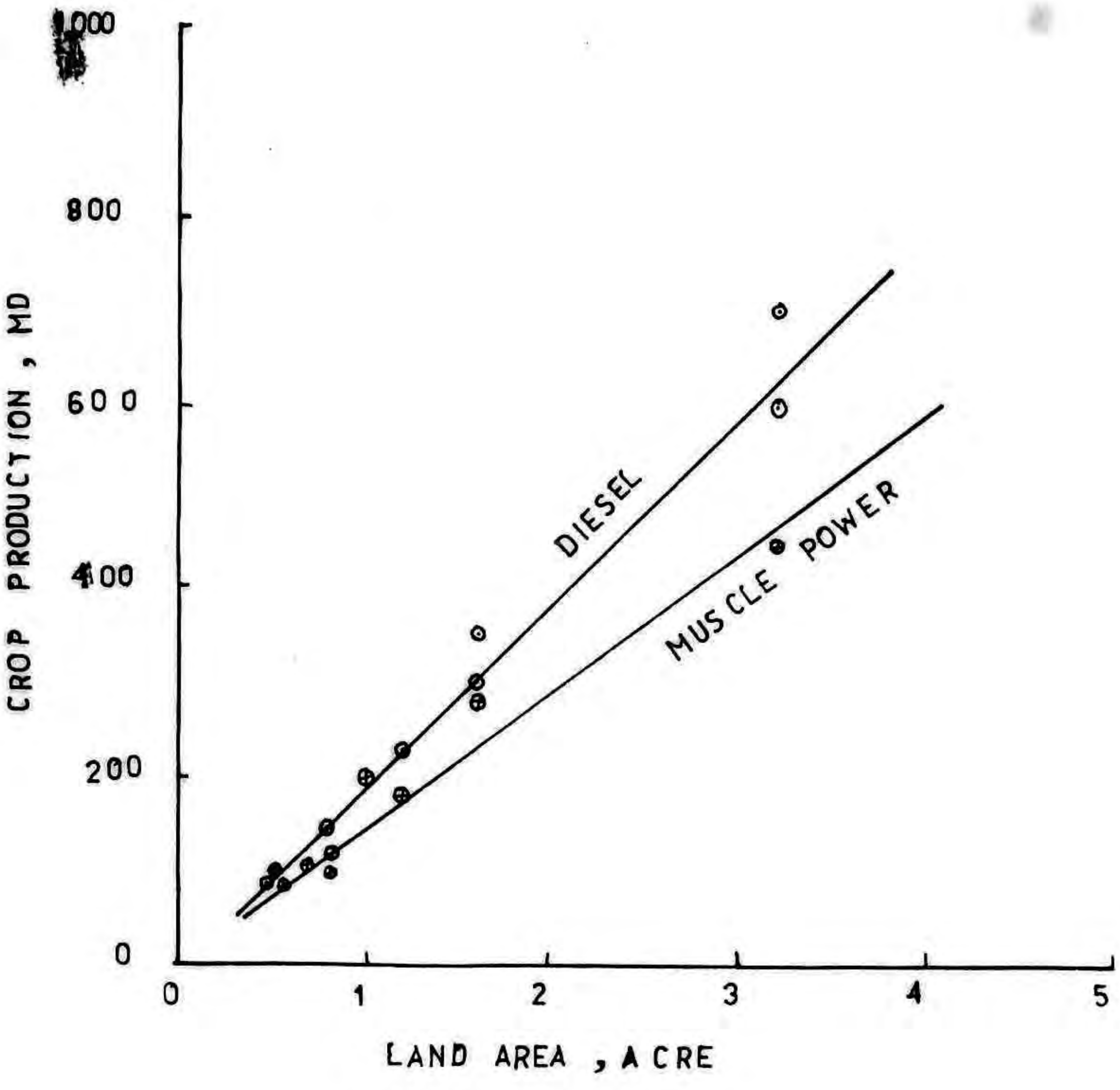


FIG - 7

ENERGY USED VS CROP VALUE (POTATO)

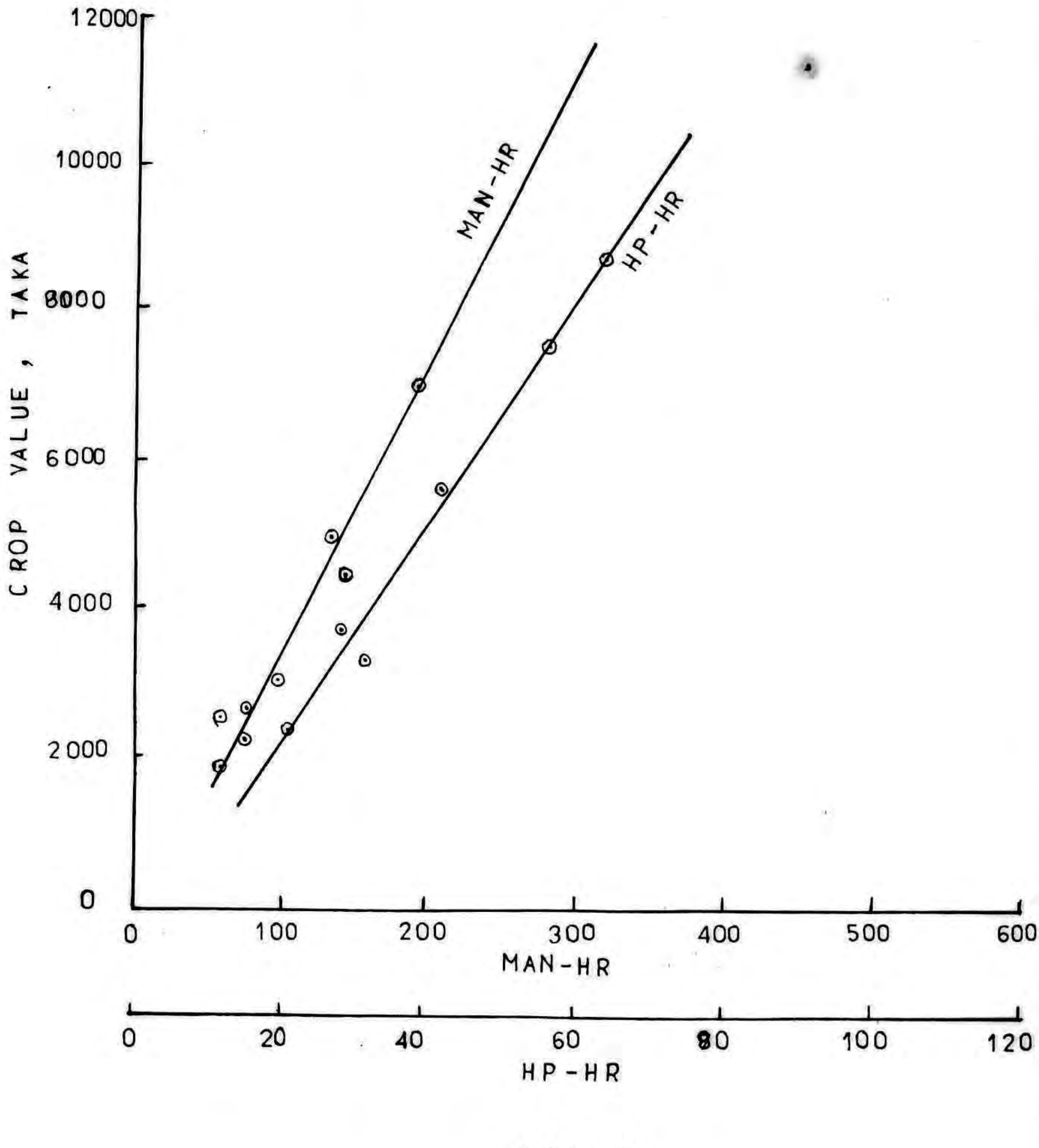


FIG-8

VALUE
CROP ^ VS IRRIGATION COST (POTATO)

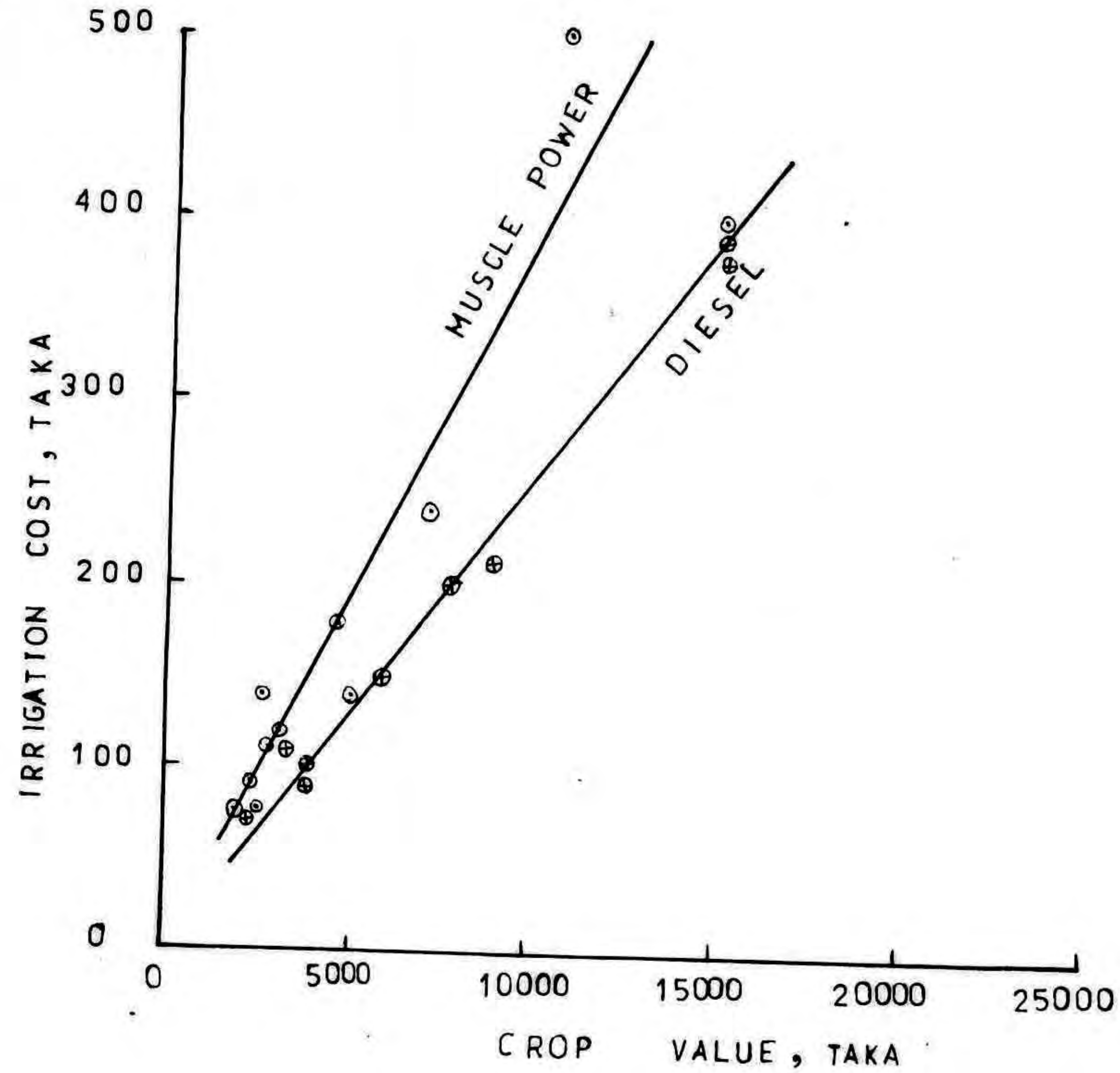


FIG-9

ENERGY USED VS % IRRIGATION COST (POTATO)

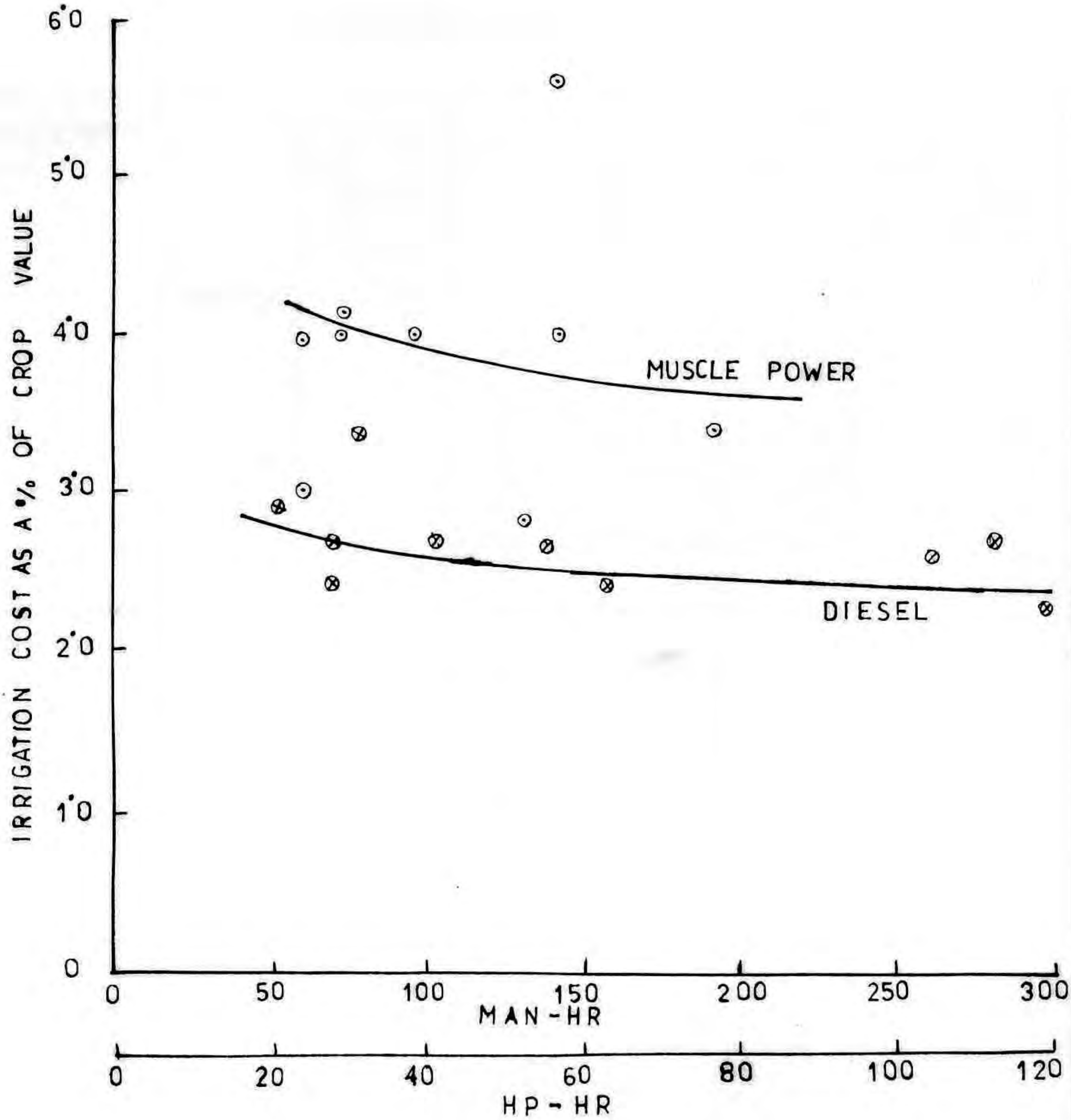


FIG-10

TABLE-7

STANDARD DEVIATIONS OF % IRRIGATION COST

IN

POTATO IRRIGATION

HUMAN MUSCLE POWER					DIESEL POWER				
SL. NO.	% IRRIGATION COST X	DIFF FROM AV $x=X-\bar{X}$	x^2	STANDARD DEVIATION $S=\sqrt{\frac{\Sigma x^2}{N}}$	SL. No.	% IRRIGATION COST X	DIFF FROM AV. $x=X-\bar{X}$	x^2	STANDARD DEVIATION $S=\sqrt{\frac{\Sigma x^2}{N}}$
1	3.84	-0.08	0.0064		1	2.90	0.25	0.0625	
2	3.00	-0.92	0.8464		2	2.67	0.02	0.0004	
3	4.00	0.08	0.0064		3	2.40	-0.25	0.0625	
4	4.15	0.23	0.0529		4	3.38	0.73	0.5329	
5	4.00	0.08	0.0064	0.747	5	2.67	0.02	0.0004	0.302
6	5.60	1.68	2.8224		6	2.67	0.02	0.0004	
7	2.80	-1.12	1.2544		7	2.40	-0.25	0.0625	
8	4.00	0.08	0.0064		8	2.53	-0.12	0.0144	
9	3.40	-0.52	0.2704		9	2.67	0.02	0.0004	
10	4.44	0.52	0.2704		10	2.23	-0.42	0.1764	
N=10	A.V. $\bar{X}=3.92$		$\Sigma x^2=5.5425$		N=10	A.V $\bar{X}=2.65$		$\Sigma x^2=0.9128$	

ENERGY USED VS WATER UTILIZED (HYV-I)

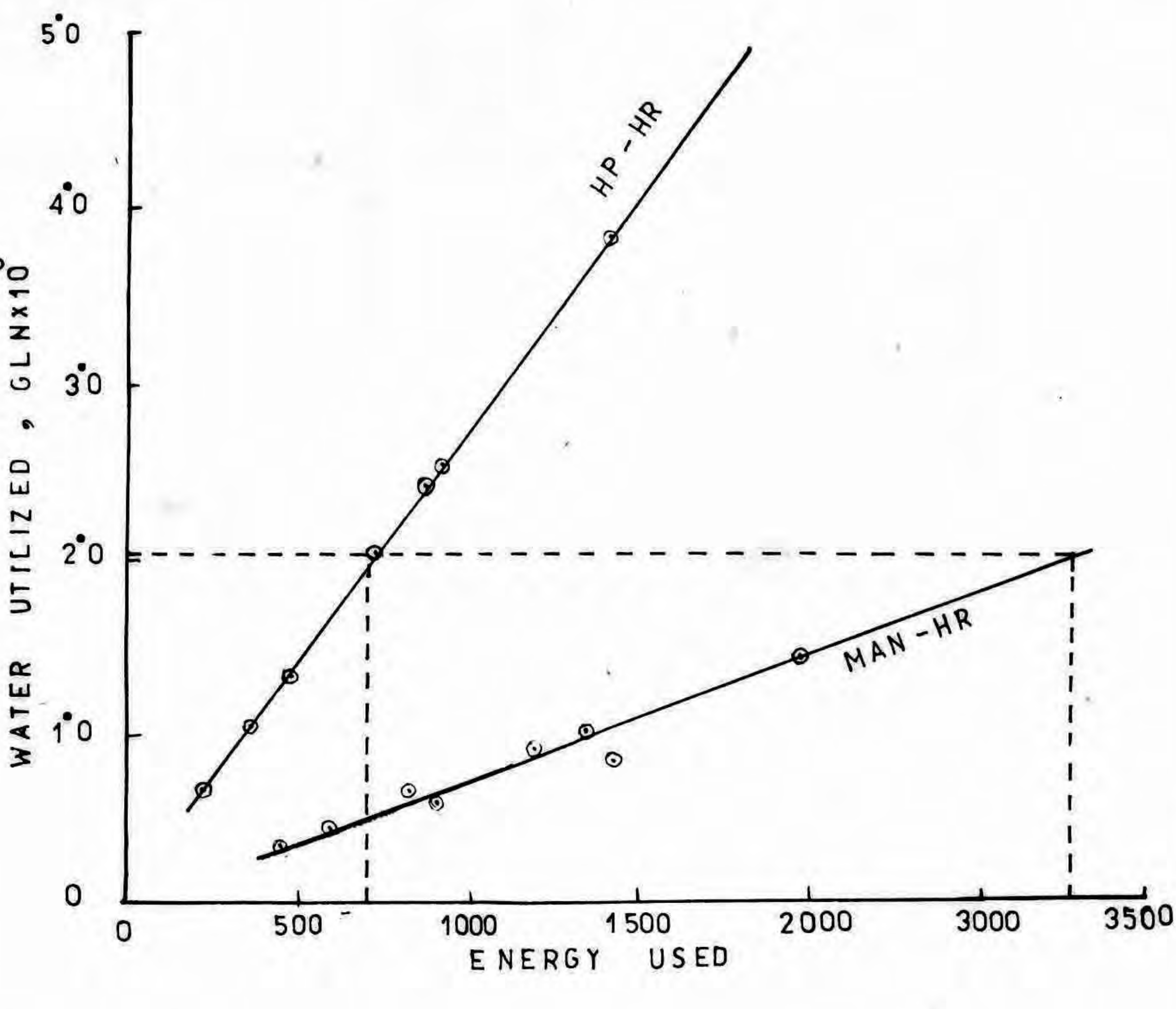


FIG. 11

LAND AREA VS IRRIGATION COST (HYV-I)

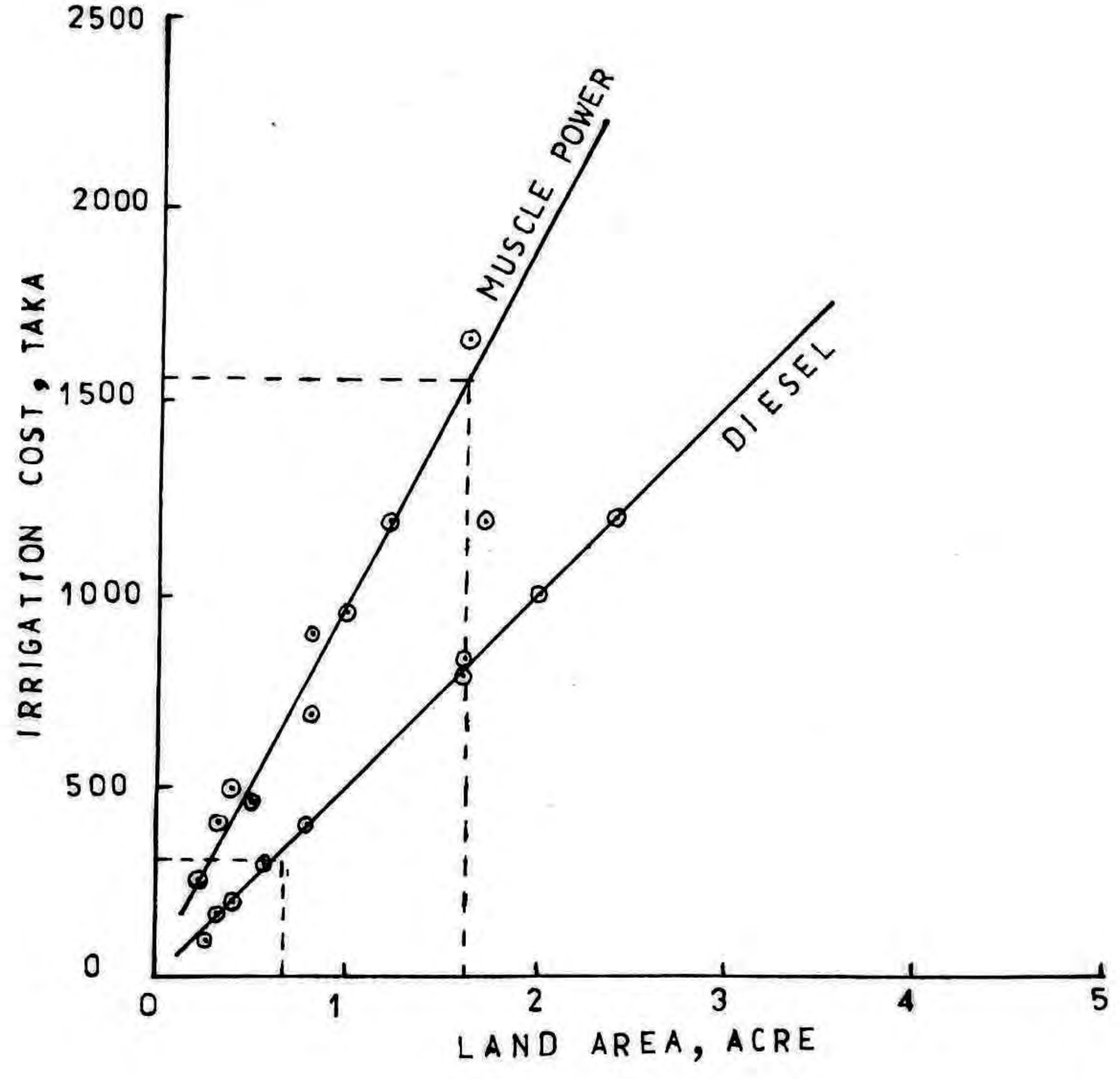


FIG-12

LAND AREA VS CROP PRODUCTION (HYV-I)

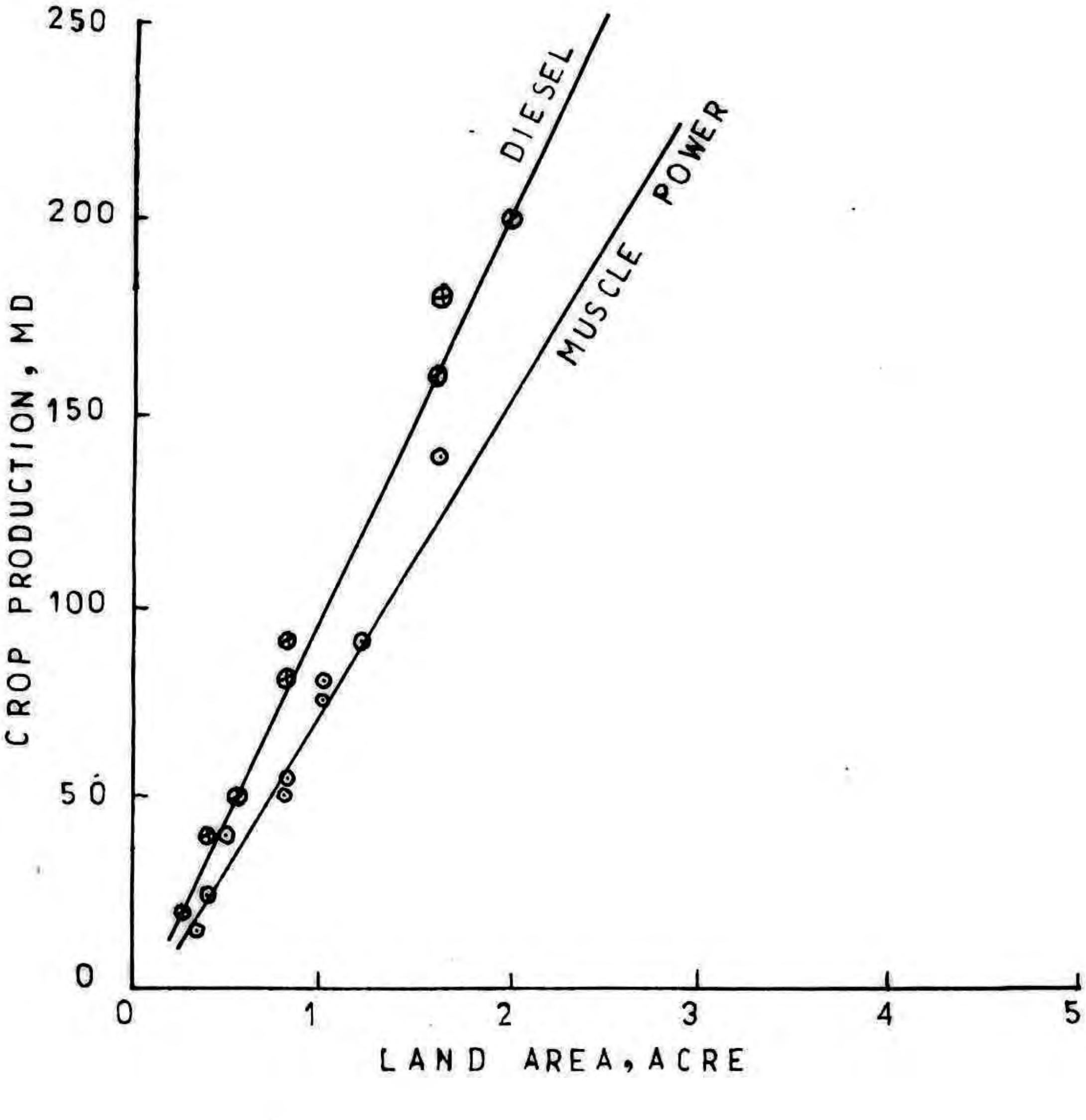


FIG-13

LAND AREA VS WATER UTILIZED (HYV-I)

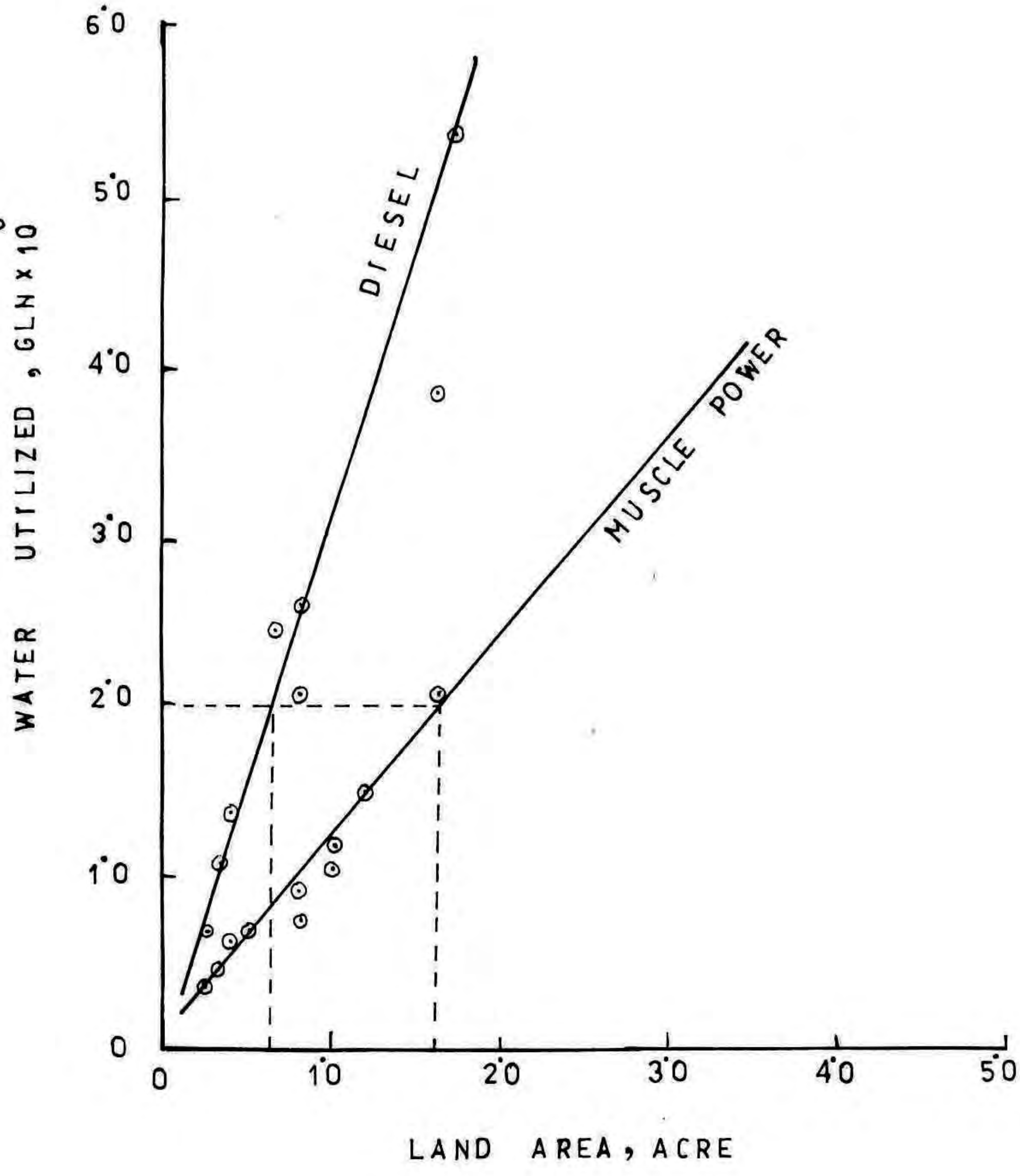


FIG-14

WATER UTILIZED VS IRRIGATION COST (HYV - I)

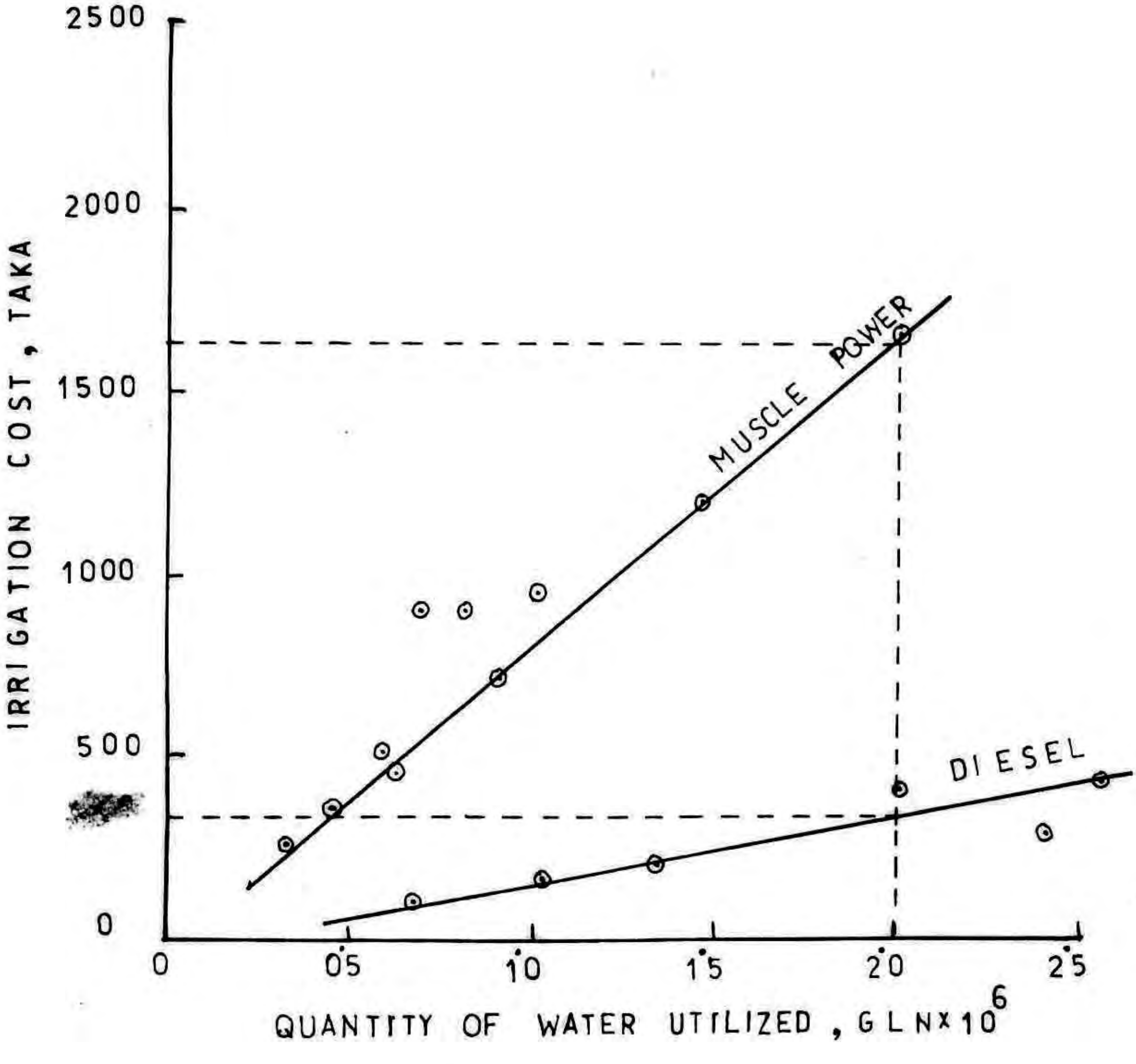


FIG- 15

ENERGY USED vs CROP VALUE (HYV - I)

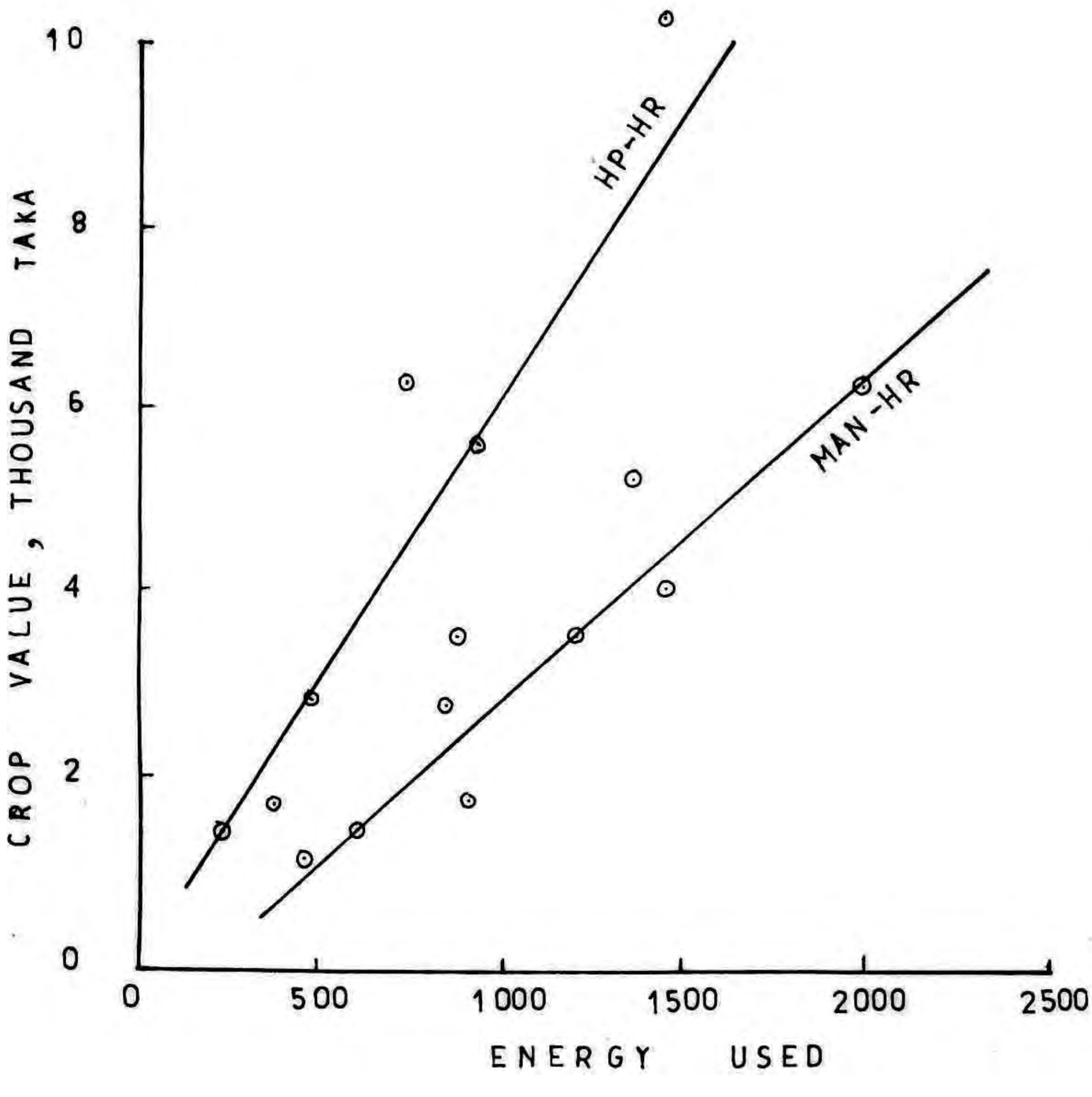


FIG- 16

CROP VALUE vs IRRIGATION COST (HYV - I)

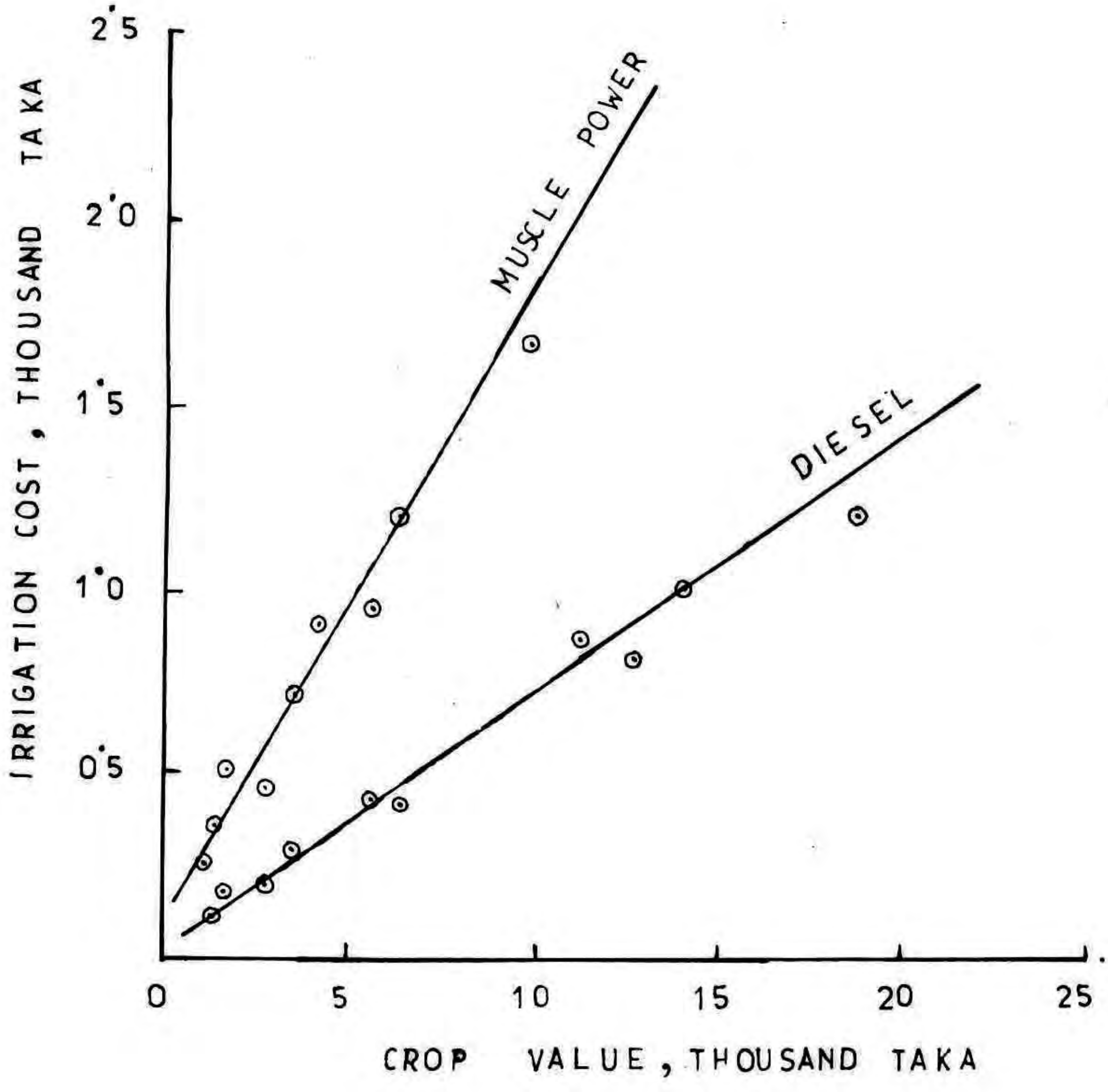


FIG - 17

LAND AREA vs HOUR OF OPERATION (HYV-I)

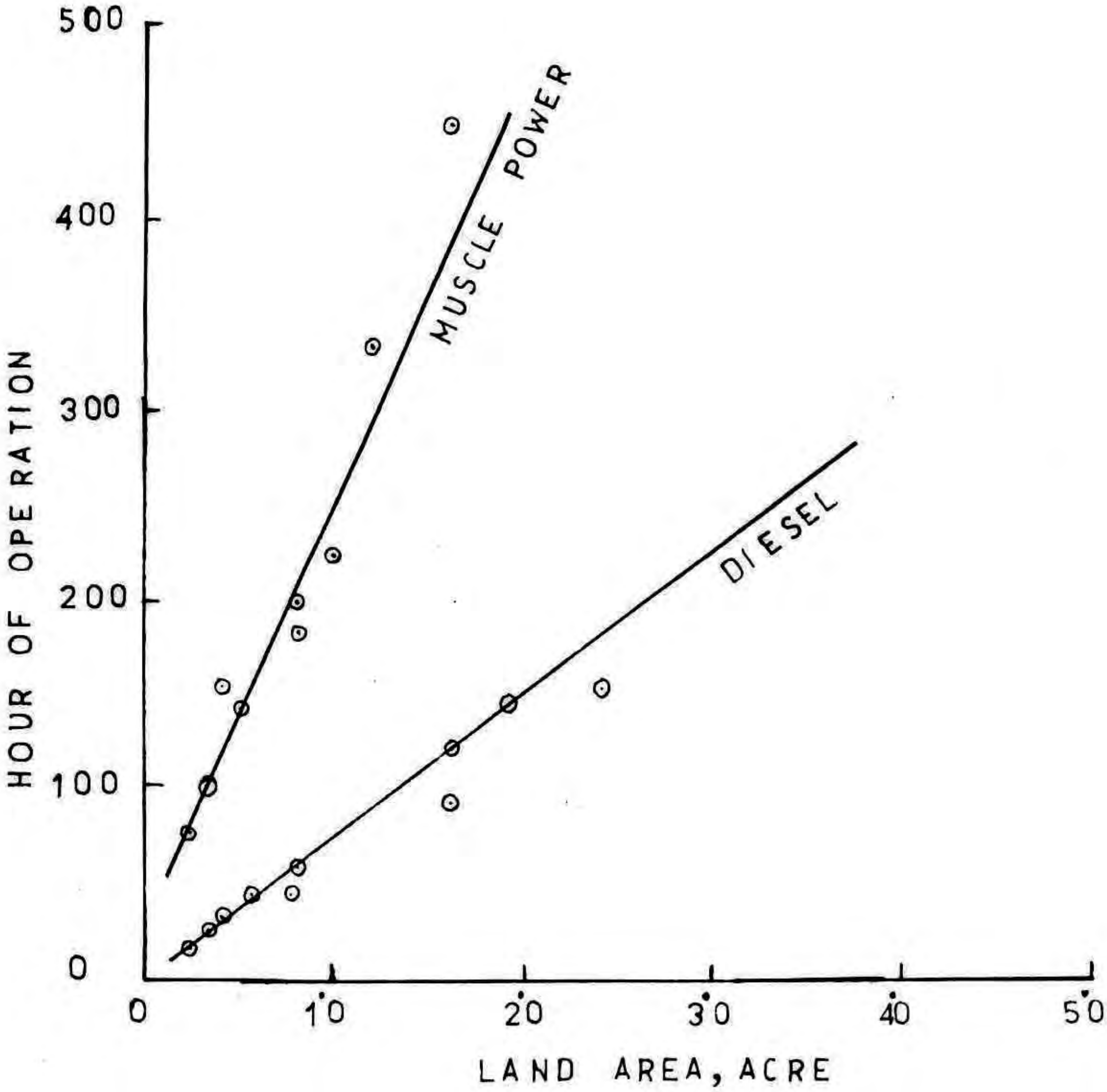


FIG-18

ENERGY USED vs % IRRIGATION COST (HYV - I)

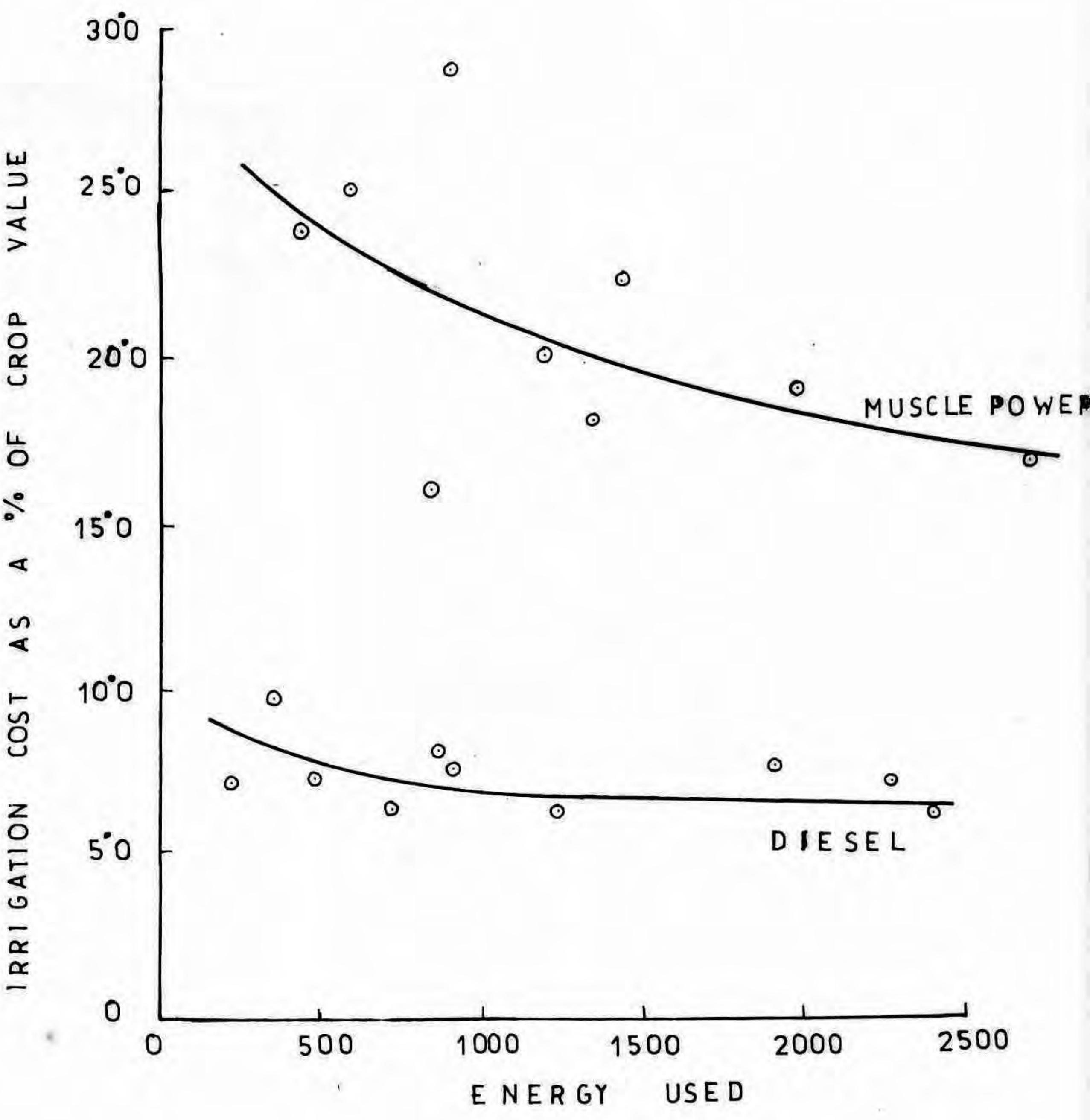


FIG - 19

TABLE-8

STANDARD DEVIATIONS OF % IRRIGATION COST

IN

HYV (I) IRRIGATION

HUMAN MUSCLE POWER

SL. NO.	% IRRIGATION COST X	DIFF. FROM AV. $x = X - \bar{X}$	x^2	STANDARD DEVIATION $S = \sqrt{\frac{\sum x^2}{N}}$
1	23.80	2.73	7.4529	
2	25.00	3.93	15.4449	
3	28.57	7.50	56.2500	
4	16.07	-5.00	25.0000	
5	20.00	-1.07	1.1449	3.922
6	22.22	1.15	1.3225	
7	18.10	-2.97	9.8209	
8	19.05	-2.02	4.0804	
9	16.84	-4.23	17.8929	
10				
N=9	AV. $\bar{X}$=21.07		$\sum x^2$=138.4094	

DIESEL POWER

S.L NO.	% IRRIGATION COST X	DIFF FROM AV. $x = X - \bar{X}$	x^2	STANDARD DEVIATION $S = \sqrt{\frac{\sum x^2}{N}}$
1	7.14	-0.17	0.0289	
2	9.52	2.21	4.8841	
3	7.14	-0.17	0.0289	
4	8.00	0.69	0.4761	
5	6.35	-0.96	0.9216	0.912
6	7.50	0.19	0.0361	
7	6.35	-0.96	0.9216	
8	7.59	0.28	0.0784	
9	7.14	-0.17	0.0289	
10	6.35	-0.96	0.9216	
N=10	AV. $\bar{X}$=7.31		$\sum x^2$=8.3262	

TABLE-9

DATA FOR FITTING THE CURVE OF LAND AREA VS CROP PRODUCTION (BY ELECTRIC IRRIGATION) BY THE METHOD OF LEAST SQUARES

i	ACRE X_i	MD Y_i	$X_i Y_i$	X_i^2
1	0.5	24	12.0	0.25
2	0.7	37	25.9	0.49
3	1.0	42	42.0	1.00
4	1.4	50	70.0	1.96
5	1.6	70	112.0	2.56
6	2.0	95	190.0	4.00
7	2.4	100	240.0	5.76
8	2.8	125	350.0	7.84
9	3.0	125	375.0	9.00
10	3.2	140	448.0	10.24
SUM 10	18.6	808	1864.9	43.10

EQUATION OF THE CURVE FOR LAND AREA VS CROP PRODUCTION (BY ELECTRIC IRRIGATION) BY THE METHOD OF LEAST SQUARES

Normal equation for curve fitting is given by:-

$$\begin{bmatrix} m & \sum xi \\ \sum xi & \sum x_i^2 \end{bmatrix} \begin{bmatrix} a_o \\ a_1 \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum Y_i X_i \end{bmatrix}$$

Putting the values from Table-9, the equation become

$$\begin{bmatrix} 10 & 18.6 \\ 18.6 & 43.1 \end{bmatrix} \begin{bmatrix} a_o \\ a_1 \end{bmatrix} = \begin{bmatrix} 808 \\ 1864.9 \end{bmatrix}$$

i.e. $10a_o + 18.6a_1 = 808$ .. .. (i)

$18.6a_o + 43.1a_1 = 1864.0$ .. .. (ii)

From (i): $a_1 = \dfrac{808 - 10a_o}{18.6}$ .. .. (iii)

Putting the value of a_1 in (ii), we get,

$$18.6\ a_o + 43.1 \times \frac{808 - 10a_o}{18.6} = 1864.9$$

or, $18.6\ a_o + 1872.3 - 23.17a_o = 1864.9$

or, $-4.57a_o = -7.40$

$\therefore a_o = 1.62$

From (iii), $a_1 = \dfrac{808-16.2}{18.6} = 42.5$

So, the equation of the curve is

$$Y_i = 42.5x_i + 1.62$$

Where Y_i = Crop production in MD.

X_i = Land area in Acres.

The curve, so obtained, is shown in fig.20

TABLE-10

DATA FOR FITTING THE CURVE OF LAND AREA VS CROP PRODUCTION (BY DIESEL IRRIGATION) BY THE METHOD OF LEAST SQUARE

i	ACRE x_i	MD Y_i	$X_i Y_i$	X_i^2
1	0.4	18	7.2	0.16
2	0.7	25	17.5	0.49
3	1.0	40	40.0	1.00
4	1.2	58	69.6	1.44
5	1.6	65	104.0	2.65
6	1.8	65	117.0	3.24
7	2.0	90	180.0	4.00
8	2.4	95	228.0	5.76
9	3.0	110	333.0	9.00
10	3.2	142	454.4	10.24
SUM 10	17.3	708	1550.7	37.89

EQUATION OF THE CURVE FOR LAND AREA VS CROP PRODUCTION (BY DIESEL IRRIGATION) BY THE METHOD OF LEAST SQUARES

Normal equation for curve fitting is given by:-

$$\begin{bmatrix} m & \sum x_i \\ \sum x_i & \sum x_i^2 \end{bmatrix} \begin{bmatrix} a_o \\ a_1 \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum Y_i x_i \end{bmatrix}$$

Putting the values from Table-10, the equation becomes:-

$$\begin{bmatrix} 10 & 17.3 \\ 17.3 & 37.89 \end{bmatrix} \begin{bmatrix} a_o \\ a_1 \end{bmatrix} = \begin{bmatrix} 708 \\ 1550.7 \end{bmatrix}$$

i.e. $10a_o + 17.3\, a_1 = 708$ .. .. (i)

$17.3\, a_o + 37.89a_1 = 1550.7$ .. (ii)

From (i), $a_1 = \dfrac{708 - 10\, a_o}{17.3}$ .. .. (iii)

Putting the value of a_1 in (ii), we get,

$$17.3a_o + 37.89 \times \frac{708 - 10a_o}{17.3} = 1550.7$$

or, $17.3\, a_o + 1550.7 - 21.9\, a_o = 1550.7$

or, $-4.6a_o = 0 \quad \therefore\ a_o = o$

From (iii), we get, $a_1 = \dfrac{708}{17.3} \doteq 40$

So, the equation of the curve is given by -

$$\underline{Y_i = 40x_i}$$

where Y_i = Crop production in MD.

X_i = Land area in Acres.

The curve, so obtained, is shown in fig. 20.

LAND AREA vs CROP PRODUCTION (HYV - II)

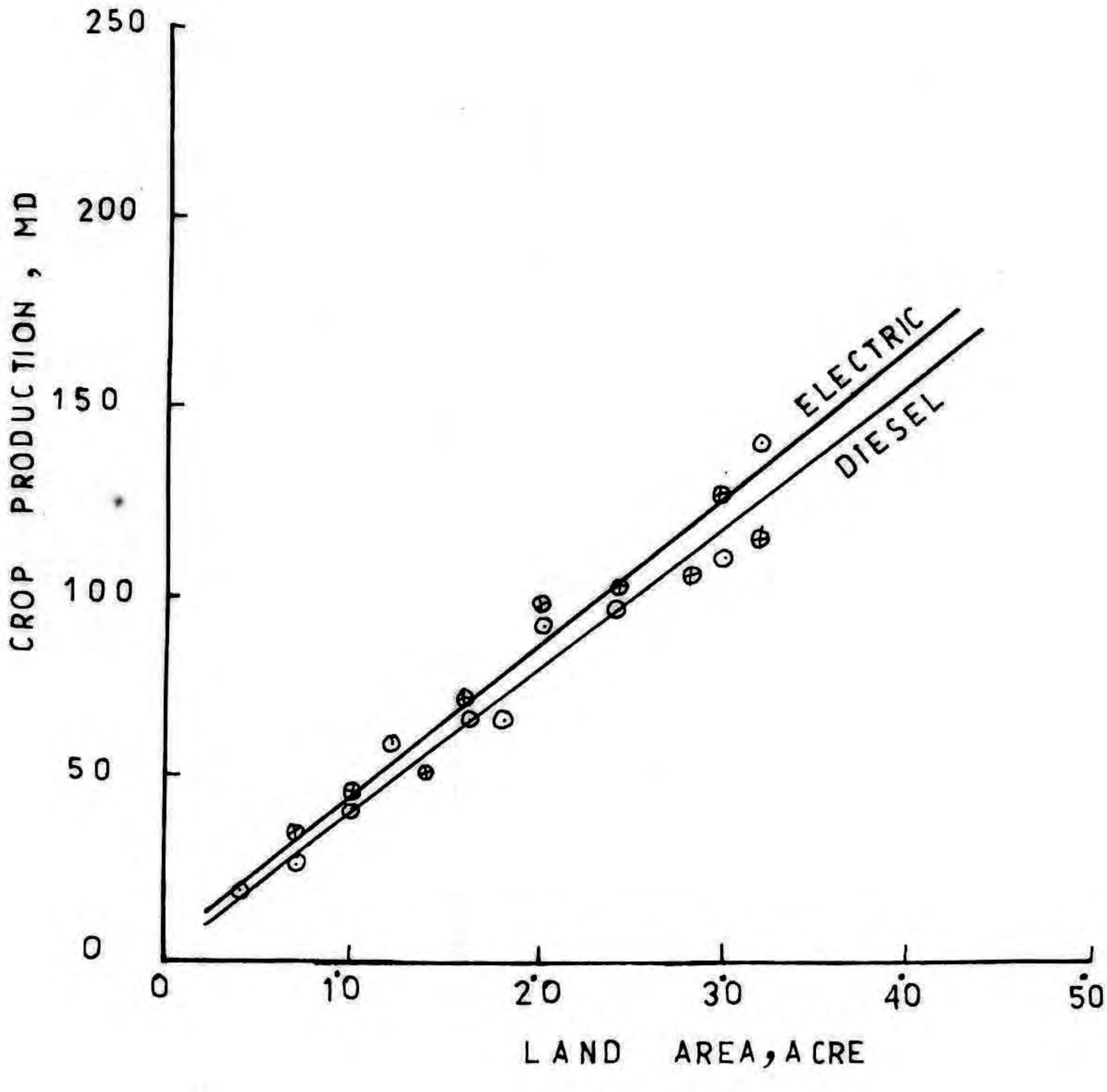


FIG-20

LAND AREA VS WATER UTILIZED (HYV - II)

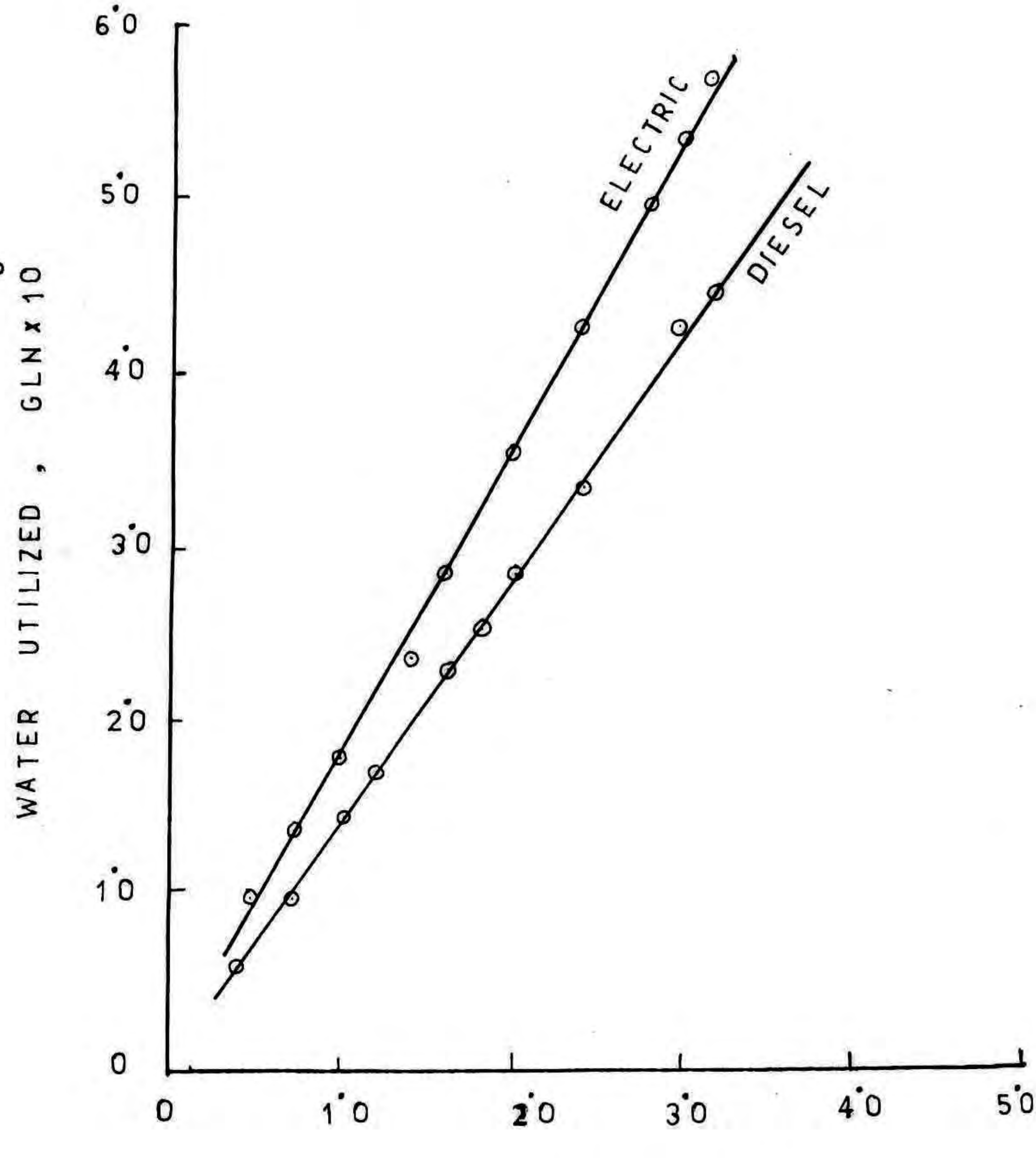


FIG- 21

LAND AREA vs ENERGY COST (HYV - II)

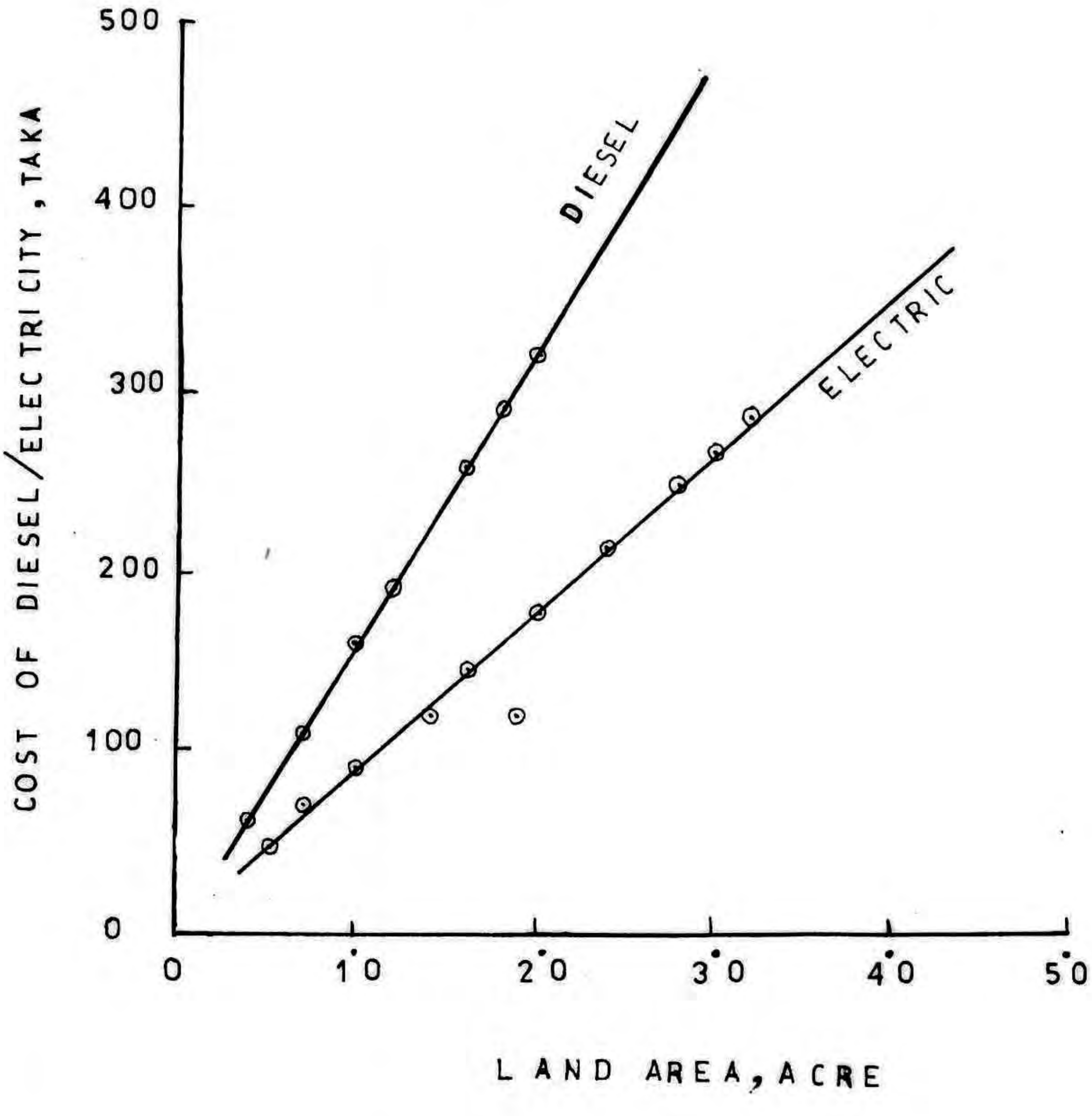


FIG- 22

CROP VALUE vs ENERGY USED (HYV-II)

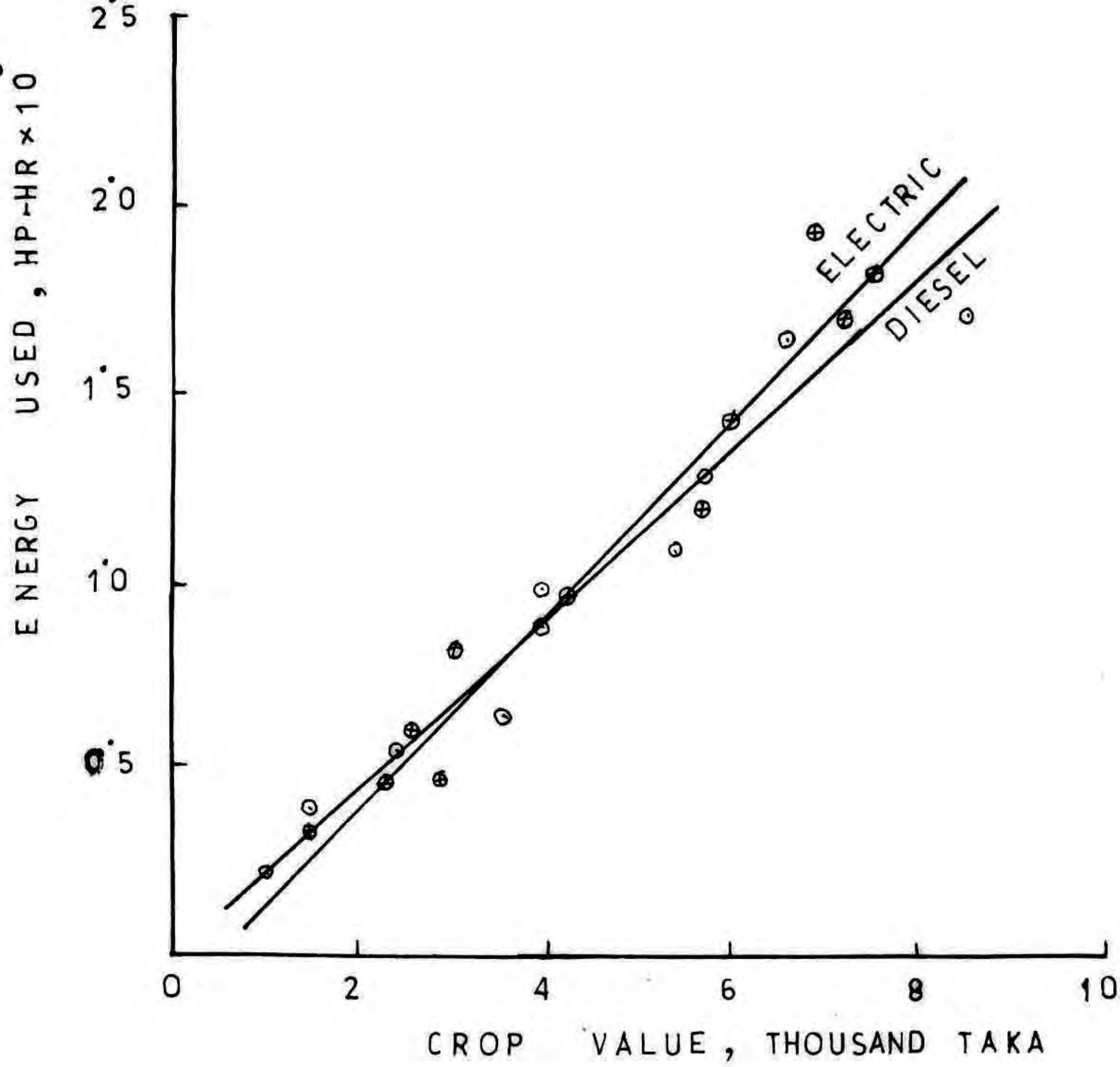


FIG- 23

CROP VALUE vs IRRIGATION COST (HYV-II)

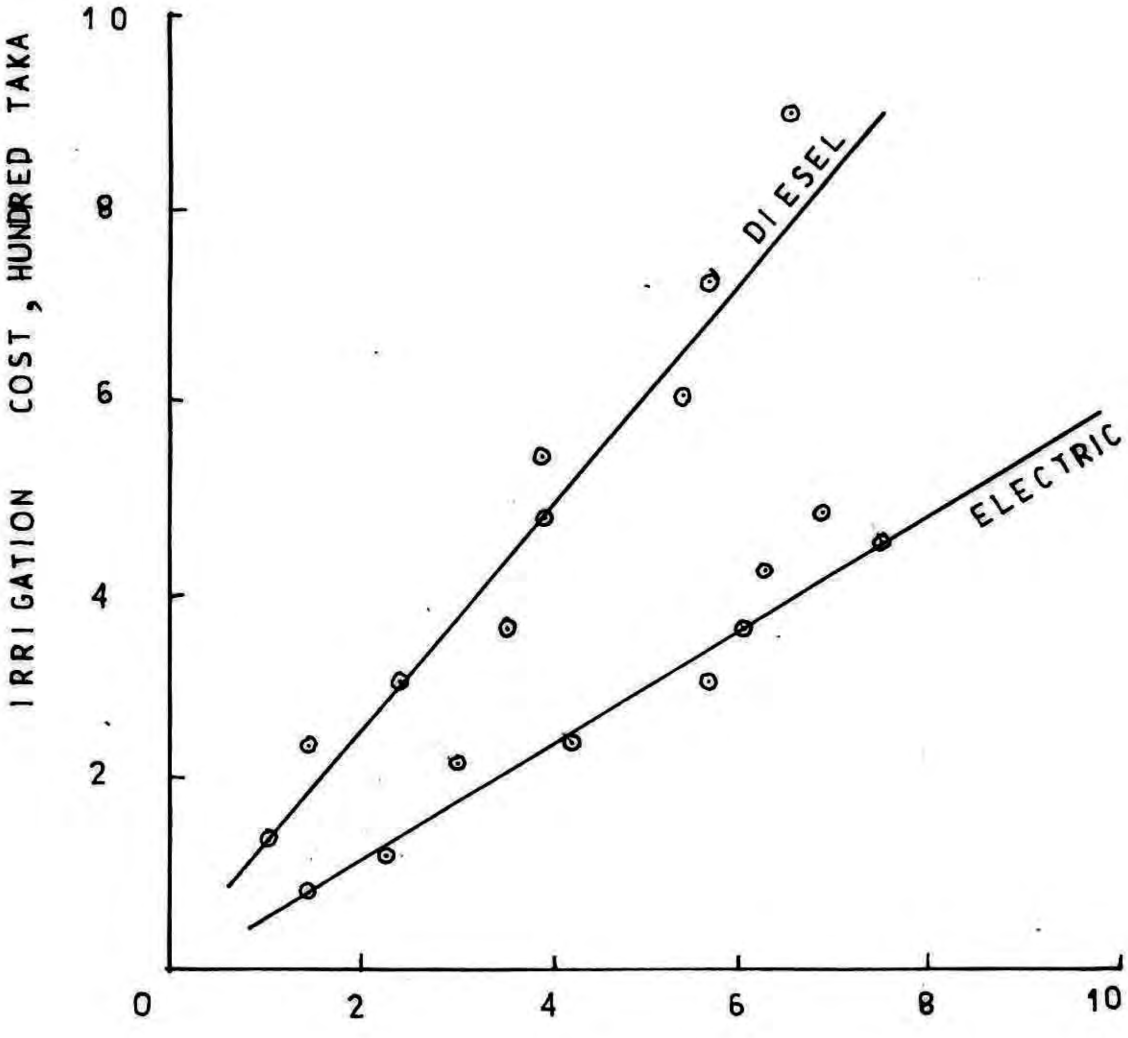


FIG-24

ENERGY USED vs % IRRIGATION COST (HYV -II)

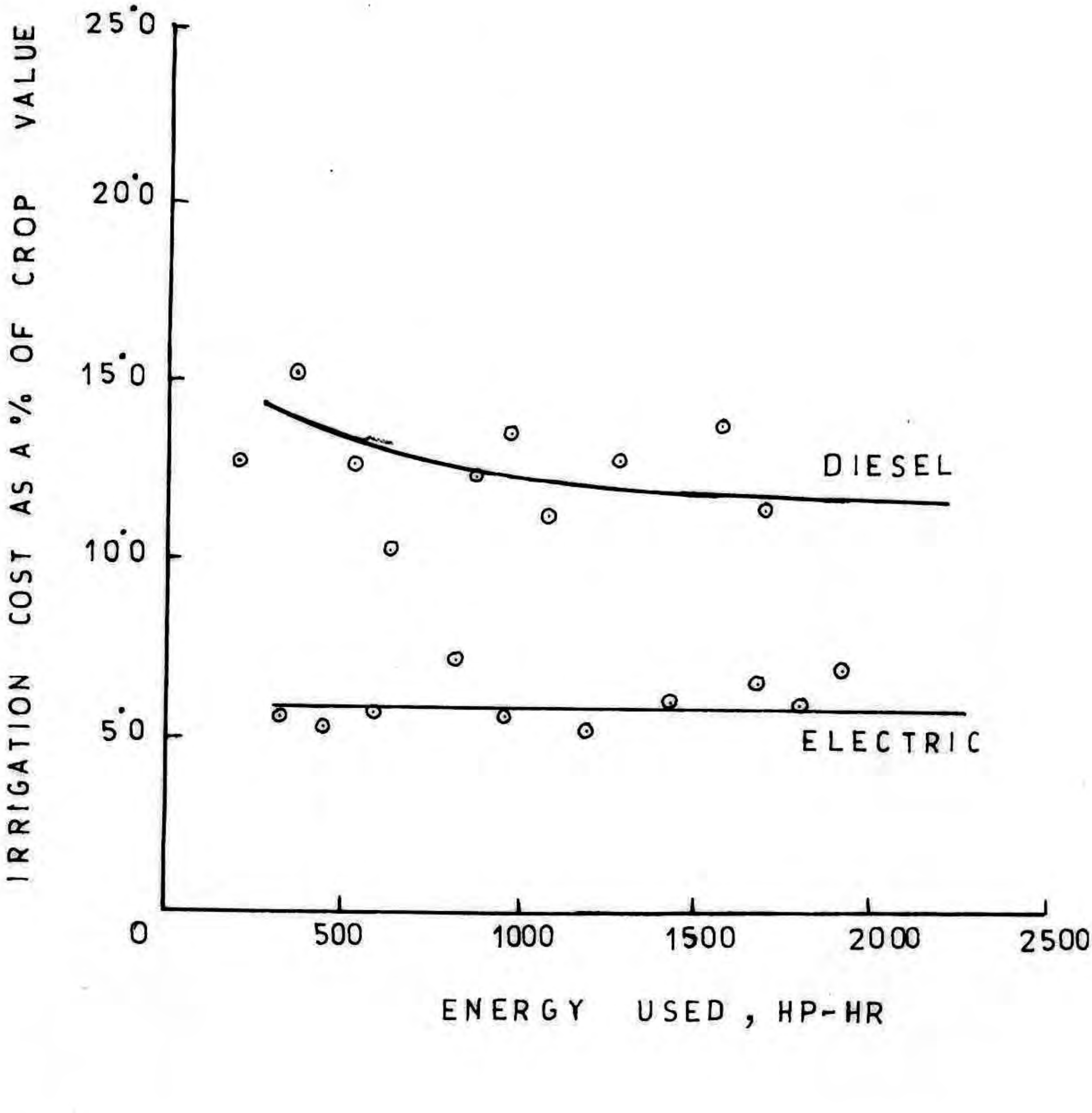


FIG- 25

TABLE-11.

STANDARD DEVIATION OF % IRRIGATION COST

I N

HYV (II) IRRIGATION

DIESEL POWER					ELECTRIC POWER				
SL. NO.	% IRRI COST X	DIFF FROM AV. $x=X-\bar{X}$	x^2	ST. DEV. $S=\frac{\sum x^2}{N}$	SL. No.	% IRRI COST X	DIFF. FROM AV. $x=X-\bar{X}$	x^2	ST.Dev. $S=\frac{\sum x^2}{N}$
1	12.59	0.02	0.0004		1	5.56	-0.50	0.2500	
2	15.33	2.76	7.6176		2	5.32	-0.74	0.5476	
3	12.50	-0.07	0.0049		3	5.95	-0.11	0.0121	
4	10.34	-2.23	4.9729		4	7.20	1.14	1.2996	
5	12.30	-0.27	0.0729	1.369	5	5.71	-0.35	0.1225	0.637
6	13.85	1.28	1.6384		6	5.26	-0.80	0.6400	
7	11.11	-1.46	2.1316		7	6.00	-0.06	0.0036	
8.	12.63	0.06	0.0036		8	6.67	0.61	0.3721	
9	13.64	1.07	1.1449		9	6.00	-0.06	0.0036	
10	11.38	1.19	1.1416		10	6.96	0.90	0.8100	
N=10	AV. $\bar{X}$=12.57		$\sum x^2$=18.7288		N=10	AV. $\bar{X}$=6.06		$\sum X^2$=4.0611	

CHAPTER-V

FARM INCOME AS RELATED TO METHODS OF IRRIGATION

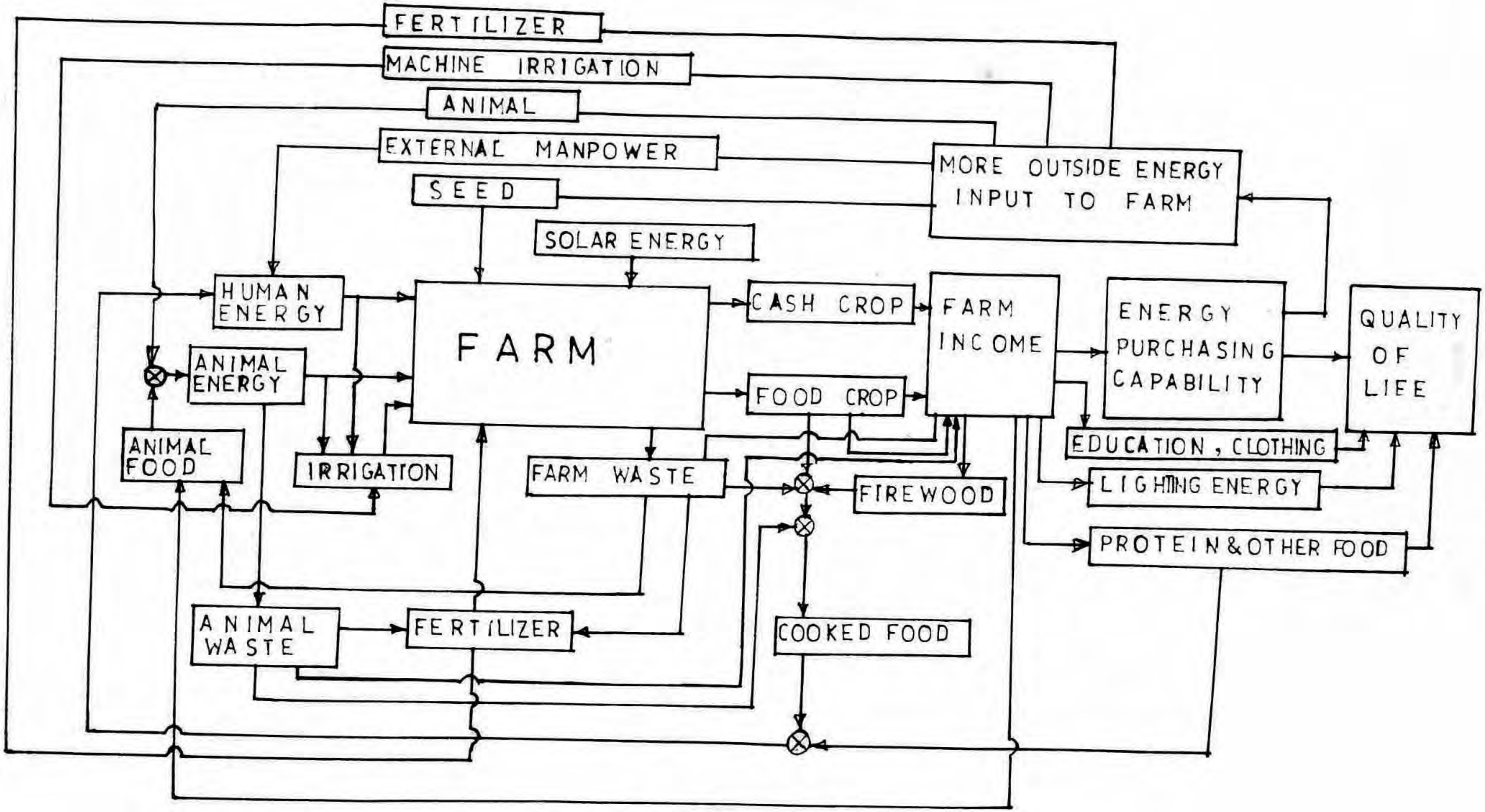
5.1 REVISED ENERGY MODEL

The open loops in the energy model of fig-1. may be closed in some cases. More outside energy input to farm may include the items like— i) Fertilizer, ii) Machine irrigation, iii) Animal iv) External Manpower and v) Seed etc. Animal food is also provided by cash purchase from the farm income. As the farm waste and animal waste produced in the farm are utilized for fertilizer and cooking, these items may be shown to give farm income. Education, clothing etc. derived from farm income, measure quality of life. With these additions, the revised energy model is shown in fig. 26.

5.1.1 SURPLUS INCOME

From the revised energy model, it is clear that farm income includes crop value, price of farm waste and animal waste. Farm expenditure includes— cost of fertilizer, irrigation cost, animal financing, wages for external manpower, cost of animal feeding, cost of seed, cost of food for family, and cost of lighting and cooking energy. The difference between farm income and farm expenditure gives the surplus income—which is a measure of the "quality of life."

With the above conclusions, the surplus income for various sources of energy for irrigation, may be calculated.



REVISED ENERGY MODEL FOR AN AGRICULTURAL UNIT

FIG- 26

5.2 ASSUMPTIONS FOR FARM INCOME CALCULATION

The following assumptions based on farmers' exper experience, agricultural extention workers; published literature and informed guesses, are made for calculating farm surplus income:-

i) Crop:- HYV of rice is produced twice a year.

ii) Crop-Production:- In the present survey, crop-production varied from 45-95 MD/ACRE. 50 MD/ACRE is taken as x a basis of calculation.

iii) Price of Materials:- All prices are estimated at market rate as on June, 1978.

iv) Paddy-Price:- An average of Tk.70/MD for various types, sold at village hats.

v) Rice-Price:- $\frac{12}{7}$ X Paddy price = Tk. 120/-

vi) Animal-Waste :- Animal waste produced by a cow is 15 seers/day.[13] It is assumed that the amount usable is half i.e. 7.5/Seers/Cow/day.

It is also assumed that 2/3 of the total usable amount is used for domestic energy and the rest 1/3 (2.5 Seers/Cow/day) is used for fertilizer. Cost of usable animal waste is Tk. 4/MD.

vii) Price of Farm Waste:- Tk. 90/acre/Season.[14]

viii) Fertilizer:- $\frac{4}{3}$ MD of urea @ Tk. 60/MD[14] and $\frac{8}{3}$ MD of T.S.P. @ Tk. 50/MD is used per acre per season.

ix) M/C Irrigation:- Total irrigation cost with 2 cusec Low Lift pump (including subsidy rate of rental @ Tk. 600/pump/Season[15]) is considered .

x) Expected Working life of Bullocks:- 10 years.

xi) Working hour:- 8 hours/day for hired labour.

xii) Cost of Labour:- Tk. 5/- per 8 man-hr.

xiii) Total Man-hr:- (for various types of Skilled farm works) - 600/acre/Season.[16]

xiv) External man-hr:- 500 acre/season(for family size varying from 4 to 6)
-400 acre/Season (for family size varying from 7 to 10)[16]

xv) Internal manpower:- 1 man(for family size varying from 4 to 6)
2-man (for family size varying from 7 to 10)

xvi) Cost of Meal:- An average figure of carbohydrate/ person/day of 2500 kcal is taken, which is 1.5 lb of rice - equivalent, i.e. Tk. 2.25/person/day for 3 meals/day.

xvii) Cost of Animal food:- Tk. 1.50 /Animal/day.

xviii) Cost of Fire wood - Tk. 20/MD.

xix) Cooking energy:- BUET survey[13] showed that cooking and lighting energy consumption increased with the farm size/capita. The curve for cooking-energy consumption(fire-wood equivalent) is approximated to a linear increase upto 6 acres(assuming a family size of 7) and then to remain constant to a cost of Tk. 350/-.

xx) Lighting Energy:- [redacted] Also the curve of lighting energy consumption vs farm size per capita is approximated to a linear increase upto 10 acres(assuming a family size of 7) and then to remain constant to a cost of Tk. 126.

5.2.1 CALCULATION OF FARM SURPLUS FOR A FARM SIZE OF TWO ACRES IRRIGATED BY DIESEL ENGINE(SUBSIDIZED).

Data:- Family size = 7

No. of Working members = 2

No. of Bullocks = 2

A) FARM INCOME:-

		TAKA
i)	Annual Crop-Production- 200MD.	14,000
ii)	Farm-Waste- @ Tk.90/-per acre per season. 2x2x90.	360
iii)	Animal-Waste-7.5Seer/day/cow @ Tk.4/MD. $\frac{7.5x2x365x4}{40}$	550
	Total	14,910

B) FARM EXPENDITURE:-

i) Fertilizer-

Urea 4/3MD/Acre/Season
@ Tk. 60/MD. 4/3x2X2X60= 320

T.S.P.- 8/3MD/Acre/Season
@Tk. 50/MD. 8/3 X2X2x50= 640

} 960

Animal Waste- 2.5 Seer/day/Cow
@ Tk. 4/MD. $\frac{2.5X\ 2X365X4}{40}$ = 183

Total 1,143

B.F:1,143

2) M/C Irrigation (Diesel)

@ Tk.300/acre/Season 2x2x300 = 1,200

(Govt.Subsidized)

3) Animal Financing-

Loan = Tk. 4000/-payable in 10 years for buying 2 bullocks.

(Depreciation)

Loan recovery per year-Tk. 400/-)
Interest 10% -Tk. 400/-) 800

4) External manpower(12) $\frac{400x2x2x5}{8}$ = 1,000

5) Seed- 15 Seer/Acre/Season $\frac{15x2x2x100}{40}$ = 150
@ Tk.100/MD.

6) Food for family-@Tk.2.25/person/diem
(an average village meal)2.25x7x365 = 5,748

7) Animal Food-@Tk.1.50/Animal/day 2x15x365 = 1,095

8) Kerosene Oil for lighting
= 70 lb(13)@ Tk. 1/-per lb. = 70

9) Fire wood for cooking (13)
= 779 lb (Fire-wood equivalent)
= 9.5 MD. @ Tk.20/MD. 20x9.5 = 190

Total =11,396

Farm Income -		..	Tk. 14,910
Farm Expenditure		..	Tk. 11,396
Farm Surplus		..	Tk. 3,514
Surplus/Cap/Yr.	$\frac{3514}{7}$	..	Tk. 502

5.3 GENERALIZED EQUATION FOR CALCULATING FARM SURPLUS FOR 2 CROPS PER YEAR, FOR SUBSIDIZED IRRIGATION.

5.3.1 SYMBOLS USED

A	=	Land area in acres.
FS	=	Farm Surplus.
FSC	=	Farm surplus per capita
FI	=	Farm Income
FE	=	Farm Expenditure
CV	=	Crop Value.
PFW	=	Price of Farm Waste
PAW	=	Price of Animal Waste
FC	=	Fertilizer Cost.
IC	=	Irrigation Cost.
AF	=	Animal Financing.
EMP	=	Price of External Manpower.
SC	=	Seed cost.
FF	=	Cost of Food for Family.
PAF	=	Price of Animal food.
LC	=	Lighting cost.
CC	=	Cooking Cost.
B	=	No. of Bullocks.
N	=	No. of Family Members.

5.3.2 EQUATION:-

$$FS = FI - FE$$

$$= (CV + PFW + PAW) - (FC + IC + AF + EMP + SC + FF + AF + LC + CC) \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Now using various data from the survey, and other assumptions made in Section 5.2.

CV = 7000 A

PFW = 180 A

PAW = 275 B

FC =480A+91.5B

IC =1800A=$300I_f$A (for Human muscle power irrigation)

= 600A=$300I_f$A (for Diese powër irrigation)

= 300A=$300I_f$A (for Electric power irrigation)

AF =400B

EMP=500A=500A M_f (for N = 7 to 10)

=600A=500AM_f (for N = 4 to 6)

SC =75A

FF =821.25N

PAF=547.5B

LC =7(A-1)+63, for $1 < A < 10$

=126, for A > 10 (13)

$=7(\frac{K}{L_f} A - 1) + 63$

CC =40(A-1)+150, for $1 < A < 6$

=350, for A> 6

$=40 (\frac{C}{C_f} A - 1) + 150$

<u>CONSTANTS:</u>

Irrigation cost factor, I_f=6.0(for human muscle power irrigation)

=2.0(for Diesel power irrigation)

=1.0 (For Electric power irrigation).

External Manpower factor,M_f=1.0 (for N=7 to 10)

=1.25(for N= 4 to 6)

Lighting cost factor = $\frac{K}{L_f}$, $\frac{K}{L_f}$ =1.0, $1 < A < 10$

$K = 10$, $L_f = A$, $A > 10$

Cooking cost factor = $\frac{C}{C_f}$, $\frac{C}{C_f}$ =1.0, $1 < A < 6$

$C = 6$, $C_f = A$, $A > 6$

From (1)

$$FS = 7000A + 180A + 275B - \Big[480A + 91.5B + 300I_f.A + 400B + 500A.M_f + 75A + 821.25N + 547.5B + 7(\frac{K}{L_f}A-1) + 63 + 40(\frac{C}{C_f} -1)+150\Big]$$

or,

$$FS = (7000 + 180)A - \Big[(480+300I_f + 500M_f + 75)A + 7(\frac{K}{L_f} + 40\frac{C}{C_f})A\Big] + (275-91.5-400-547.5)B - 821.25N - 166$$

or, $$FS = 6625A - (300I_f + 500M_f + 7\frac{K}{L_f} + 40\frac{C}{C_f})A - 764B - 821.25N - 166 \quad .. \quad .. \quad .. (2)$$

$$FSC = \frac{FS}{N} \quad .. \quad .. \quad .. \quad .. (3)$$

5.3.3 **CHECK** :-

For the 2-acre typical family

$A = 2$, $I_f = 2$, $M_f = 1$, $\frac{K}{L_f} = 1$, $\frac{C}{C_f} = 1$

$B = 2$, $N = 7$

From eQ-(2)

$FS = 6625 \times 2 - (300\times2+500\times1 + 7+ 40)2-764\times2$

$- 821.25\times7 - 166$

$= 13250-(600+500+47)2-1528-5748.75-166$

$= 13250 - 2294 - 1528 - 5748.75 - 166$

$= 13250 - 9736$

$= 3514$

$FSC= \frac{3514}{7}$ = Tk. 502.

5.3.4 GENERALIZED EQUATION OF FARM SURPLUS FOR SELF INVESTED IRRIGATION.

It is now considred necessary to investigate the effect on farm surplus in case the rural region is already electrified, and the farmer wishes to own his diesel engine or electric motor driving 2 cusec low lift pumps. This, of course, assumes that suitable source of water is also available so as to be able to use LLP's.

Cost figures of 2 cusec, 15 hp, diesel and electric pumps are Tk. 30,000 and Tk. 20,000 respectively, sold at a reduced rate to farmers interested in buying the irrigation machinery outright, supplied by Bangladesh Agricultural Development Corporation.

Let C = Capital cost of the pump and engine(or motor)

Then C= 20,000 E_c, where —

E_c = 1.5 for diesel irrigation

= 1.0 for electric irrigation.

Interest @ 10% = 2000 E_c .. .. .. (4)

Depreciation (with engine life=15yrs) = $\frac{20000\ E_c}{15}$

= 1333 E_c.

Annual Fixed Cost= Interest + Depreciation

= 3333 E_c . . .. (5)

Let OC = Operation and maintenance cost

OC = 100.M_c.A ; where Mc =1,for electric irrigation

=2,for diesel irrigation.

Irrigation cost, IC = C + OC

=3333 E_c+100Mc.A . . ..(6)

$$F\ S=6625A-(100Mc+500Mf+7\frac{k}{Lf}+40\frac{c}{Cf})A$$

$$-3333\ E_c-764B-821.25N-166. \quad .. \quad ..(7)$$

The above formula would be applicable if the farmer desired to operate one or the other source of energy,but not at the same time.

5.4 COMBINATION OF SOURCES OF ENERGY WITH TRANSMISSION LINE INSTALLED.

So far, the irrigation costs and other aspects with both subsidized and self-invested irrigation-using diesel and electric power, for small farm size has been considered. The study was confined to the electrified areas only which required no transmission line cost. In the following sections the case with transmission line cost is being considred for a larger farm size.

5.4.1 ALTERNATIVE ENERGY SOURCE FOR IRRIGATION

Although irrigation is cheaper with electric energy, the probability of interruption, specially with a distribution line of some length, may require to make alternate arrangements(Diesel engines), specially for larger farm sizes and at peak season of irrigation.

Let us consider a farm size (needing irrigation water) of 30 acres. The command area of a 2 cusec LLP is 14-24 acres.[11] The figure on command area is low becuase of institutional problems of management and other factors. But if the farmer uses his own engines, the command area may increase and a 2 cusec electric pump may be sufficient to irrigate . 30 acres of land. But due to the problem of unreliability of electric power, the farmer may also buy a 2-cusec diesel pump to substitue during the periods of interruption.

From previous data, quantity of irrigation water required per acre = 3.33 million gallons, i.e. 100 million gallons for 30 acres.

Annual Fixed Cost:- As a typical realistic case,

Cost of Transmission line	= Tk.	30,000
Cost of 2cusec, 15HP, Electric pump	=Tk.	20,000
Cost of 2 cuse, 15HP, diesel pump	=Tk.	30,000
Total	=Tk.	80,000

Assuming life of Engine, motor and transmission line to be 15 yrs.—

$$\text{Depreciation} = \frac{80,000}{15} = \text{Tk. } 5,333$$

Interest @ Tk.10% = Tk. 8,000

= Tk.13,333

Operating Cost:-

For diesel pump, operating cost = Tk. 100/million Gallons of Water.

For electric pump, operating cost= Tk.50/Million galls. of Water.

Total irrigation cost, if the total 30 acre land is irrigated by the Electric pump is—

Tk.13,333 + Tk,5,000 = Tk. 18,333.

And the cost, when the land is irrigated by the diesel pump would be—

Tk.13,333 + Tk.10,000 = Tk.23,333.

As a combination of both the diesel and electric pump is necessary (to substitute during the periods of the interruption),—the figure of the total irrigation cost of Tk. 20,000 forthe combination, may perhaps be chosen, in a realistic way.

Thus, fund available for operating cost=

= 20,000-13,333 = 6667.

Now,let G_D= Quantity of Water to be lifted by the diesel pump(in million gallons).

GE = Quantity of water to be lifted by the electric pump (in million gallons).

Therefore,

$100G_D + 50\ G_E = 6667$ .. .. (i)

Also $G_D + G_E = 100$ .. .. (ii)

From (ii), $100\ G_D + 100\ G_E = 10000$ .. .. (iii)

Substracting(i) from (iii) we get —

$50\ G_E = 3333$

$\therefore G_E = 66.67$ million gallons.

$G_D = 33.37$ million gallons.

5.4.2 FARM SURPLUS

Farm size, A = 30

No. of Bullocks, B = 18

Family Member, N = 10

Irrigation Cost IC = 20,000

$\therefore$ FS = 6125A -764B -821.25N-476 -20,000

= 6125 X30 -764x18-821.25 X 10 -476-20000

= Tk. 140,710.

$$\therefore \text{FSC} = \frac{140,710}{10} = \text{Tk. } 14,071.$$

It is necessary to remember that the above figure on FSC is for a single family only, giving a high per capita surplus income. It is likely that the above type of calculations applied to co-operative farming with contribution of land, bullocks, working members and portions of fixed costs, and with irrigation water managed judiciously, in the way indicated above, per capita income for each member of each seperate family would perhaps rise to some extent.

5.5 OPTIMUM COMBINATION OF SOURCES OF IRRIGATION ENERGY

(Irrigation Energy management by Linear Programming)

Let us consider a farm size of 50 Acres to be irrigated by a 3 cusec, 20 hp, electric pump and a 15hp, 2 cusec, disel pump. Water required is — 3.33 Million gallons per acre. The electric pump costs Tk. 25,000/- and the transmission line cost is Tk. 30,000/-. Operating cost per hour is Tk. 4.40 for the diesel pump and TK.3.00 for the electric pump.

Availability of diesel and electric is assumed to be 70% and 60% respectively. It is required to find the operating period of each of the two pumps with minimum cost.

Solution:-

Water required = $3.33 \times 10^6 \times 50 = 166 \times 10^6$ glns.

Water discharge per hour of the diesel pump = $22 \times 10^3 \times 2 = 44 \times 10^3$ glns.

Water discharge per hour of the electric pump = $22 \times 10^3 \times 3 = 66 \times 10^3$ glns.

The maximum uninterrupted combined working hour (assuming 8 months of irrigation period, 10 hours per day) is - $30 \times 8 \times 10 \times 2 = 4800$ hours.

Assuming an over-all availability of about 2/3 (63%), total operating period of the two pumps (combined) is - $4800 \times 0.63 = 3020$ hours.

<u>The Linear Programming Model:</u> Therefore takes the form:-

Let X_1 = Operating hours of the diesel pump

X_2 = Operating hours of the electric pump.

Then the problem is to Minimize —

$$Z_x = 4.4\, x_1 + 3.0\, x_2$$

With the constraints——

$$X_1 + X_2 \geqslant 3020$$

$$44x_1 + 66x_2 \geqslant 166 \times 10^3$$

$$\text{or, } 4x_1 + 6x_2 \geqslant 15000$$

<u>Dual Problem:-</u>

Maximize - $Z_y = 3020\, Y_1 + 15000\, Y_2$

with the constraints —

$$Y_1 + 4Y_2 \leqslant 4.4$$

$$Y_1 + 6Y_2 \leqslant 3.0$$

<u>Equivalent Model:-</u> Introducing slack variables to consider the inequality, the equivalent model becomes

(o) $Z_y - 3020\, Y_1 - 15000\, Y_2 = 0$

(1) $Y_1 + 4Y_2 + Y_3 = 4.4$

(2) $Y_1 + 6Y_2 + Y_4 = 3.0$

<u>Simplex Tableau:-</u>

Basic Variables	Co-efficients of Z_y	Y_1	Y_2	Y_3	Y_4	Right side of equation
Z_y	1	-3020	-15000	0	0	0
Y_3	0	1	4	1	0	4.4
Y_4	0	1	6	0	1	3.0

Ist. Iteration:-

Considering the first row, the smallest co-efficient is—15000. So, Y_2 is taken as the new entering basic variable. Again, $\frac{3.0}{6} < \frac{4.4}{4}$. So Y_4 is chosen as the leaving variable. Dividing the 3rd row by 6

	Z_y	Y_1	Y_2	Y_3	Y_4	
Z_y	1	-3020	-15000	0	0	0
Y_3	0	1	4	1	0	4.4
Y_4	0	1/6	1	0	1/6	0.5

Multiplying 3rd row by 15000 and adding with Ist row; multiplying 3rd row by 4 and substracting from 2nd row, we get,

	Z_y	Y_1	Y_2	Y_3	Y_4	
Z_y	1	-520	0	0	2500	7500
Y_3	0	1/3	0	1	-2/3	2.4
Y_2	0	1/6	1	0	1/6	0.5

2nd Iteration:-

Again, considering Ist row, Y_1 is selected as the new entering variable and Y_3 is chosen as the leaving variable.

Multiplying the 2nd row by 3,we get,

	Z_y	Y_1	Y_2	Y_3	Y_4	
Z_y	1	-520	0	0	2500	7500
Y_3	0	1	0	3	-2	7.2
Y_2	0	1/6	1	0	1/6	0.5

Multiplying 2nd row by 520 and adding with Ist row, Dividing 2nd row by 6 and substracting 3rd row from it, we get—

	Z_y	Y_1	Y_2	Y_3	Y_4	
Z_y	1	0	0	1560	1460	11,244
Y_1	0	1	0	3	-2	7.2
Y_2	0	0	-1	½	-½	0.7

Therefore, for the original problem, for minimum cost, operating period for the diesel pump should be 1560 hours and that for the electric pump should be 1460 hours.
Total operating cost = 11,244.

5.5.1 FARM SURPLUS:-

Annual Fixed Cost: Depreciation + Interest @ 10%

$$= \frac{25,00 + 30,00 + 30,000}{15} + \frac{85,000}{10}$$

$$= 5667 + 8500 = 14,167$$

Annual Operating cost= 11,244

∴ Irrigation cost I C = 14,167 +11,244 = 25,411

Farm Size, A = 50

Family Members, N = 10

No. of Bullocks, B = 28

$$FS = 6125A - 764B - 821.25N - 476 - 25,411$$

$$= 6125 \times 50 - 764 \times 28 - 821.25 \times 10 - 476 - 25,411$$

$$= \text{Tk. } 250,759$$

$$FSC = \frac{250,759}{10} = \text{Tk. } 25,076/\text{Year.}$$

Rate of rise of surplus income/cap, by following a better methodology of irrigation water management is seen to be higher compared to that shown in section 5.4.2, as shown below :-

$$\% \text{ Increase of land size} = \frac{50-30}{30} \times 100 = 66.67\%$$

% Increase of Surplus income/cap.

$$= \frac{25076-14071}{14071} \times 100 = 78.21\%$$

This reflects the advantage of efficient management of electrical energy for irrigation.

TABLE-12

DATA FOR FARM SURPLUS WITH HUMAN

MUSCLE POWER IRRIGATION

FAMILY SIZE - 7

NO. OF BULLOCKS = 2

SL. No.	FARM SIZE (ACRE)	FARM SURPLUS/CAP (TAKA)	FARM SURPLUS STARTS AT FARM SIZE (ACRES)
1	0.5	-757	
2	0.8	-575	
3	1.0	-452	
4	1.2	-330	
5	1.5	-146	1.75
6	1.8	+20	
7	2.0	+159	
8	2.2	+2.75	
9	2.5	+464	
10	3.0	+768	

TABLE-13.

DATA FOR FARM SURPLUS WITH DIESEL POWER IRRIGATION(SUBSIDIZED)

FAMILY SIZE = 7.

NO. OF BULLOCKS = 2.

SL. NO.	FARM SIZE (ACRE)	FARM SURPLUS/ CAP/YR (TAKA)	FARM SURPLUS STARTS AT FARM SIZE (ACRE)
1	0.5	-672.00	
2	0.8	-450.00	
3	1.0	-280.57	
4	1.2	-140.00	
5	1.5	+110.00	1.39
6	1.8	+325.00	
7	2.0	+502.00	
8	2.2	+650.00	
9	2.5	+893.29	
10	3.0	+1283.00	

TABLE-14

DATA FOR FARM SURPLUS WITH

ELECTRIC IRRIGATION(SUBSIDIZED)

FAMILY SIZE - 7

NO. OF BULLOCK = 2.

SL. NO.	FARM SIZE (ACRE)	FARM SURPLUS/CAP/YR (TAKA)	FARM SURPLUS STARTS AT FARM SIZE (ACRE)
1	0.5	-650	
2	0.8	-420	
3	1.0	-237	
4	1.2	-80	
5	1.5	+175	1.31
6	1.8	+400	
7	2.0	+587	
8	2.2	+750	
9	2.5	+1000	
10	3.0	+1411	

TABLE-15

DATA FOR FARM SURPLUS WITH DIESEL POWER IRRIGATION (SELF INVESTED)

FAMILY SIZE = 7

NO. OF BULLOCKS = 2.

SL NO.	FARM SIZE (ACRE)	FARM SURPLUS/CAP/YR (TAKA)	FARM SURPLUS STARTS AT FARM SIZE (ACRE)
1	1.0	-937	
2	1.5	-520	
3	2.0	-98	
4	2.5	+325	2.10
5	3.0	+740	
6	3.5	+1160	
7	4.0	+1581	
8	4.5	+2000	
9	5.0	+2420	
10	5.1	+2500	

TABLE-16

DATA FOR FARM SURPLUS WITH ELECTRIC POWER IRRIGATION (SELF INVESTED)

FAMILY SIZE - 7

NO. OF BULLOCKS-2

SL. No.	FARM SIZE (ACRE)	FARM SURPLUS/CAP/YR (TAKA)	FARM SURPLUS STARTS AT FARM SIZE (ACRE)
1	1.0	-685	
2	1.5	-280	
3	2.0	+168	
4	2.5	+560	
5	3.0	+1021	1.85
6	3.5	+1450	
7	4.0	+1877	
8	4.5	+2300	
9	5.0	+2730	

FARM SIZE Vs SURPLUS
(PARAMETER -IRRIGATION METHOD)
FAMILY SIZE- 7
NO. OF BULLOCKS-2

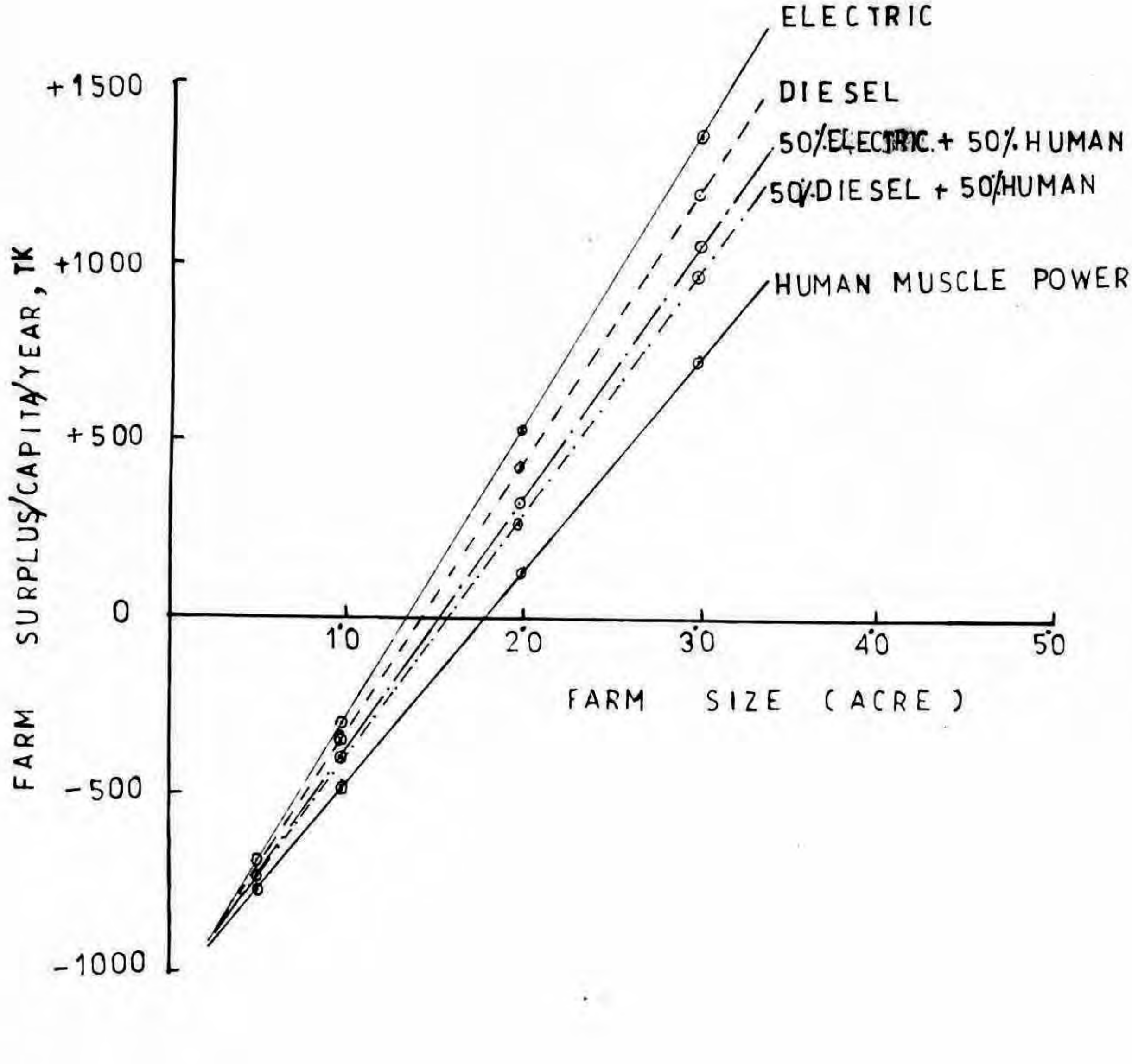


FIG- 27

FARM SIZE vs FARM SURPLUS

(PARAMETER - NO. OF BULLOCKS)

FAMILY SIZE - 7

DIESEL IRRIGATION

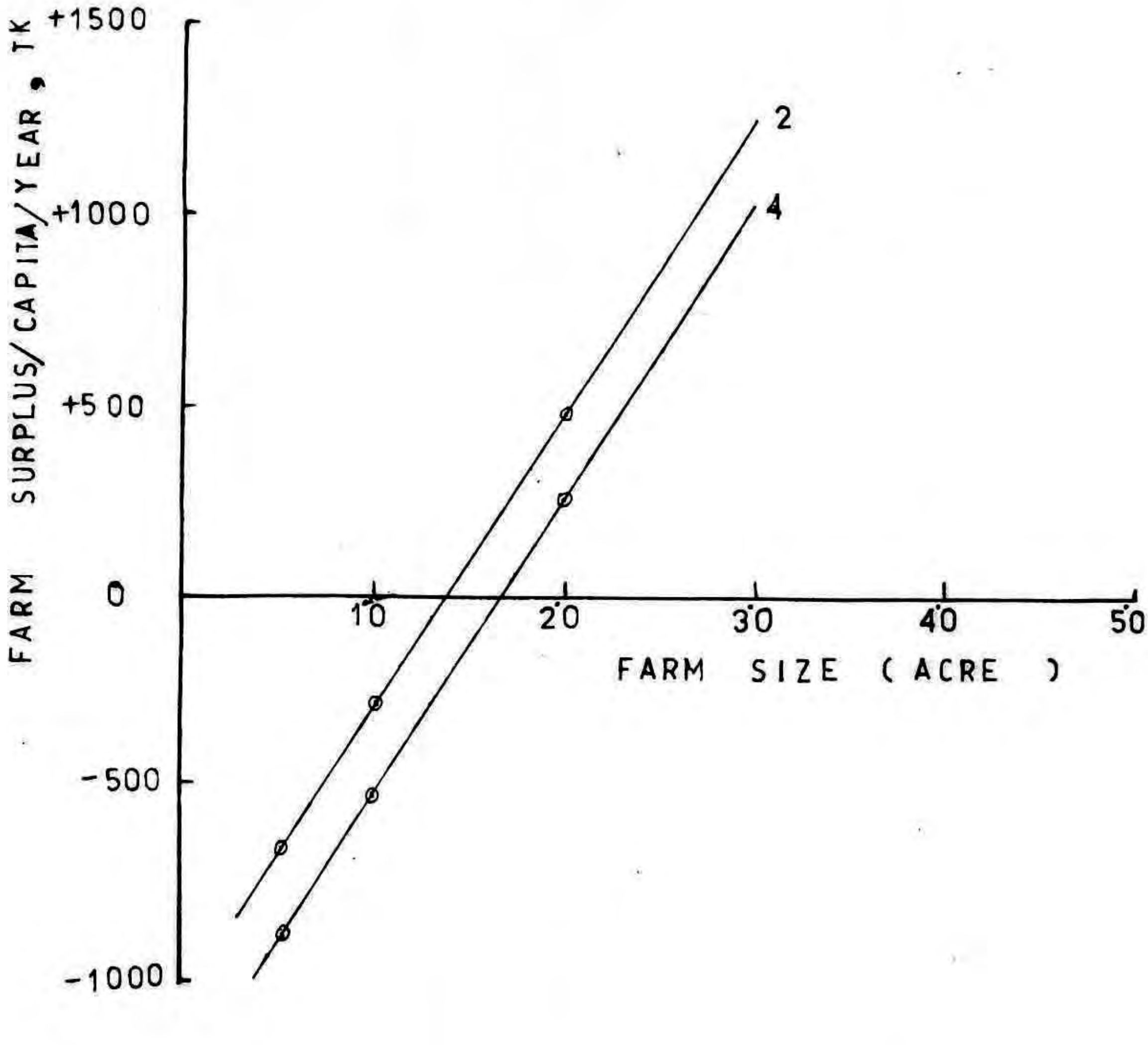


FIG- 28

FARM SIZE VS FARM SURPLUS

(PARAMETER - FAMILY SIZE)

NO. OF BULLOCKS - 2

DIESEL IRRIGATION

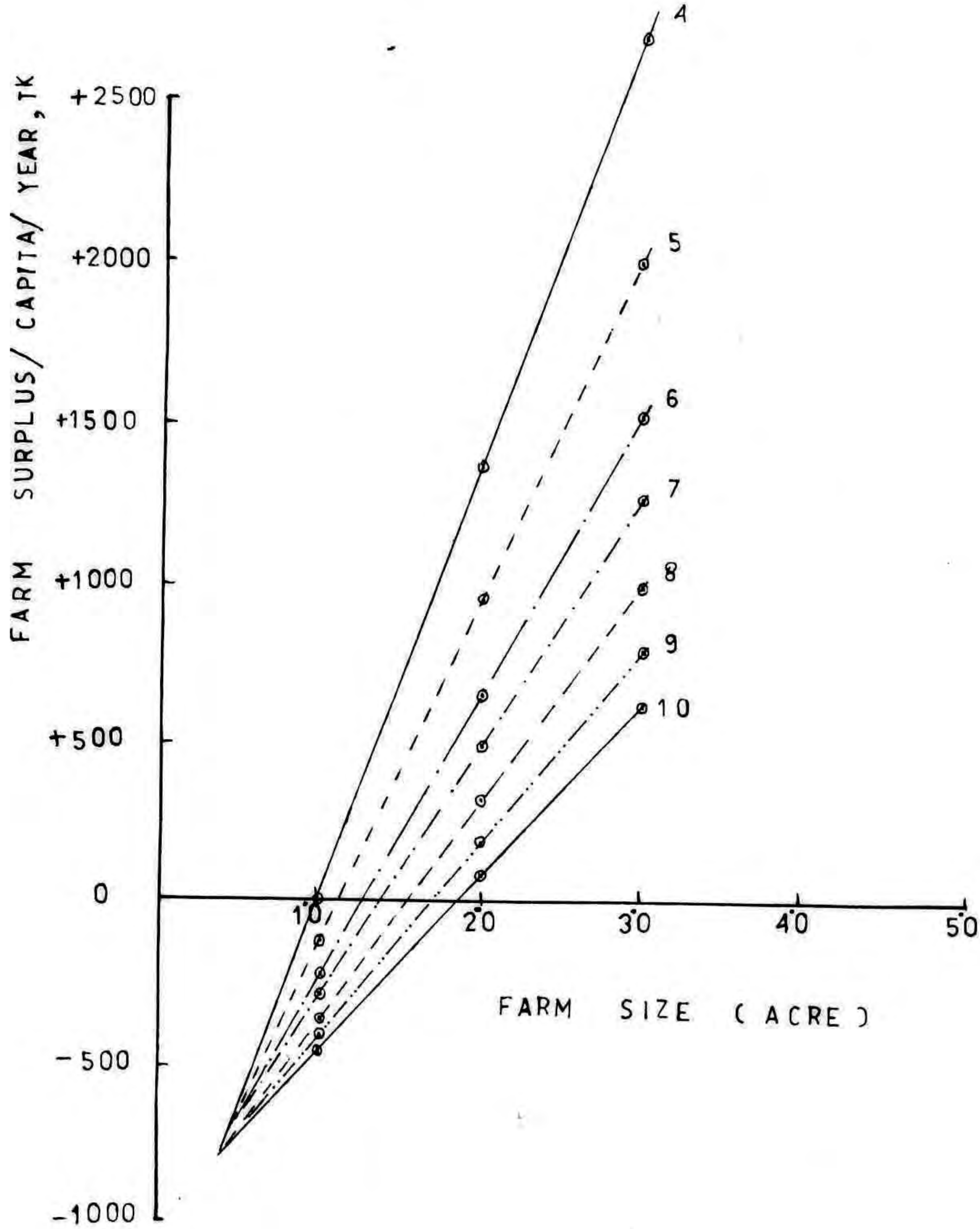


FIG- 29

FARM SIZE vs FARM SURPLUS
(PARAMETER - FAMILY SIZE)
NO. OF BULLOCKS - 2
ELECTRIC IRRIGATION

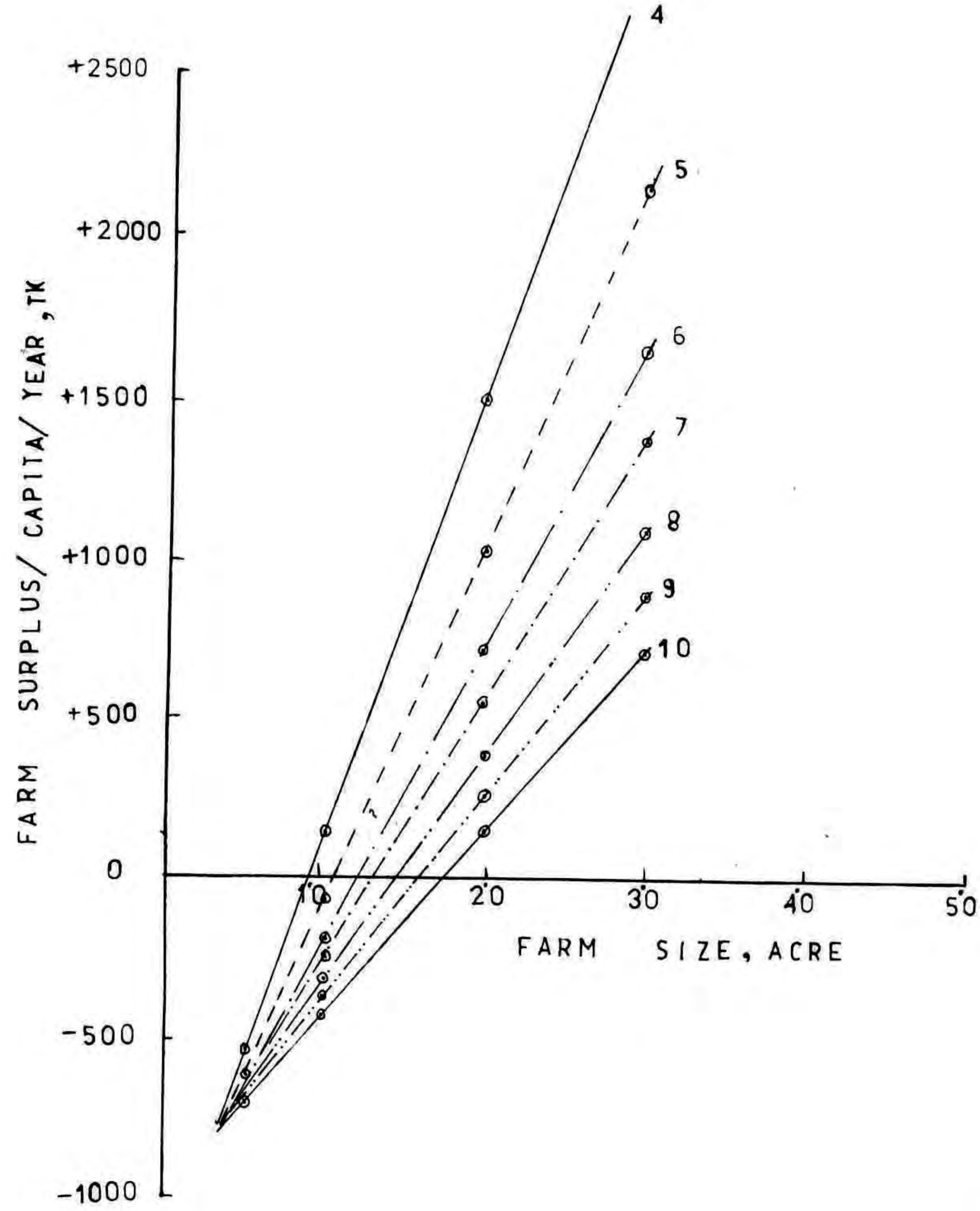


FIG- 30

FARM SIZE VS FARM SURPLUS

(PARAMETER - FERTILIZER COST)

FAMILY SIZE - 7
NO. OF BULLOCKS - 2
ELECTRIC IRRIGATION

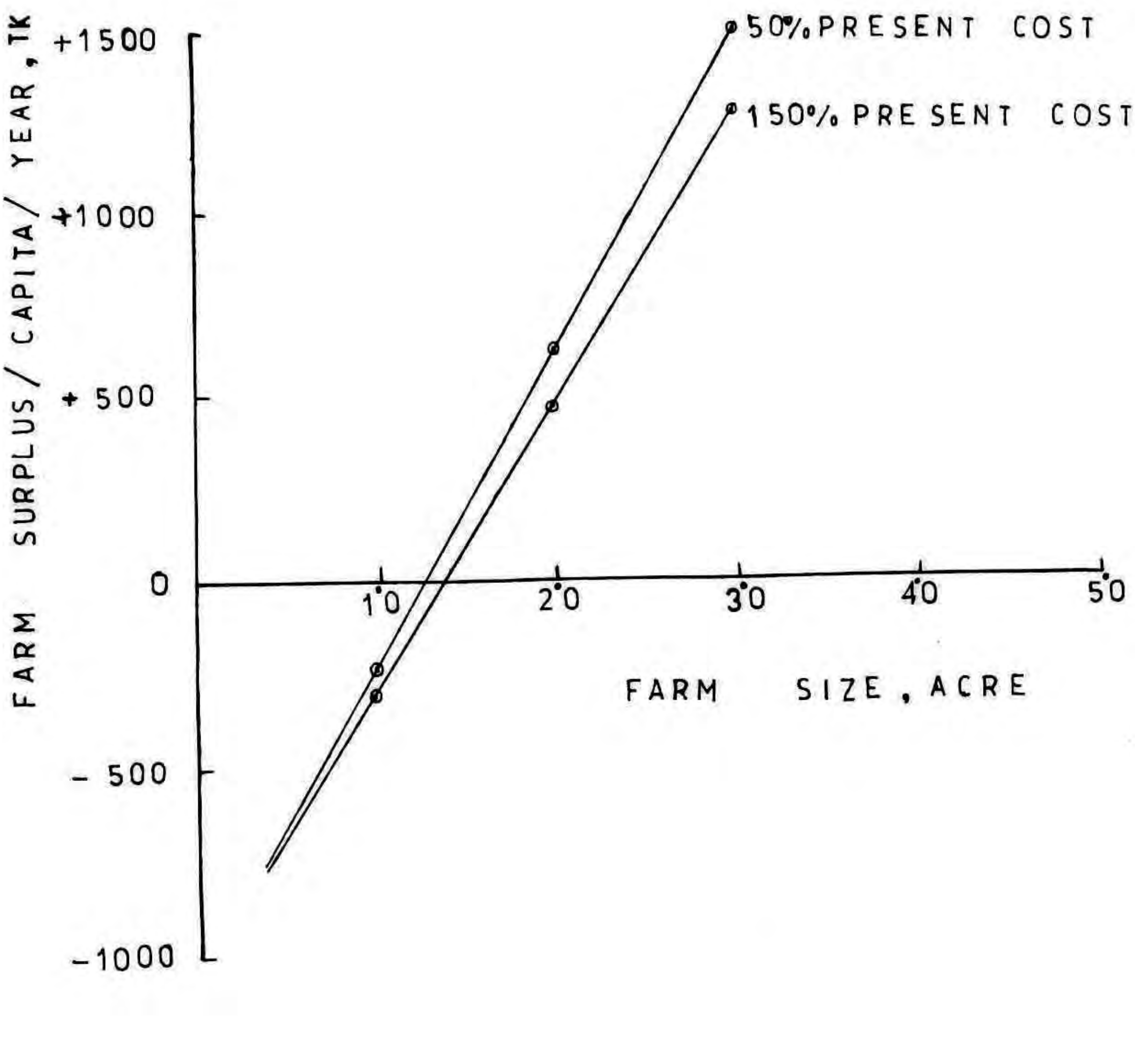


FIG- 31

FARM SIZE VS SURPLUS
(PARAMETER - FERTILIZER COST)
FAMILY SIZE - 7
NO OF BULLOCKS - 2
DIESEL IRRIGATION

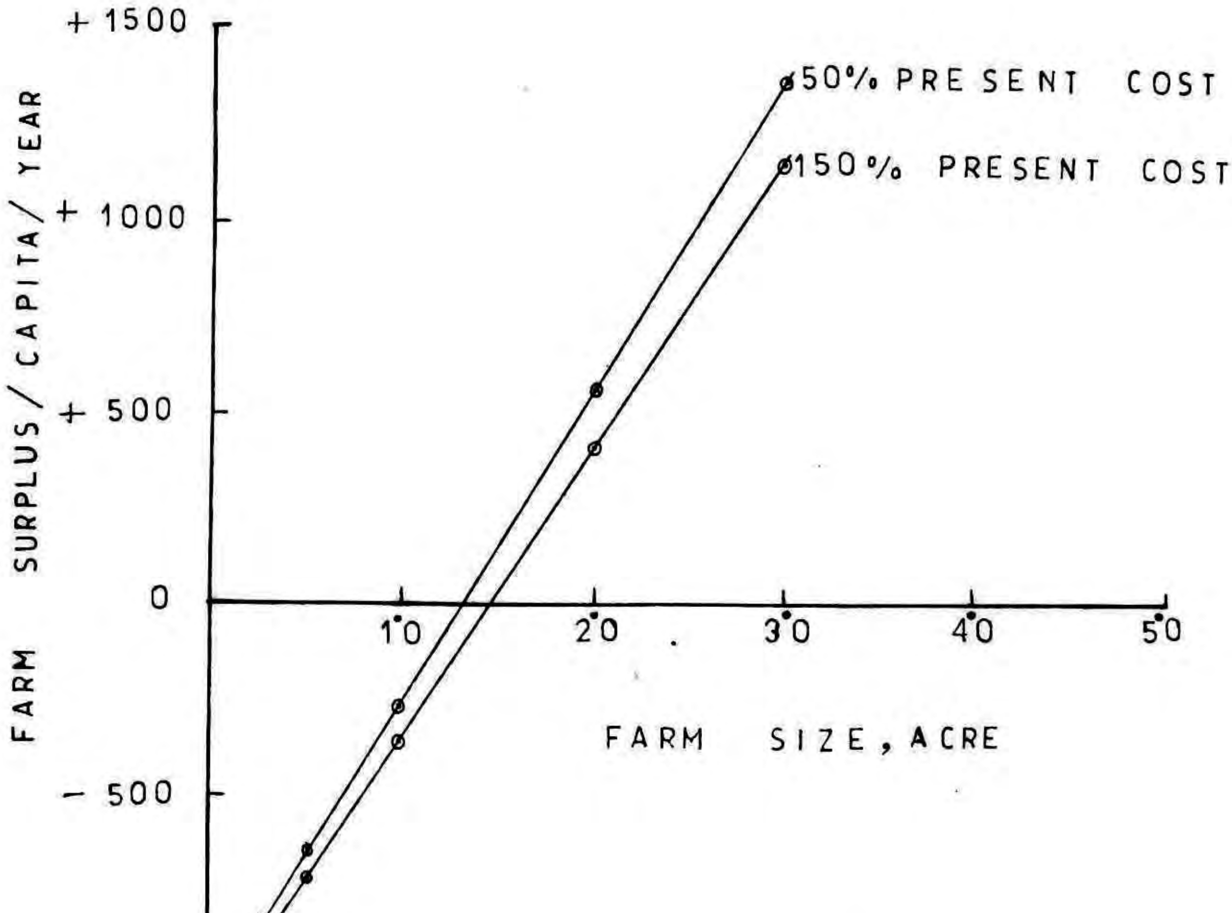


FIG- 32

FARM SIZE vs SURPLUS

(PARAMETER - SELF-INVESTED IRRIGATION)

ELECTRIFIED AREA

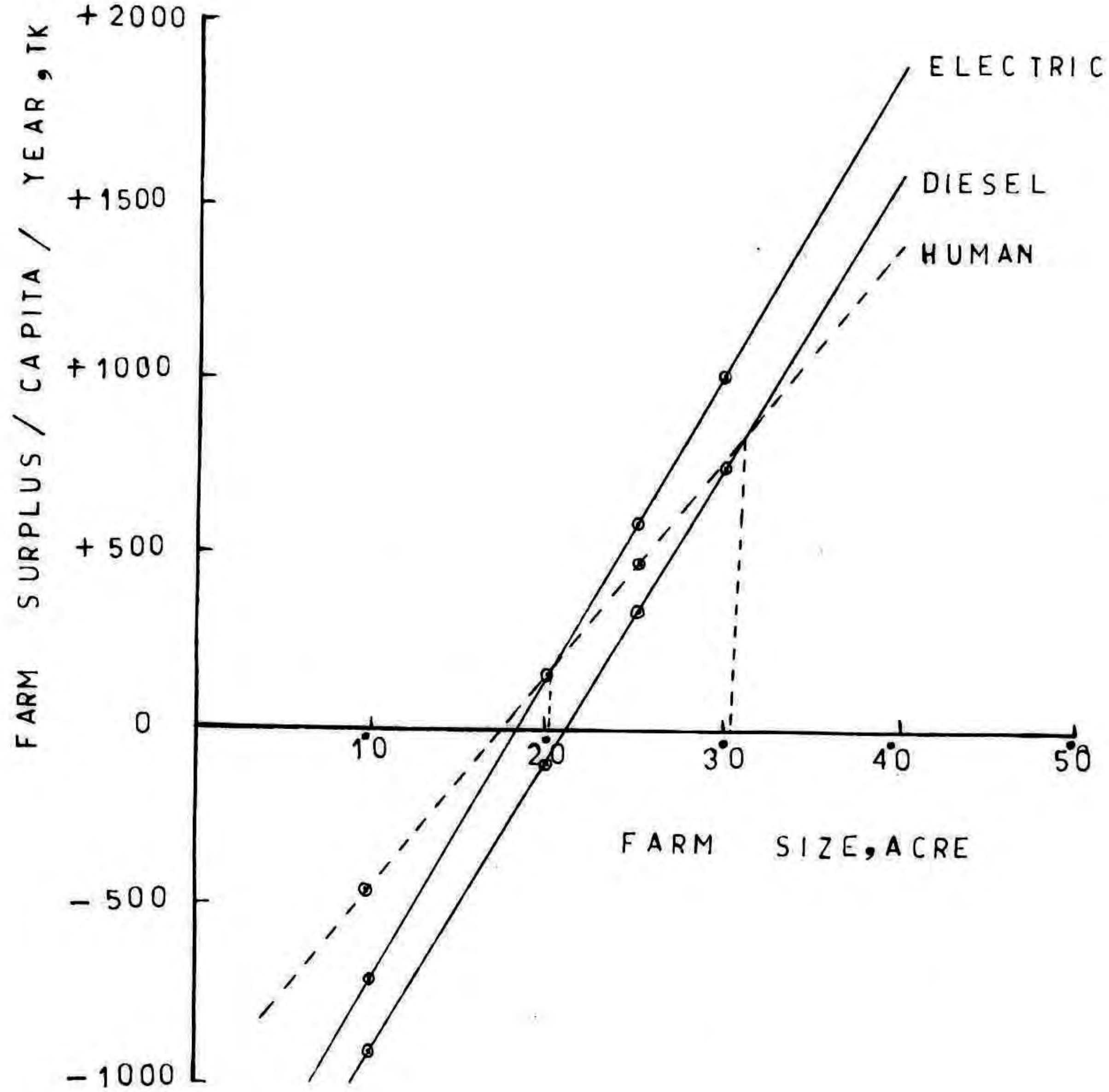


FIG- 33

FARM SIZE vs FARM SURPLUS
(SELF INVESTED)
PARAMETER - IRRIGATION METHOD
UNELECTRIFIED AREA

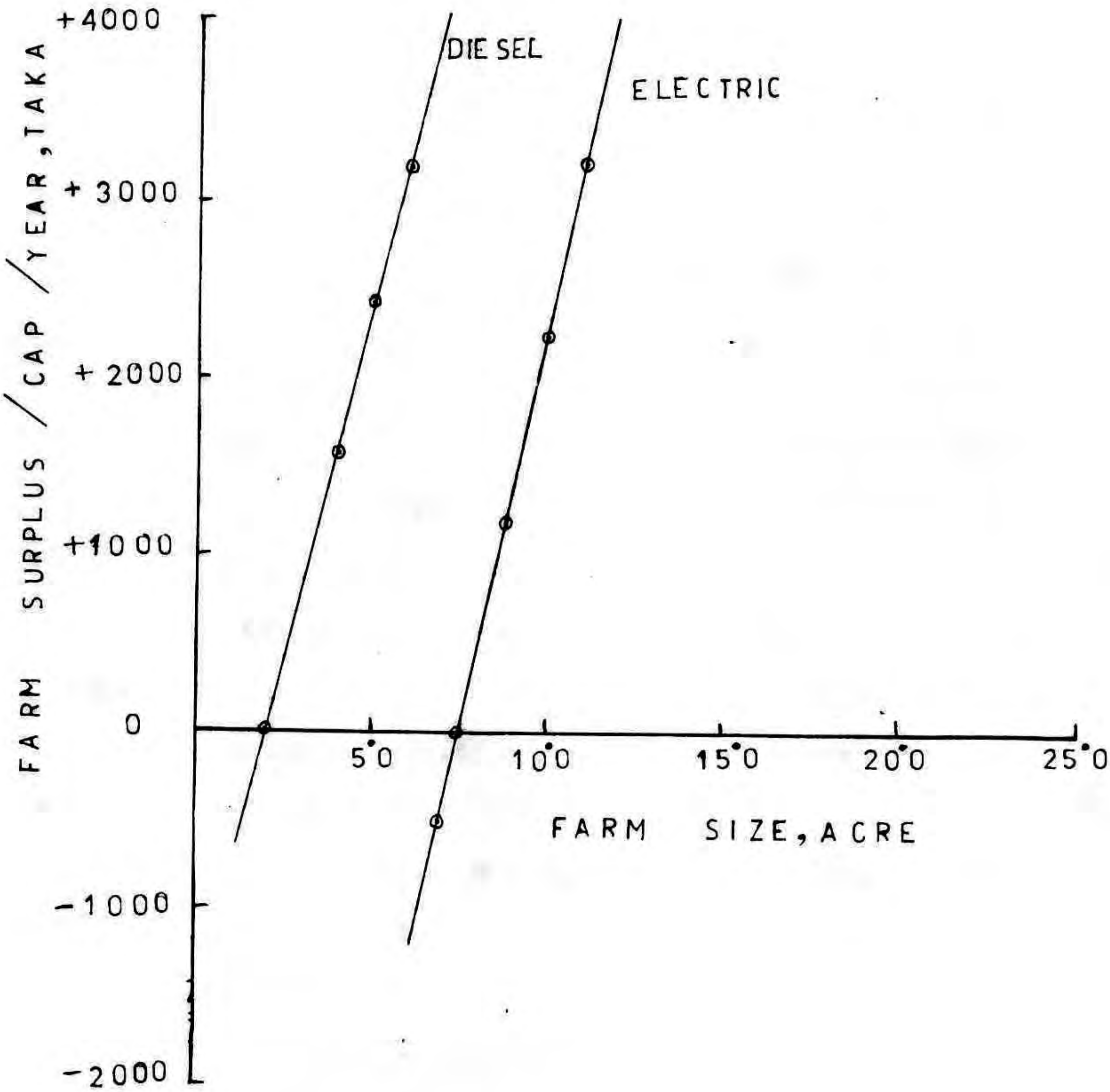


FIG- 34

CHAPTER-VI

DATA - ANALYSIS

6.1 POTATO-IRRIGATION

With human muscle power, the irrigation cost per acre is - Tk. 150/-; water utilized per acre is - 45,000 Gln, Crop production per acre is - 175 Md, whereas, with diesel power, the irrigation cost is- Tk. 125/- per acre, water utilized per acre is - 58,000 Gln and crop production per acre is- 190 Md. as seen from figs. 7,9 and 10 respectively. Also from fig.5, we see that with human muscle power, 100 X 10^3 Gallons of Water is lifted with an energy input of 265 man-hrs and with machine power, same quantity of water is lifted by an energy input of 62 hp-hr. From fig.6, it is observed that with human muscle power, 100X10^3 gallons of water is lifted with a cost of Tk. 330/-,whereas, with machine power, same quantity of water is lifted with a cost of Tk. 215/- only,

So, it is seen that with muscle power, with20% more irrigation cost, water lifted per acre and crop production per acre is 22.4% and 7.8% less than those with machine power. Also we see that for lifting same quantity of water , man-hr required is 4.27 times of hp-hr, and the cost involved is 1.53 times with human muscle power.

6.2 HYV IRRIGATION-I.

6.2.1 MUSCLE POWER VS DIESEL POWER :

In HYV - irrigation, it is observed that - with muscle power, the irrigation cost per acre is - Tk. 960/-, water Utilized per acre is 1200 X 10^3 glns and crop production per acre is 73 Md., Whereas, with machine power, the irrigation cost per acre is 510/-;water utilized per acre is - 3150x10^3 glns.

and production per acre is 100 Md. as seen from figs.15, 17, and 16, respectively. Also from fig. 14, we see that with human muscle power, 2 X 10^6 gallons of water are lifted with an energy input of 2,750 man-hr and with machine power, the same quantity of water is lifted by an energy input of 720 hp-hr. And it is seen from figs.17 and 15 that the cost involved to lift this quantity of water is Tk. 1540/- and Tk.320/- for muscle power and machine power respectively.

So, it is clear that with diesel power, average water utilized and production per acre is 162% and 37% more respectively than those with muscle power. But with muscle power, the irrigation cost is - 1.88 times than that for machine power. Also we see that for lifiting same quantity of water, man-hr required is 3.82 times of hp-hr required and the cost involved with muscle power is 4.82 times of machine power.

6.2.2 HYV IRRIGATION-II

Diesel Power VS electric power:-

It is observed from table-6 that with diesel power, the irrigation cost is double that of electric power. And from figs. 22 & 23, it is seen that with diesel power, water utilized per acre is- 1.4 X 10^6 and production per acre is 40 Md and the figures for electric power are 1.8X10^6 and 42.5 respectively. However, it is seen from figs24 that cost of diesel is Tk. 160/- per acre and the electricity cost per acre is Tk. 90/-.

6.2.3 STANDARD DEVIATION OF COST DATA

In Potato irrigation the standard deviation of % Irrigation cost (with respect to crop value) is-0.747 for human muscle power irrigation and 0.302 for diesel power irrigation (Table-7). So the dispersion is greater for human muscle power irrigation.

In HYV-I irrigation, the standard deviation of % irrigation cost is 3.922 with human muscle ppwer irrigation and 0.912 with diesel power irrigation (Table-8).

In HYV-II irrigation, the standard deviation of % irrigation cost is- 1.369 with diesel power irrigation and 0.637 with electric irrigation(Table-9).

6.2.4 FARM -SURPLUS WITH VARIOUS PARAMETERS

Considering Tables. 11,11 and 12, it is clear that with human muscle power irrigation, Farm surplus starts at farm size 1.75 acre; whereas with diesel power irrigation farm size for surplus income is 1.39 acres and with electric power irrigation, farm surplus starts at 1.31 acres

Fig. 28 shows that as the number of bullocks increased from 2 to 4, farm size required for surplus income increased from 1.35 acres to 1.65 acres.

Figs. 29 shows that with diesel power irrigation, farm surplus decreased from Tk. 2750 to Tk. 650 as the number of family members increased from 4 to 10 for a farm size of 3.0 acres.

Comparing figs. 29 and 30 it is seen that for a farm size of 3.0 acres and a family size of 4 members- the farm surplus/cap/yr. is - Tk. 2750 for diesel power irrigation and Tk. 3000 for electric power irrigation. And with same farm size, for a family size of 10 members- the farm surplus /cap/yr. is only Tk. 650 for diesel power irrigation and Tk. 750 for electric power irrigation.

6.3 EFFICIECY OF MAN AS A MACHINE

With data obtained in this investigations, it is possible to attempt an estimate of human muscle power in comparison with other relevant sources of energy.

A) POTATO IRRIGATION

From fig.5, we see that for lifting 100×10^3 gallons of water,

man-hr required = 265

and hp - hr. required= 62

The equivalence, therefore is—

265 man-hr = 62 hp-hr.

or 1 man = 0.2334 hp(for normal daily working hour).

B) HYV-I IRRIGATION

From fig. 14, we see that for lifting 2×10^6 gallons of water,

man-hr required = 2750

and hp-hr required = 720

So, equivalence becomes—

2750 man-hr = 720 hp-hr.

or, 1 man = 0.262 hp (for normal working hr).

Hence the assumption of the power output of 1 man $\simeq$ ¼ hp.(for normal working hours) seems a reasonable quantitative relationship, in so far as irrigation energy, specifically is concerned.

CHAPTER-VII

D I S C U S S I O N

7.1. HUMAN MUSCLE POWER VS DIESEL POWER :

Traditional methods of irrigation using human muscle power show a fairly low efficiency of utilization. It is also economically not satisfactory as is found from the results of data on potato irrigation. Results from the data of HYV irrigation requiring irrigation—water about 40 times than that of potato-irrigation point out about the worst situation with the human muscle power-where the irrigation cost is about double that of diesel power, but quantity of water lifted is less than half and consequently the production suffers. However with muscle power irrigation, capital cost is very low, there is no institutional problem.

However, if these traditional systems can be somewhat modified, and improved and the effort put in to lift water to the fields made less energy-consuming, there can be a significant increase in the irrigated area. Research work on traditional irrigation implements may have considerable effect on the cost-factor involved.

7.2 DIESEL POWER VS ELECTRIC POWER,WITH SUBSIDIZED RATES AVAILABLE.

Comparison of diesel and electric irrigation under this condition, shows that the total irrigation cost (including security deposite, rental, electric connection charge, labour cost, payment of guard and machineman, fuel cost) is double with diesel than that of electric. The average figures on water utilization and crop-production is somewhat more with electric-irrigation.However,the crop-production is also dependant on soil-fertility.

7.3 FARM SURPLUS WITH DIFFERENT IRRIGATION METHODS

On determining the Farm Surplus income, it is found that with human muscle power irrigation,(irrigation "running cost" being considerably higher), to acheive surplus income,a greater farm size than that for diesel irrigation is required. With electric power irrigation, farm surplus starts with a smaller farm size and a higher surplus income can be acheived.

The situation is better with the human muscle power for a small farm size, when it is compared with other methods of self-invested irrigation. From the view-point of surplus-income,it is found to be economic to use these traditional methods for a farm size of 2 acres than to use a machine requiring high capital cost, even if made available at reduced promotional prices.

Use of electrical energy for irrigation purpose is economic if rural electrification schemes have materialized near the farmstead. For the unelectrified areas, large amount of expenditure is required to bring in the electrical facilities to the farmstead. With some realistic assumptions made for drawing distribution lines to the farm itself from rural electrification schemes existing in a nearby area,it is found that—to acheive surplus income,a farm size of more than about 8 acres would be necessary.

7.4 PROBLEMS WITH DIESEL POWER:

The capital cost of a 15 hp, 2 cusec diesel pump is Tk. 30,000 and that of an electric pump(same hp and pump capacity) is Tk. 20,000[17]. So, diesel pump has higher capital charges and also requires considerably skilled operation. With diesel power, effective command area may decrease somewhat because of a lost working hours due to engine trouble, inadequate repair facilities, scarcity of spare-parts and irregularity of fuel supply.

7.5 ADVANTAGES OF ELECTRIC POWER

Electrical pumps may acheive somewhat larger command areas with less engine breakdown, except for power interruption and have the advantage of needing little attention during the irrigation season. Electricity reduces the operation cost to about half— which is an incentive to the farmers to expand the irrigated area,provided electricity is available to them.

7.6 PROBLEMS WITH ELECTRIC POWER

7.6.1 PROBLEM OF AVAILABILITY OF ELECTRIC POWER

Through electric energy for irrigation comes out to be most economic and efficient, the hours of availability may be somewhat uncertain, too. There exists the adverse situations of electric interruptions, specially during the stormy weather. The situation would be aggravated further, reducing the availability factor considerably, if, in addition, a separate overhead distribution line is to be drawn to the farm from the nearest distribution centre or transformer station.

Therefore, for larger farms and during peak seasons of irrigation, it would be essential to keep an alternative (Diesel Engines) to tackle the situation of lack of availavility of electric energy. The problem of management of the energy sources so as to secure optimum economic return has been studied in detail in section 5.5.

7.6.2 PROBLEM OF TRANSMISSION LINE COST

The other main problem lying with the electric irrigation is the cost of transmission lines which is estimated as about Tk. 40,000 per pump(18). If a major part of this cost is allocated to household and some agrobased rural industries, electrically operated pumps will perhaps become more economic than have been proved in the study.

It is to be remembered that the economics of electrically operated deep tube wells have not been studied in this work. In cases where electricity is available at the farmstead, and no transmission cost is involved, irrigation by deep tube wells may also become economic.

CHAPTER-VIII

C O N C L U S I O N

8.1 CONCLUSSIONS:

From the present study, the folliwing conclusions can be drawn :-

1. Traditional methods of irrigation using human muscle power is less efficient, both in economy and output of work. Their effaciency decreases further for irrigation of crops requiring more irrigation water.

2. Research work is to be done to modify the techniques used in the traditional methods to improve their efficiency and to make less energy-consuming.

3. Diesel-irrigation costs more than the electric power irrigation. The command area is likely to be somewhat lower with the diesel-engines due to engine-trouble, inadequate repair facilities, scarcity of spare parts and irregularity of fuel supply—resulting in non-operation periods.

4. Irrigation with electric power requires least operation cost—which is an incentive to the farmers to expand the irrigated area. Operation and maintenance trouble is less with electric power irrigation.

5. For farm sizes upto 2 acres use of human muscle power comes out to be more economic than buying a machine for irrigation, from the viewpoint of acheiving surplus income.

6. When cost of transmission lines is to be included, for self-invested electric irrigarion, a farm size of more than about 8 acres may yield surplus income.

7. For large farm sizes and during peak seasons of irrigation, it would be necessary to provide for alternate sources of irrigation energy as the availability factor of electrical energy may tend to be somewhat low, in conjunction with a transmission line.

8. With electric power and diesel irrigation in large areas, the command area may increase more than proportionately with respect to pump size, if the institutional problems of management can be minimized, specially when a group of farmers may be involved in the same irrigation management system.

8.2 SCOPE OF FURTHER STUDY

Research work may be done to find modified techniques of muscle power irrigation of increased efficiency. Use of animal energy for irrigation, specially when excess animal energy and surface water is available, may also be xxxx considered.

At present no data is attainable regarding the xxxxkabil availability factors of both electric and diesel irrigation. Assumed, but seemingly realistic data have been used in this study for evaluating irrigation by electrical energy. Specially and it has been necessary to assume the same type of data for diesel irrigation too.

More precise reliability data on rural electrification schemes (specially for farm irrigation) are essential to work out correct methodology for farm irrigation energy management.

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TYPICAL SURVEY SHEET

DEPTT. OF ELECT. ENGG.

B.U.E.T., DACCA.

DATE: ______________

VILLAGE ______________ P.O. ______________ P.S. ______________ DIST ______________

TYPE OF HOUSING NO: OF HOUSES

BUILDING ______________

TINSHED ______________

THATCHED ROOF ______________

JUTE STICK ROOF ______________

(a) NAME OF HOUSE MASTER ....

(b) EDUCATIONAL QUALIFICATION...................................

(c) ANNUAL INCOME (APPR)

i) FROM AGRICULTURE SOURCES .... TK..........

ii) FROM OTHER SOURCES .... TK..........

TOTAL TK

d) NO. OF FAMILY MEMBERS ....

e) NO. OF SCHOOL/COLLEGE GOING CHILDREN :

SCHOOL ....

COLLEGE..............

) WORKING ANIMALS:

NIMALS	NO.	WORKING HOURS PER DAY												TOTAL
		BAI	Jai	ASA	SRV	BAD	ASW	KAR	AGR	POU	MAG	FAL	CHT	
OW														
ULLOCK														
UFFALO														
ONKEY														
ORSE														

) IMPLEMENTS: NO.

COMPLETE PLOW ....

RICE HUSKER ....

GRINDER ....

TILLER ....

OTHERS ....

6. TOTAL LAND .... (ACRES)

7. CROP PRODUCTION

	TYPE	AREA(ACRES)	PRODUCTION (MDS).
a) PADDY	AMAN(SOWN)		
	AMAN(TRANS)		
	BORO		
	HYV		
b) PULSE	MASURI		
	KHESARI		
	MUG		
	GRAM		
c) OILSEED	MUSTARD		
	TEEL		
	SOYABIN		
d) SPICES	CHILLY		
	ONION		
e) POTATO			
f) OTHERS			

. IRRIGATED LAND & EQUIPMENT ....

A) LAND INFORMATION

	CROPS			
	POTATO	HYV	OTHERS	TOTAL
i) IRRIGATED LAND AREA .... (ACRES)				
ii) LAND AREA LACKING IRRIGATION......				
iii) SOURCE OF WATER				
iv) SOURCE OF POWER				
v) TYPE OF OWNERSHIP:				
• OWNED BY THE CULTIVATOR				
OWNED BY THE LABOURS EMPLOYED				

	POTATO	HYV	OTHERS	TOTAL
vi) TYPE OF IRRIGATION MANAGEMENT BODY				
CULTIVATOR HIMSELF				
EMPLOYED LABOUR				
CO-OPERATIVE ,.....				
LOCAL GOVERNMENT				

ENERGY INFORMATION

a) MACHINE POWER

i) MACHINE SIZE				
ii) PUMP SIZE				
iii) PIPE SIZE				
iv) NO. OF DAYS OF IRRIGATION PER SEASON				
v) NO. OF HOURS/DAY				
MONTHS: BAISAKH				
JAISTHA				
ASAR				
SRAVAN				
VADRA				
ASWIN				
KARTIK				
AGRAN				
POUSH				
MAGH				
FALGUN				
CHAITRA				
TOTAL				
vi) ENERGY USED PER YEAR				
vii) QUANTITY OF WATER UTILIZED /YEAR (GLN)....				

b) HUMAN POWER

i) TYPE & CAPACITY OF THE ITEM USED				
ii) NO. OF MEN REQUIRED				
iii) NO. OF DAYS OF IRRIGATION PER SEASON				

iv) NO. OF HOURS OF OPERATION/DAY......

		POTATO	HYV	OTHERS	TOTAL
MONTHS	BAISAKH				
	JAISTHA				
	ASAR				
	SRAVAN				
	VADRA				
	ASWIN				
	KATRIK				
	AGRA				
	POUSH				
	MAGH				
	FALGUN				
	CHAITRA				
TOTAL					

v) QUANTITY OF WATER UTILIZED PER YEAR				
vi) ENERGY USED PER YEAR				

c) ANIMAL POWER

i) TYPE & CAPACITY OF THE ITEM USED.				
ii) NO. OF ANIMALS USED				
iii) NO. OF DAYS OF IRRIGATION PER SEASON				

iv) NO. OF HOURS OF OPERATION/ DAY

MONTHS	BAISAKH				
	JAISTHA				
	ASAR				
	SRAVAN				
	VADRA				
	ASWIN				
	KARTIK				
	AGRA				
	POUSH				

		POTATO	HYV	OTHERS	TOTAL
MONTHS	MAGH				
	GALGOON				
	CHAITRA				
TOTAL					

v) QUANTITY OF WATER UTILIZED/YEAR (GLN)

vi) ENERGY USED PER YEAR

) COST INFORMATION:

a) MACHINE POWER:
i) FIXED COST
ii) RUNNING COST
TOTAL ....

b) HUMAN POWER :
i) DIRECT COST(WAGES)
ii) INDIRECT COST
TOTAL ....

c) ANIMAL POWER :
i) DIRECT COST(FEED)
ii) INDIRECT COST
TOTAL ....

. FARMER'S REMARK ON WATER SUPPLY:
ABUNDANT
SUFFICIENT
NOT SUFFICIENT

). FARMER'S REMARK ON THE IRRIGATION SYSTEM:
GOOD
FAIR
POOR

1. FARMER'S SUGGESTIONS IF ANY

12) ENERGY CONSUMPTION:-

a) FOR COOKING

	CONSUMPTION (MND/YEAR)	USED (HRS/DAY)	BTU/YEAR
i) FIRE WOOD ...			
ii) JUTE STICK ...			
iii) NARA ...			
iv) WATER HYACINTH			
v) FARM WASTE			
vi) PADDY WASTE			
vii) ANIMAL WASTE			
viii) OTHERS			

b) FOR LIGHTING

	CONSUMPTION (BTU/MONTH)	USED (HRS/DAY)	BTU/MONTH
i) KEROSENE			
ii) OTHERS			

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