CHAPTER - I

INTRODUCTION AND DESIGN OF THE STUDY
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1.1 Preamble

Agriculture is the major sector of economic activity. Agriculture is the source of livelihood for more than two third of our population. So it can be rightly called the backbone of our economy. Agriculture is the oldest occupation of the world. The human society depends on agriculture. Even today in the highly developed industrial countries, agriculture plays a major role as the supplier of raw materials for industries and commerce apart from its basic role in supplying food, clothing and shelter. Therefore, agriculture is important as the welfare of a state to a large extent is dependent upon the prosperity of its agriculture. Agriculture is the corner stone of development. Indian agriculture is known for its multi-functions of providing employment, livelihood, food, nutritional and ecological securities.

The need for rural base industries especially agro based industries should be more emphasized. In a country like India, where more than 80 per cent of the population live in rural areas and more than two third of our population are dependent on agriculture and allied sector, Agro based industries in our countryside hold great promise to bring about substantial improvement in the quality of life of the rural people. These industries will play an increasingly important role in income and employment generation in the coming decades, with continuous increase in labour force in rural areas and declining employment opportunities in agriculture. Therefore, there should be proper integration
and coordination between agriculture and industry to ensure intensive and extensive development of agriculture, there by creating additional employment for the rural population. The growth of agro based industries will help in raising the standard of living of the rural population by providing them more income, consumer goods at cheaper rates and social economic overheads. An expanding agriculture sector will increase the demand for non-farm inputs like fertilizers, agricultural machinery, and implements which are manufactured in the non-agricultural sector. The stimulus received by the industrial sector in turn increases the demand for wage, goods and raw materials, which help to expand agriculture employment and income. This in turn creates market demand for consumer goods of industrial origin by providing a future stimulus to industrialization and development of market.

The tertiary sector also expands with the development of trade and commerce. In addition to production of food articles, agriculture is the main supplier of raw materials to industries. The significance of this role depends on the importance of agro based industries in the total industrial sector. It may be recalled that industrialization in India started with the setting up of factories for processing of agriculture commodities or manufacturing industries whose raw materials were produced on farms. There has been significant diversification of agriculture and the agro based industries in number and expanded their production during the last few decades.
Agriculture is the most important sector in Indian economy and it is basically an energy conversion industry. The energy use pattern for crops has varied under different agro-climatic zones. The use of energy in crop production depends on the availability of energy sources and the capacity of the farmers. Agricultural productivity is proportional to energy input in the form of improved seeds, fertilizers, chemicals, irrigation and mechanization including management practices (Kalbande and More, 2008).

**Rice - Cultivation and Harvesting**

Methods of growing differ greatly in different localities, but in most Asian countries the traditional hand methods of cultivating and harvesting rice are still practiced. The fields are prepared by plowing (typically with simple plows drawn by water buffalo), fertilizing (usually with dung or sewage), and smoothing (by dragging a log over them). The seedlings are started in seedling beds and, after 30 to 50 days, are transplanted by hand to the fields, which have been flooded by rain or river water. During the growing season, irrigation is maintained by dike-controlled canals or by hand watering. The fields are allowed to drain before cutting.

Rice when it is still covered by the brown hull is known as paddy; rice fields are also called paddy fields or rice paddies. Before marketing, the rice is thresher to loosen the hulls—mainly by flailing, treading, or working in a mortar—and winnowed free of chaff by tossing it in the air above a sheet or mat.
In the United States and in many parts of Europe, rice cultivation has undergone the same mechanization at all stages of cultivation and harvesting as have other grain crops. Rice was introduced to the American colonies in the mid-17th cent. and soon became an important crop. Although U.S. production is less than that of wheat and corn, rice is grown in excess of domestic consumption and has been exported, mainly to Europe and South America. Chief growing areas of the United States are in California, Mississippi, Texas, Arkansas, and Louisiana. The world's leading rice-producing countries are China, India, Indonesia, Bangladesh, and Thailand. Total annual world production is more than half a billion metric tonbes (The Columbia Electronic Encyclopedia, 2012).

**Energy**

Energy is said to be the engine for growth and development in all economies of the world. In all parts of the world today, the demand for energy is increasing almost on a daily basis. According to Pimental (1992), energy is one of the most valuable inputs in agricultural production. Sufficient availability of the right energy and their effective and efficient uses are prerequisites for improved agricultural production (Handan et al., 2009). The Energy use in agriculture has become more intensive as the Green Revolution led to the increasing use of high yielding seeds, fertilizers and chemicals as well as diesel and electricity. Energy consumption per unit area in agriculture is directly related to the development of the technology in farming and the level of production. Inputs such as fuel,
electricity, machinery, seed, fertilizer and chemical take significant share of the energy supplies in the production system of modern agriculture. Thus, the use of intensive inputs in agriculture and access to plentiful fossil energy has provided an increase in food production and standard of living (Selim et al., 2005).

Energy has been a key input of agriculture since the age of subsistence agriculture. It is an established fact worldwide that agricultural production is positively correlated with energy input (Singh, 2002). Agriculture is both a producer and consumer of energy. It uses large quantities of locally available noncommercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living (Singh et al., 2003).

Energy is one of the most valuable inputs in crop production. It is invested in various forms such as mechanical power (farm machines), human labour, animal draft, chemical fertilizer, pesticides, herbicides etc. The amount of energy used in agricultural production, processing and distribution should be significantly higher in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. It was realized
that crop yields and food supplies are directly linked to energy (Stout, 1990). Intensive cultivation, as a result of introduction of high yielding varieties in mid 1960’s and the urgent need for securing the food security for India’s teeming millions, required high energy inputs and better management practices.

All the farming operations in crop production require energy inputs in various forms and in varying magnitude. Besides, there is also variation in the use of energy from one farmer to another even for the same set of farming operations (Halim et al., 1999). In recent years, the use of mechanical power is increasing and that of animal power decreasing in agriculture. It is argued that animal component is the important component of agriculture for sustainability of the system. The inadequate supply of human labour especially during peak seasons affects various farm operations. Therefore, it is necessary to examine the energy use pattern, source of energy and their profitability so that suitable policy frame work can be formulated. Therefore, an attempt was made to assess the energy use pattern in paddy cultivation under irrigated situations of Thoothukuid district, Tamil Nadu state.
The present study has analyzed energy requirement and energy efficiency in paddy cultivation in Thoothukudi district, Tamilnadu. This is followed by an analysis of energy-output relationship and its implications for future energy demand. Finally, some options to meet the energy demand whilst reducing environmental footprints are discussed.

1.3 Scope of the Study

This study is an attempt to analyze energy requirement and energy efficiency in paddy cultivation in Thoothukudi district, with specific aims to evaluate the performance and determinants of performance efficiency. Agriculture is both a producer and consumer of energy. It uses large quantities of locally available noncommercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living. The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery. The commercial energy used in agriculture increased nearly six fold with growth rate of 11.8 per cent between
1980-81 to 2000, but the share of agriculture in total energy consumption in the country increased 2.3 to 5.2 per cent during the same period (Surendra Singh, 2002). About 57 per cent of the Indian population depends upon agriculture. The study concentrates on the routine agricultural activities of the households omitting the energy sources like solar and wood. The role of other sectors like household, industry and transport is not included in the study. This scientific study on the energy use pattern is necessary for minimizing energy use and maximizing profit of the cultivators.

The results of this study can help farmers, resource managers and policy makers to develop alternative technologies; practices, and energy optimal plan to save non-renewable energy inputs to sustain production without substantial reduction in the level of output and of course, without imposing a significant economic burden on the farmers. The aims of this study were to determine energy and energy efficiency in Thoothukudi District which belongs to paddy cultivated areas and to investigate the efficiency of energy consumption.

1.4 Statement of the Problem

The energy and agriculture relationship is becoming more and more important with the intensification of the cropping systems. Energy budgets for agricultural production can be used as first step towards identifying crop production processes. The input elements need to be identified in order to prescribe the most efficient methods for controlling them. The benefits of energy
analysis are to determine the energy invested in every step of the production process, to provide a basis for conservation and to aid in making sound management and policy decisions for efficient management of scarce resources for improved agricultural production.

Effective energy use is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction. The rising price of energy, particularly of crude oil, has significant implications for profitability of agriculture. Increasing use of energy-based inputs and rising oil prices are likely to enhance the cost of production in agriculture especially in paddy production.

The present study has analyzed sources of energy and the cost of energy-based inputs. This is followed by an analysis of energy-output relationship and its implications for future energy demand. Finally, some options to meet the energy demand whilst reducing environmental footprints are discussed. Therefore, the present study is undertaken towards this by evaluating the energy requirement and energy efficiency in paddy cultivation and by giving useful resource management plans for the paddy cultivators.
1.5 Objectives of the Study

The overall objective of the study is to an energy requirement and energy efficiency in paddy cultivation in Thoothukudi District, Tamilnadu”. The following objectives have been framed with the aim to achieve them.

1. to examine the socio-demographic characteristics of the paddy cultivators in the study area;
2. to estimate the cost and returns structure of paddy cultivation for two groups of farmers namely small farmers and medium farmers;
3. to investigate the energy requirement and to make an economic analysis of paddy in respect of the small and medium farmers in Thoothukudi district;
4. to estimate own and cross price elasticity of demand of different energy inputs for the small and medium farmers; and
5. to identify the constraints perceived by the farmers in the study area.

1.6 Hypotheses of the Study

The present study attempts to test the following hypotheses in line with the objectives mentioned above.

1. There is no significant difference in yield of paddy between the small and medium farmers.

2. There is no significant difference in the amount spent for inputs between the small and medium farmers producing paddy
3. There is positive relationship between the cost and output of paddy in the study area.

1.7 Methodology

This section attempts to discuss the methodology adopted for the study. Designing a suitable methodology and selection of analytical tools are important for a meaningful analysis of any research problem. In this section an attempt has been made to prepare a methodology for the present study. It includes sample design, collection of data, period of the study and tools used for the analysis.

1.7.1 Area of the Study

Thoothukudi District comprises of eight taluks are Ettayapuram, Kovilpatti, Ottapidram, Sathankulam, Srivaikundam, Thoothukudi, Tiruchendur and Vilathikulam,. The researcher has selected Srivaikundam taluk for this study. Srivaikundam taluk consists of two blocks namely, Srivaikundam and Karunkulam. Both the blocks are taken for the study. The farmers in Srivaikundam taluk have found that paddy cultivation is more profitable. The area under paddy cultivation is increasing. Paddy is four months crop and it is mainly grown for the market. It is considered as a poor man’s commercial crop, because according to the availability of capital, the scale of operation is adjustable.
1.7.2 Period of the Study

This study gives importance to the secondary data which covers a period of 20 years from 1992-93 to 2011-12. The field survey was conducted from July 2015 to December 2015 for the collection of primary data. The period of study was confined to a single agricultural year 2014-15, one Kharif season and one Rabi season.

1.7.3 Sample Design

Multistage stratified random sampling technique has been adopted for the study taking Thoothukudi district as the universe, the Taluk as the stratum, the Village as the primary unit and Paddy Cultivators as the ultimate unit. Thoothukudi district comprises of eight taluks and 12 blocks. Among them, Srivaikundam taluk has been chosen as the study area. Srivaikundam taluk comprises of two blocks namely Srivaikundam and Karunkulam which are taken for the present study.

There are 36 revenue villages in Srivaikundam block and twenty nine revenue villages in Karunkulam block. In the 36 revenue villages of Srivaikundam block there are 6,867 paddy cultivators. Similarly in Karunkulam block, there are 29 revenue villages, 5,645 paddy cultivators. Totally there are 65 revenue villages and 12,512 paddy cultivators in Srivaikundam taluk. Giving due weightage to the number of villages in each block 15 villages from Srivaikundam block and another 15 villages from Karungulam were selected at random on the basis of total number
of farmers. Finally, in the 30 revenue village selected, there were 4,668 paddy cultivators. From each revenue village 10 per cent of the paddy cultivators were selected randomly for the study. Hence, a total of 467 sample paddy cultivators were selected. It is shown in the Table 1.1.

**Table: 1.1 - Sampling Design of the Study**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Block / Name of Villages</th>
<th>Total Paddy Cultivators</th>
<th>Sample Paddy Cultivators</th>
<th>Block-wise Selected Paddy Cultivators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Srivaikundam Block</td>
<td>2396</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>1</td>
<td>Srikalahandi Block</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Aniyaparanallur</td>
<td>79</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Arumugamangalam</td>
<td>99</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Eral</td>
<td>110</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Iruvappapuram</td>
<td>205</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Maramangalam</td>
<td>176</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Korkai</td>
<td>229</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Kongaravankurichi</td>
<td>186</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Kottarakkurichi</td>
<td>90</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Sawyerpuram</td>
<td>82</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Siruthondanallur</td>
<td>201</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Srivaikuntam</td>
<td>204</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Thollappanpannai</td>
<td>209</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Vallavallan</td>
<td>204</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Velur Kasba</td>
<td>214</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2396</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Karunkulam Block</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Alanda</td>
<td>164</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Arampannai</td>
<td>184</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cherakulam</td>
<td>110</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ellainacickenpatti</td>
<td>209</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Karunkulam</td>
<td>175</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Kilavallanadu</td>
<td>73</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Manakarai</td>
<td>157</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Poovani</td>
<td>80</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Sekkarakudi</td>
<td>138</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

Con/-.....
The farmers with less than five acres were considered as small farmers and farmers with five acres and more were considered as the medium farmers. The marginal and large farmers were dropped in size, hence for the analytical purpose both were excluded in the present study. In paddy cultivation out of 467 sample farmers, 210 farmers were small farmers and the remaining 257 farmers were medium farmers. In some aspects, the farmers of those cultivating an area of more than 10 acres were grouped under the category of medium farmers.

### 1.7.4 Collection of Data

**Primary Data**

A survey of study area was undertaken to form a crystal clear picture of the process and activities involved in pulse cultivation under actual farming conditions. Based on the information gathered at farm level, a detailed schedule was drafted, pre-tested and used in the field survey. The objectives of the study were clearly explained to the farmers personally and their cooperation were
ensured. The details regarding the general characteristics of the sample farmers, farm structure size of holding, cropping pattern cost and returns, energy requirements, energy efficiency and other aspects relating to the overall objectives of the study were collected from the sample farmers through the direct personal interview method. Even though the farmers did not maintain adequate farm records and accounts they were able to furnish the particulars on the strength of their long association with farming. However to minimize suitable cross checks and rechecks were carried out.

Secondary Data

Secondary Data were collected from Office of Assistant Director of Economics and statistics, Thoothukudi District, Assistant Director of Agriculture, Srivaikunadam taluk, _G‘ Return, District Statistical Office, Thoothukudi, Statistical Hand Book, Thoothukudi District and Indian Horticulture Data Base. In addition to that book, Journals and magazines were referred. Journals such as Indian Journal of Agricultural Marketing, Journal of Agricultural Economics, Indian Journal of Marketing and other relevant Journals were referred for collecting secondary data for the study.

1.7.5 Tools Used for the Analysis

Trend Model Forecasting

In order to analyse the trend in area, production and productivity of paddy various trend analysis are used. Trend models, otherwise called deterministic
models often catch the fluctuations occurring in business and economic variables. Most frequently used trend models are linear, quadratic, logarithmic and exponential. The trend models employed in this study are presented below.

1. Linear Trend Model \( Y = a + b \ T + u_t \)
2. Quadratic Trend Model \( Y = a + b + c \ T^2 + u_t \)
3. Logarithmic Model \( \log Y = a + \text{log}T + u \)
4. Cubic Trend Model \( Y = a + bT + c \ T^2 + d \ T^3 + u_t \)
5. Exponential Trend Model \( Y = a + b \ e^{ct} + u_t \)

Where, \( T \) = Time variable
\( a, b, c, d \) = coefficients of the regression model to be estimated
\( u_t \) = value of error variable at time \( _=T' \)

**Average Annual Growth Rate (AAGR)**

The average annual growth rate shows the average percentage change of the base year to current year.

The formula used for this computation is:

\[
\text{AAGR} = \frac{1}{n} \sum_{t=1}^{n} \left( \frac{Y_t - Y_{t-1}}{Y_{t-1}} \right) \times 100
\]

Where \( Y_t \) and \( Y_{t-1} \) are values for current year and base year respectively and \( n \) is the number of years of the time series (Acharya 1988).
Log-linear Multiple Regression

In order to identify the energy inputs which influence per acre value of output energy for small and medium farmers producing paddy, the following form of log-linear multiple regression model was used.

\[
\log Y = \beta_0 + \beta_1 \log X_1 + \beta_2 \log X_2 + \beta_3 \log X_3 + \beta_4 \log X_4 \\
+ \beta_5 \log X_5 + \beta_6 \log X_6 + \beta_7 \log X_7 + u \ldots \ldots (1)
\]

Where,

\[
Y = \text{Per acre value of output energy MJ},
\]

\[
X_1 = \text{Human energy per acre in mega joules},
\]

\[
X_2 = \text{Bullock energy per acre in mega joules},
\]

\[
X_3 = \text{Fertilizer energy per acre in mega joules},
\]

\[
X_4 = \text{Pesticide energy per acre in mega joules},
\]

\[
X_5 = \text{Irrigation energy per acre in mega joules},
\]

\[
X_6 = \text{Mechanical energy per acre in mega joules},
\]

\[
X_7 = \text{Seed energy per acre in mega joules},
\]

\[
u = \text{Disturbance term},
\]

\[
\beta_0, \beta_1 - - - - \beta_7 \text{ are the parameters to be estimated.}
\]

The above model (1) was estimated by the method of least squares.
Chow's Test

To test the structural difference between small and medium farmers producing paddy, Chow's test was adopted. The formula for Chow's test is

\[ F^* = \frac{\sum e^2 - (\sum e_1^2 + \sum e_2^2)/k}{(\sum e_1^2 + \sum e_2^2)/(n_1+n_2-2k)} \]

Where,

\[ \sum e^2 = \text{Unexplained sum of squares for pooled category}, \]

\[ \sum e_1^2 = \text{Unexplained sum of squares for small farmers}, \]

\[ \sum e_2^2 = \text{Unexplained sum of squares for medium farmers}, \]

\[ k = \text{the number of parameters including intercept term in the model}, \]

\[ n_1 = \text{Number of observations for small farmers}, \]

\[ n_2 = \text{Number of observations for medium farmers}, \]

To examine whether structural differences existed at the intercept level and/or at slope level, both intercept and slope dummy variables were introduced in the model (1).

\[ \log Y = \alpha_0 + \alpha_1 D + \sum \log X_i + (\beta_i + D\delta_i) + u \ldots (3) \]

\[ i=1 \]

Where,

\[ Y = \text{per acre value of output energy in mega joules}, \]

\[ X_i = \text{Human energy per acre in mega joules}, \]
$X_2 =$ Bullock energy per acre in mega joules,

$X_3 =$ Fertilizer energy per acre in mega joules,

$X_4 =$ Pesticide energy per acre in mega joules,

$X_5 =$ Irrigation energy per acre in mega joules,

$X_6 =$ Mechanical energy per acre in mega joules,

$X_7 =$ Seed energy per acre in mega joules,

$D =$ Dummy Variable represents '0' for small farmers and '1' for medium farmer

$u =$ Disturbance term,

$\alpha_0, \alpha_1, \beta_1, \beta_2, \ldots, \beta_7$ are the parameters to be estimated.

The model (3) was worked out by the method of least squares.

**Translog Cost Function**

Complementarities of energy inputs are measured from the estimation of Allen Elasticity of Substitution (AES) derived from translog cost function (Subramaniyan, 1994). The following form of translog cost function was used for the present study.

\[
\log C = \alpha_0 + \sum \alpha_i \log P_i + \alpha_6 \log Y + \frac{1}{2} \beta_{11} (\log P_1)^2 + \frac{1}{2} \beta_{22} (\log P_2)^2 \\
+ \frac{1}{2} \beta_{33} (\log P_3)^2 + \frac{1}{2} \beta_{44} (\log P_4)^2 + \frac{1}{2} \beta_{55} (\log P_5)^2
\]
\begin{align*}
  &+ \beta_{12} (\log P_1) (\log P_2) + \beta_{13} (\log P_1) (\log P_3) + \beta_{14} (\log P_1) (\log P_4) \\
  &+ \beta_{15} (\log P_1) (\log P_5) + \beta_{23} (\log P_2) (\log P_3) + \beta_{24} (\log P_2) (\log P_4) \\
  &+ \beta_{25} (\log P_2) (\log P_5) + \beta_{34} (\log P_3) (\log P_4) + \beta_{35} (\log P_3) (\log P_5) \\
  &+ \beta_{45} (\log P_4) (\log P_5) + u \quad \text{(A)}
\end{align*}

Where,

\begin{align*}
  &C = \text{Per acre Cost of Cultivation (₹),} \\
  &Y = \text{Value of per acre Output Energy (₹),} \\
  &P_1 = \text{Price per unit of Human Energy (₹),} \\
  &P_2 = \text{Price per unit of Bullock Energy (₹),} \\
  &P_3 = \text{Price per unit of Fertilizer Energy (₹),} \\
  &P_4 = \text{Price per unit of Pesticide Energy (₹) and} \\
  &P_5 = \text{Price per unit of Mechanical Energy (₹).}
\end{align*}

The cost-share equation for the energy inputs can be derived by using Shephard's lemma:

\begin{align*}
  S_i = \alpha_i + \beta_{i1} \log P_1 + \beta_{i2} \log P_2 + \beta_{i3} \log P_3 + \beta_{i4} \log P_4 + \beta_{i5} \log P_5 \quad \text{(B)}
\end{align*}

Where,

\begin{align*}
  &i = 1, 2...,5
\end{align*}
\[ S_i = \text{Share of } i^{\text{th}} \text{ energy input in the cost of cultivation.} \]

The above equations (A) and (B) were jointly estimated by using Zellner's equation (Zellner, 1962). Seemingly Unrelated Regression which asymptotically presents more efficient estimates than ordinary least square method.

**Garrett Ranking Technique**

In order to analyse the constraints faced by the paddy cultivators producers at the production and also to analyse any other constraints faced by them, the Garrett ranking Technique was used. It gives the change of orders of constraints into numerical scores. The major advantage of this technique as compared to simple frequency distribution is that here constraints are arranged based on their importance from the point of view of the growers. Hence the same numbers of respondents with two (or) more constraints are given different ranks (Kumar et al., 1999) Garrett formula for converting ranks into per cent was given by the following equation.

\[ \text{Per cent Position} = \frac{100x(R_{ij} - 0.5)}{N_j} \]

Where,

\[ R_{ij} = \text{Rank given for } i^{\text{th}} \text{ factor (constraint) by } j^{\text{th}} \text{ individual} \]

\[ N_j = \text{Number of factor (constraints) ranked by } j^{\text{th}} \text{ individual} \]

The relative position of each rank obtained from the above formula was converted into scores by referring to the table given by Garrett (Translation of 21
orders of merit into units of scores) for each factors. Scores of all individuals were added and then divided by the total number of respondents for the specific factor (constraint). Finally mean scores for all the factors were arranged in descending order and the ranks were given.

1.8 Limitations of the Study

The information on paddy cultivation was collected by interview schedule method through personal interview with the sample of small and medium farmers confined to a particular area. Farmers in general were not maintaining detailed accounts on farming and the information on cost and returns were elicited from their memory and their experience. Now farmers in general are mostly using tractor technology for cultivation.

The other sectors like domestic, industrial and transportation may not be included in the present study. In the agricultural sector itself, the energy sources like solar and wood are not included. The embodied energy derived of other machineries were not considered in the production process. Due to lack of money and lack of time, the researcher has collected the data from 467 respondents in the study area for the purpose of analysis and discussion.
1.9 Scheme of Study Work

The thesis entitled "Energy requirement and energy efficiency in paddy cultivation in Thoothukudi District, Tamilnadu” is organized into seven chapters as follows.

CHAPTER - I INTRODUCTION AND DESIGN OF THE STUDY

This chapter presents the discussion on the various types of energy sources, problem focus, scope of the study, objectives of the study, hypotheses of the study, methodology, limitations and chapter scheme of the study.

CHAPTER -II  REVIEW OF LITERATURE AND RELATED CONCEPTS

The review on past studies relating to energy utilisation, efficiency of energy and use of energy are discussed in this chapter. Various concepts used in this study are also defined.

CHAPTER –III  PROFILE OF PADDY PRODUCTION, STUDY AREA AND CHARACTERISITCS OF SAMPLE FARMERS

A brief description of the study area and characteristics of sample farmers are discussed in this chapter.

CHAPTER -IV  COST, RETURNS AND ENERGY UTILISATION OF PADDY

The data relating to cost, returns and utilisation of energy in paddy cultivation between small and medium farmers are taken into consideration and analysed in this chapter.
CHAPTER –V  ENERGY REQUIREMENT AND DETERMINANTS OF PER ACRE OUTPUT ENERGY OF PADDY

In this chapter, an attempt has been made to identify and analyse the energy requirements and determinants of per acre output energy of paddy and energy use efficiency of different energy inputs used in the production of paddy.

CHAPTER–VI COMPLEMENTARITIES BETWEEN ENERGY INPUTS OF PADDY

This chapter attempts to examine the complementarities between renewable and non-renewable energy inputs used in the production of paddy in Thoothukudi district.

CHAPTER –VII SUMMARY OF FINDINGS, CONCLUSION AND SUGGESTIONS

A summary of work done and salient findings of the study are presented. Conclusions are drawn after verifying the hypotheses of the study and their implications for policy are stated.