CHAPTER - II

REVIEW OF LITERATURE AND CONCEPTS

2.1 General

In this chapter, a comprehensive review of various earlier studies relevant to this study is presented in three sections. The first section concentrates on studies covering pattern of energy utilisation in agricultural activities. The second section is devoted to discuss studies relating to major crops and to find out the productivity, intensity and efficiency of energy use in the production, the third section relates the determinant factors of energy consumption in agricultural sectors and the fourth section concentrates on studies covering the specific problems of the agricultural sector in the use of energy and the future prospects.

2.2 Studies covering Pattern of Energy Utilisation in Agricultural Activities

Arora (1978) described the role of inputs in agriculture. According to him, the high yielding varieties of seeds have, no doubt, brought out vistas of hope for increasing productivity to a level hitherto unheard of, provided the hunger and thirst of soil is perhaps, crucial to any programme of agricultural development. Other pre-requisites in this respect will be timely provision of inputs, viz., fertilizers, improved seeds, pesticides, improved implements etc.
Panday (1979) described that it has been the age old practice of farmers in this country to use manures mainly in the form of cow-dung with domestic rubbish, in the fields for raising various crops. These measures were regularly put in the fields while filling the land before sowing the seeds. Of late, chemical fertilizers, of one kind or another, either alone or in combination with manures, have come into use.

The study of the flow of energy and the cycles of materials in small human groups, which could have been the foundation stone for human ecology, ecological anthropology and energy economics, is usually classified as ecological anthropology. Although corporative studies on energy flows in agriculture (Pimental and Pimental, 1979) clearly belong to agricultural energy economics, they use the findings of ecological anthropologists on output-input energy ratios in traditional systems. Therefore, it is not surprising that there should have been attempts to measure the energy output-input ratio in agriculture.

Revelle (1980) made an attempt to provide a macro level analysis of the rural energy use pattern in India. The study inferred that the rural people in India are tied to poverty and misery because they use too little energy and use it inefficiency. The study argues that the transformation of the rural Indian Society could be brought about by increasing.

Aslam (1980) mentioned that in the field of agriculture the more important technology which includes; improved varieties of seeds, use of chemical
fertilizers, kind of materials used for protection of crops against pests and diseases, and new designs of mechanical equipment have brought about significant changes.

Leach (1980) stated that although agriculture in the U.K. consumes one per cent of the total energy, the energy input for man is comparable with that of heavy industries. During the era of cheap energy supplies (1952-72) the consumption of agricultural energy rose by 70 per cent, nearly twice as much as the increase in the national fuel consumption during the same period.

Srivastava et al., (1982), conducted a study of animal power and agricultural machinery. They described the role of both traditional and modern agricultural methods in various agricultural operations.

Johar et al., (1983) described the role of chemical fertilizers, agricultural machinery and agricultural labour in Punjab farming. According to him, during the period of 1997-98 the total consumption of chemical fertilizers reached the level of 762 thousand nutrient tonnes of which Nitrogenous (N), phosphatic (P\textsubscript{2}O\textsubscript{5}) and potassic (K\textsubscript{2}O) contribute 526, 207 and 29 thousand nutrient tonnes respectively during 1980-81.

Rajendran et al., (1987) attempted to compare non irrigated farms and rain fed farms with respect to the energy use pattern, the cost of cultivation, the income and the energy productivity in Coimbatore district of Tamil Nadu in 1980-81. This study showed that irrigated farms used more of human, bullock, mechanical and electrical energy than rain-fed farms.
Bala et al., (1989) assessed the energy use pattern for three socio-economic
groups in Bangladesh in 1987. They used a huge model to analyse energy flow of
integrated farm units of an electrified village in Bangladesh. The study showed
that the energy used in crop production on large farms was greater than on small
or medium sized farms.

Kombairaju (1989) analysed the energy consumption pattern in crop
production of Naickenpalayam village of Perianaickenpalayam block, Coimbatore
District, in 1989. The findings of this study showed that among the various
irrigated crops the energy intensity was the highest for paddy (1056.01
Kwh/month) and the lowest for topioca (248.10 kwh/month). The total energy
requirement of banana has been estimated at the highest as 8966.52 kwh/ha as
against 4752.06 kwh/ha for paddy. The study showed that there was scope for
improvement in farm income which depends on energy efficient and cost saving
technologies.

Mittal et al., (1989) identified the energy parameters for raising crops
under various irrigation treatments in Indian Agriculture. It was concluded that the
specific energy requirements for the production of crops did not differ
significantly with irrigation methods.

The Department of Bio-Energy (1991) in its annual report outlined the
study of the Energy Resource Assessment and Planning for a village called
Thimmapuram in Krishnagiri Taluk of Dharmapuri District in the north-western
part of Tamil Nadu during the year 1990-91. The findings of the study showed that
marginal farms were the most-energy intensive in the cultivation of paddy, jasmine and finger millet. It was found that irrigation was the most energy intensive among farm operations. It has been estimated the total energy requirement for paddy was 33.756 MJ/ha.

Sahdev Singh et al., (1992) conducted a study in six villages of Meerut District of Northern India region covering 500 crop plots representing 24 farmers. The collected data were analysed statistically to examine the mathematical relationship between energy inputs and crop yield of wheat, sugarcane and maize. For all the three crops, yields seemed to be linearly correlated with the total energy input.

Singh et al., (1992) discussed the rural energy system in India. According to them, agriculture has a very close link with the rural energy system. The author used the “Indira Gandhi Institute’s Rural Energy Agricultural Model (INGRAM)”, It captures the interaction between crop production and associated residues, livestock, production system, fertilizers, household energy, etc., in a linear programming framework. The model has spelled out implications for a variety of policy alternatives and scenarios ranging from increased fertilizer prices and increased rural population.

Joshi et al., (1992) developed a simple linear model to minimize the cost function for an energy supply system consisting of a mix of energy sources and conversion devices. This model was applied to a typical village in India for both the domestic and the irrigation sectors. The energy-demand assessment was made
with an energy audit. The results of the study showed that agricultural residues were preferred energy sources. For irrigation, diesel powered pumps were preferred to electric pumps.

Ramaswamy et al., (1993) examine the annual energy utilization in the agricultural sector of Kambiliampatti village of Dindigul Anna District. The percentage contribution of energy input from different sources showed that the major input was from chemical fertilizer (69.2 per cent) while 30.8 per cent accounts for the rest, human energy 15.3 per cent, animal energy 9.1 per cent, pesticide 2.9 per cent, organic manure 2.3 per cent and electricity 1.2 per cent. The study estimated per acre, per farmer and per capita energy consumption was 43,867 M.J, 81,816 MJ and 19,873 M.J. respectively.

Thakur et al., (1993) conducted a survey to study the economic and energy use patterns under various categories of farms for the cultivation of wheat crop in Madhya Pradesh during the period 1988-89 to 1989-90. A total of 250 farmers were selected from all the farm categories. The regression analysis showed the linear relationship among energy and cost, energy and yield and energy and net profit and they were significant. The relationship among energy use and human power and energy use and bullock power was found to be not significant.

Lakshmi (1997) analysed the total human energy input into various agricultural operations, 0.13 per cent of human energy goes into ploughing 0.26 percent into seeding, 14.69 percent into irrigation, 11.09 per cent into transplanting, 4.17 per cent into harvesting 5.17 per cent into sowing, 11.82 per
cent into bullock pair days. For woman 2.27 per cent goes into seeding, 0.24 per cent into transplantation and 48.39 per cent into weeding.

Saini et al., (1998) stated in their article that the source wise existing energy use pattern in various cropping systems. This revealed that the highest proportion of energy supplied to different cropping systems was from chemical fertilizers except in vegetable-based rotations where in the major source of energy was human labour, followed by chemical fertilizers and farmyard manure (FYM). However, in rice-potato rotation, the major proportion of energy was supplied through FYM, followed by human labour. The amount of energy used through pesticides and herbicides was negligible due to low infestation of the crops by insect pests and diseases and sufficient family labour available for manual weeding in various crops. The energy used through the implements and machineries was higher in those relations which included wheat crop, revealing thereby that wheat threshing was mostly done by power thresher in the study area.

Ozkan et al., (2004) have determined the energy use in the Turkish agricultural sector for the period of 1975-2000. In the study, the inputs in the calculation of energy use in agriculture include both human and animal labour, machinery, electricity, diesel oil, fertilizers and seeds. A total of 36 agricultural commodities have been included in the output. Energy values are calculated normally by multiplying the amounts of inputs and outputs by their energy equivalent with the use of related conversion factors. The results indicate that total energy input increases from 17.4 GJ/ha in 1975 to 47.4 GJ/ha in the year 2000.
Similarly, total output energy results from 38.8 to 55.8 GJ/ha in the same period. As a consequence, the output-input ratio is estimated to be 2.23 in 1975 and 1.18 in 2000. This result shows that there is a decrease in the output-input energy ratio.

Narayananmoorthy (2006), has concluded that that the linkages between the adoption of DMI and electivity use on three water intensive crops namely banana, grapes and sugarcane, using farm level survey data collected from 200 farmers selected from Maharashtra, a western state of India. Electricity saving in terms of money value comes to about `3,454 / ha for sugarcane, `4,811/ha for grapes and `7,934 / ha for banana. The share of area under water intensive crops such as paddy, wheat, sugarcane, banana and other similar crops in the gross irrigated area has been increasing since the introduction of green revolution in Indian agriculture. Since these crops provide relative higher profit, farmers tend to cultivate them predominantly under surface irrigation method using ground water.

Since most of the pump sets used for lifting water from wells are being operated using electricity, the use of electricity in agriculture has obviously increased over the years. Though the impact of electrically operated pump sets in increasing the cropping intensity, productivity of crops, etc., has been clearly documented in India, it is argued in recent years that the electricity in agriculture is not used efficiently mainly because of cultivation of crops predominantly under conventional flood method of irrigation as well as subsidised electricity supply to agricultural consumers.
Moorthy and Raju (2009) have analysed the electricity energy consumption of agricultural sector in Indian context. This study revealed that considerable difference in the energy requirement and energy consumption has been observed during season. The energy saving potential was highest for East Godavari where maximum of paddy was cultivated among the three districts. The sum of electrical energy requirements of various sources of cultivation was estimated to be equal to 11.03 million units where as reports from utility shows those 18.08 million units have been consumed from October 2005 to January 2006.

2.3 Studies covering Major Crops and Productivity, Intensity and Efficiency of Energy use in the Production

Cropping patterns have a decisive role to play in adding to agricultural productivity. Facts reveal that it could be influenced by numerous factors. Several attempts have been made to identify these factors. Singh (1963) has conducted an extensive study and observed that among the numerous factors influencing cropping patterns, a special mention must be made of the rate of returns and availability of finance. However, his analysis seems to be incomplete as it is concerned mostly with groundnut cultivation.

Pant and Jain (1972) have defined cropping pattern as the percentage of the area of land under different crops on the farm. Rathak (1991) has a slightly different view about it. In his opinion cropping system means growing crops in sequence on the same piece of land in one year. However, as Peter (1979) has put
it cropping pattern details with the nature of crops that were raised and the percentage of area under each one of them in a specified period of time.

Grewal et al., (1975) have indicated that the HYVs do well only under assured and managed supplies of irrigation. Likewise, a study based on survey conducted in Dobhi block of Jaunpur district in Eastern U.P. (Shrinath Singh, 1976) has indicated that Cultivators with own assured irrigation facilities are the first to adopt HYV varieties. Other cultivators have followed subsequently in bringing small areas under HYV on experimental basis to see its profitability.

Arora (1976) has given an entirely different view about cropping patterns. To him it means the most efficient use of land and other resources of the cultivators. According to Mathur (1987) a good cropping pattern reflects the most efficient use of land and other resources during a particular period of time. Agarwal (1989) has interpreted the concept of cropping pattern as the area of land devoted to different crops in terms of the total (or gross) cropped area. Prasannakumari (1989) also defines the crop wise distribution of cultivated land area.

According to Mamoria (1976), cropping pattern means the production of area under different crops at a particular period of time. The same view has been expressed by writers like Ruddar Dratt and Sundharam (1991); Mishra Puri (1987); Tyagi (1987); Sankaran (1979); Sairam and Kandaswamy (1994).

Saini (1979) in his study “Allocation Efficiency in Agriculture-crop level analysis” covered 200 farms of 100 each, in the districts of Meerut and
Muzaffarnagar in Uttar Pradesh. The analysis was based on the Farm Management data for 1955-56. Cobb-Douglas production function was fitted with output as the dependent variable and area, labour, bullock labour, farm manures and fertilizers and irrigation as five independent variables. The analysis indicated that output was highly responsive and significantly related to land, followed by human labour.

Carson et al., (1979) studied the variability in rice yield. Of the seven independent variables, damages by natural forces were reported to be the most significant factor affecting yield. Fertilizer and herbicide also had a significant impact on the yield of rice.

Pimental and Pimentel, (1979) in their study the energy analyses in agriculture include computation of the energy content in inputs that go into crop production and comparison of the same with the energy content in the output. For instance, energy input includes energy content of seeds irrigation, human and animal power etc., Studies indicate that the output/input ratio under Indian conditions is in the range 1.5 to 2.7.

Harris, (1980) carried out a study in North Arcot, Tamil Nadu. He found that the water supply and seasonal conditions were the most significant objective limitations for the adaptation of HYVs technology. Chambers et al., (1980) and Ratna Reddy (1989) also came out with similar conclusions from their studies.

Swaminathan, (1983) a reputed agricultural scientist, has evolved high-yielding varieties through increase in productivity rather than through expansion
of the area cultivated. It involves the transfer of research from experimental laboratories to the farm. Agricultural research centers strive to maximize yield through optimum use of resources. These centers seek to develop technologies, suitable to the socio-economic conditions of a region, through integrated socio economic and biological research. Under taking on-farm testing, demonstrations operational research projects and the like examine the validity and viability of experimental findings. However, the farmer’s yields are often reported to be lower than those obtained at the experimental stations. The difference between experimental station yield and the actual farm yields referred to as yields gap.

Niranjan Pant et al., (1983) while studying the farmers’ organizations and irrigation management in some command area of Bihar found that a large percentage of farmers used HYVs seed with other bio-chemical inputs.

Suryawanishi and Gaikwad (1984), in their study, “an analysis of yield gap in Rabi and Jowar in Ahamednagar district” found that, there was a wide gap in yield when the new technology was adopted. The yield was just 2.12 quintals / ha, under traditional method of cultivation, 3.42 quintals/ha, when there was partial adoption of technology and 7.02 quintals/ha when it was fully adopted as in demonstration of plots. Multiple regression analysis showed that early sowing not only increased yield of jowar but also resulted in the increase of productivity of the resource. Recommended varieties, fertilizers and timely sowing were found to be important factor to reduce the yield gap.
Dhawan (1986), explained in his study of irrigation and water management in India that the conjunctive use of surface and ground water has increased that adoption of HYV technology and profitability in the North-Western India.

According to Desai (1986), the HYVs have spread virtually to all irrigated land and they have replaced the local varieties.

Athreya et al., (1986) came to a new conclusion from their intensive study of South Indian Agriculture in two eco types ‘wet’ and dry’ areas. They found that more than half of the wet area has been cultivated with HYVs. The reason for the widespread use of HYVs was shorter duration and their higher yields. They also indicated that the LIVs (locally improved varieties) are preferred for several reasons viz., taste, high price in the markets, etc. On the whole, LIVs are less sensitive to pest attacks, and thereby less risky to cultivate.

According to Noor Mohammad (1987), the cropping pattern was a reflection of response of soil to ecological conditions in an area. In the opinion of Shrivastava (1987) cropping pattern refers to the various types of crops grown at a time and over a period of time according to the type of soil, size of holding and other factors.

Dingar and Vishnuprasad, (1987) have defined it as the shift from traditional varieties of crops to new and high yielding varieties, diversion of area from less to more remunerative crops and introduction of new crops.

Rajendran et al., (1987) have attempted to compare the irrigated farms and rain fed farms with respect to the pattern of energy use, the cost of cultivation, the
income and productivity of energy in Coimbatore district of Tamil Nadu in 1980-81. This study had revealed that the irrigated farms used more of the human, the bullock, the mechanical and the electrical energy than those of the rain fed farms.

Bala et al., (1989) have made an assessment of the energy use pattern of three socio-economic groups in Bangladesh in 1987. They used the Huge’s model to analyse the energy flows in the integrated farm units of an electrified village in Bangladesh. Their study revealed the fact that the energy used in the crop production in large farms was greater than those in the small and the medium sized farms.

Bhatnagar et al., (1989) have estimated that the energy consumption in the agricultural sector was 6.6 per cent of the total commercial energy consumption in the country. This study had analysed the energy utilization pattern in the agricultural sector and had identified various technical and administrative measures which could promote energy conservation. The study had shown that the per hectare requirement of diesel and electricity (for both pumping sets and tractors was about 80 litres and 90 kwh respectively for paddy, wheat and maize cultivations in the Northern Regions of India.

Mittal et al., (1989) have identified the energy parameters for raising crops under various irrigation levels in Indian agriculture. It was found that the specific energy requirements for the production of the crops did not vary significantly with the different irrigation methods adopted.
Surendra Singh et al., (1990) have observed that paddy and wheat were the two major crops in the state of Punjab in India and they were grown under crop rotation practices. These crops consumed most of the energy that was used in the farms of Punjab. The multistage stratified random sampling technique was followed for conducting a farmers’ survey to study the energy consumption pattern for the cultivation of paddy and wheat. Irrigation had accounted for the maximum energy consumption in all the farming operations for both paddy (81.9 per cent) and wheat (38.1 per cent). The specific energy consumption for paddy was 5.87 MJ/Kg and for wheat it was 4.46 MJ/Kg. Paddy had accounted for 90.9 per cent and wheat for 94.3 per cent respectively of the total energy input from the commercial sources and the rest of the energy needed was met through the non-commercial sources. The cultivation of oil crops and pulses on a large scale, as alternative crops had reduced the dependence on commercial energy sources to a certain extents.

Dhawan et al., (1990) have calculated that in Punjab, the paddy crop had utilised 33,410 MJ/ha, with an average yield of 37.329 q/ha as against 7,167 MJ/ha with an average yield of 18.08 q/ha in West Bengal.

Dhawan and Mittal (1990) have made a study of the Energy Requirements for Cotton under different and Varied Methods of Irrigation. Three irrigation methods were selected, namely, (i) The ridges and furrows method. (ii) The long bed furrows method and (iii) The beds and channels method and they were actually carried out in an experiment in the Tamil Nadu Agricultural University,
Coimbatore, under the auspices of the AICRP for studying the energy requirements in the agricultural sector.

Duraisamy (1991) applied the profit function method to study the differences in resource use efficiency between educated and uneducated farmers in paddy production. In this study, the technical and allocative efficiency were tested with three variable inputs such as labour, fertilizer, bullock labour and three fixed inputs such as capital, land and education using Zellner’s seemingly unrelated Regression Model.

The result showed that the educated farmers have absolute allocative efficiency whereas uneducated farmers did not have absolute allocative efficiency. This implied that the educated farmers perfectly maximized profit and the uneducated farmers did not. It was determined that these two groups were not equal in relative economic efficiency.

The elasticity of paddy supply with respect to variable inputs and fixed inputs was less than one, that is, inelastic. Among the prices of variable inputs, the effect of wage rate on paddy supply appeared to be much stronger compared to the other input prices. The output supply elasticity with respect to land was unity with respect to capital that was negligible, being 0.05. The variable input inelasticity indicated that the demand for variable inputs, labour, fertilizer and bullock labours were elastic with respect to the changes in their own price and paddy price.

Yadav et al., (1991) in their study analysed the energy requirements in the production of potato. They took Biharsharif block of Nalanda district as the study
area for the period 1977-78. They analysed the marginal value productivity of
different types of energy using, Cobb-Dougles production function. The findings
and suggestions were as follows.

In the cultivation of potato, the inputs chemical fertilizer and seed energies
jointly accounted for nearly 92 per cent of the energies used in their study area.
They found that the costliest energy input was human energy (19.47 per unit) and
the cheapest one was chemical fertilizer (3.08 per cent). The ratio of marginal
value productivity to respective factor cost for land, irrigation and seed energy was
greater than unity indicating the scope to increase the area under potato cultivation
in the study area.

Nirmala (1992) has fitted the restricted profit function along with input
demand functions to examine the allocative efficiency and supply response of
farms producing modern varieties of rice (IR20 and Co 37) in the irrigated area of
Gokilapuram village of Madurai District in Tamil Nadu. The data used in this
study were collected during the rabi season of the agricultural year 1985-86 of
Gokilapuram village.

The analysis of output supply and labour demand elasticity revealed that
the two varieties of rice were not so responsive to changes in rice price. This
indicated that manipulation of rice price may not be very effective in increasing
output supply. The demand for labour with regard to real wage rate was elastic in
both cases. The negative and low response of output supply and labour demand to
increase the price of fertilizer, irrigation and mechanical labour implied that the manipulations of these factor prices are not an effective policy measures.

The indirect estimates for the two rice varieties revealed that land and labour were the dominant factors of production. The shares of other factors were quite low in Gokilapuram village.

Mathew et al., (1993) analysed energy flow patterns in rain fed paddy cultivation under three puddling treatments-bullock drawn plough, power tiller and tractor. Their study included energy consumption per hectare for treatment with bullocks, tractor and tiller. The results revealed that: (a) energy consumption per hectare for treatment with bullocks, tractor and tiller was 14.2, 14.2 and 15.0 GJ, respectively: (b) output input ratio for tractor, bullock and filter treatment was 7.63, 6.58 and 5.4 respectively; (c) fertilizers and chemicals constituted a major portion of total energy input and (d) the share of human power was maximum in planting and harvesting operations.

Munidora Swamy Naidu et al., (1994) have made a study of the role of the commercial energy in the transformation of agriculture from the traditional subsistence type to that of the modern scientific type. The study had come to the conclusion that the increases in the per hectare crop yields in the developing countries in recent years had been realized mainly through the use of intensive inputs such as fertilizers and pesticides.

Singh et al., (1995) have found that the per hectare energy use had varied significantly among the different types of soil conditions of farms, the raising of
varied crops and the varied climate complexes, the various levels of technology and the various size categories of farms. They had reported that the output had been affected significantly by the farm size, the seeds, the pesticides and the number of tractor hours used.

Shukla et al., (1996) have conducted a study in the different areas of the Barailly district of Uttar Pradesh and have reported that the use of electricity and the tractor power were higher in the developed areas and in the larger farms.

A study was undertaken by Dutta (1997) to examine agricultural production efficiency and farm size of major crops. The district of Ranchi was selected for the purpose of small farms and large farms and peasant farms and capital farms. The study revealed that the small size farms are relatively more efficient than the large sized farms in the production of paddy, while the large farms were relatively more efficient in the production of wheat. With regard to potato, no clear evidence of efficiency differences between small and large farms has emerged. The peasant farms were more efficient than the capitalist farms with regard to all the three crops of paddy, wheat, and potato.

Lakshmi (1997) had analysed the total human energy input in the various agricultural operations and had observed that 0.13 per cent of the human energy was used for ploughing 0.26 per cent for weeding, 14.69 per cent for purposes of irrigation, 11.09 per cent for transplanting, 4.17 per cent for harvesting and 5.17 per cent for sowing.
Amarjit Singh and Singh (1998) have recommended that energy plays a major role in the agriculture development of the state. Since agricultural development has reached a plateau in the state with almost no scope of change in net sown area, cropping intensity, irrigated area, cropping pattern, etc., in the near future, the requirement of energy will be determined by the behaviour of the farmers reflected in the technological path adopted by them. The potential of energy conservation needs to be realised through mass education campaign and by providing economic incentive to conservation and imposing disincentives on inefficient use. Sustained efforts are needed to look for an economically suitable alternative to Paddy crop which is largely responsible for power and groundwater consumption. A shift of 20 per cent of the area from paddy will considerably reduce the pressure on electricity demand because paddy crop alone accounts for three-fourths of the total electricity consumed in the agricultural sector.

Pratap S. Birthal et al., (1998) had looked at one experiment that the demand for commercial energy based inputs like fertilizers and diesel would increase with the shift in cropping pattern from coarse cereals to fine cereals or commercial crops. Farmers in pursuit of profit maximization take decisions considering productivity levels and input-output prices. Current input prices favour the use of commercial energy based inputs. Since commercial energy has become a crucial input in crop production in India, any reduction in commercial energy use in agriculture may adversely affect crop productivity and production. Technological intervention appears to be only option to minimize the use of
commercial energy. Some technologies like integrated nutrient management, integrated pest management, etc., need to be scaled-up. Energy use efficiency can also be improved by practising good husbandry as there is scope for increasing yield through higher inputs use efficiency.

Seed is one among the important components in the new agriculture technology package program. The adoption of high yielding seed variety is related to many factors such as mode of irrigation, availability of seeds, farm size, knowledge of the farmers, financial position of the farmers, quality of the lands, etc.

There are a large number of studies which show that there is a relationship between adoption of High Yielding Varieties (HYV) and the availability of irrigation. Farmer (1979) found that in South Asian rice fields, assured well controlled irrigation is crucial for the successful adoption of HYVs. He also found that the farmer without a pump set found it difficult to adopt the HYVs.

Saini et al., (1998) have found that the total amount of energy used in the production was the highest in maize potato-wheat rotation (38 GJ/ha) followed by rice-potato (27 GJ/ha), maize-Foria-Wheat (25 GJ/ha), which was mainly due to greater use of FYM, seed tubers and human labour in potato crop. The least energy use was observed in sesame-wheat rotation which was due to low use of high energy inputs, especially FYM and chemical fertilizers in sesame crop which was generally grown on marginal lands that were away from the farm house. Overall, around 15 per cent of total energy used in these cropping systems was
through human labour for different farm operations which included both family labour as well as hired-in human labour. The largest amount of energy under unirrigated conditions was used in rice-wheat (18 GJ/ha), followed by maize-wheat rotation (17 GJ/ha).

Saini et al., (1998) have concluded that the farmers have to compromise very little in terms of net returns if they are to adopt energy optimized plans. Since the energy optimal plans showed saving of energy intensive inputs like chemical fertilizers, human labour and traction power to a large extent as compared to that of returns optimized plans, it implied that the farmers in hills were more energy conscious in using the energy inputs wisely and judiciously. For this it was suggested that short duration training on farm management small farmers so that they may be able to understand the importance of judicious allocation use of scarce energy inputs to have more energy efficient, economically viable and sustainable farming systems.

Saini et al., (1998) have suggested that those rotation crops which included potato and other vegetable crops were relatively less energy efficient. The cropping systems were more energy efficient under irrigated conditions than under un-irrigated conditions. This was because of the higher yield under irrigated conditions as the irrigation did not involve substantial energy input other than human labour, implying thereby that energy efficiency of crops can be greatly improved through irrigation in the study area.
They also further stated that the existing net energy output and energy output-input ratios in different cropping systems on large farms revealed that the large farms also exhibited the same pattern of energy input-output relationship as on the small farms with a few exceptions. Sorghum-berseem and rice-berseem rotations were more energy efficient on large farms as compared to those on small farms.

Roy et al., (1998) narrate that cropping patterns almost always start with a crop of aman (rainy season) rice. When water is non-limiting, farmers favour Swarna Mahsuri, which subsequently delays the production of boro rice by about 15 days. This cropping sequence (rice – potato - sesame) is the farmer’s preference for maximizing returns and productivity. Farmers who plant potatoes were harvested early, boro rice was planted on time. Potatoes do not enter into the cropping sequence when soils were too heavy or in areas where drainage was problematic. These areas were restricted to the double cropping of rice. The most surprising feature of the sequential cropping system is the dominance of a moderately long-duration rice variety to start the sequence. The cultivator of preference in the rainy aman season is still swarna Mahesuri a 135 to 140 day variety characterized by high yields, good cooking quality, and wide adaptability. Earlier maturing varieties, such as IR 36 were available, but farmers were willing to accept lower boro productivity if water for the summer season was readily available.
Roy et al., (1998) has examined in their papers the strong preference for a moderately long duration rice variety to initiate a triple cropping sequence suggests that the Conventional wisdom about the catalytic role of high yielding varieties of rice in facilitating the place of potatoes in the cropping system is somewhat misplaced.

Agriculture has been an important sector of the country. Crop production is the most important sub-sector of the agricultural sector. Rice, maize, fruits and sugarcane are important sub sector of the agricultural sector. Rice, maize, Fruits and Sugarcane are important domestic food commodities and foreign exchange earners. Energy is an indispensable production resource. It is essential to all activities and its importance cannot be over emphasized. The agricultural production system is an energy conversion process which harnesses most abundant solar energy in the form of food energy. For efficient conversion, a variety of energy inputs are required viz, energy required in physical operations, energy applied in the form of the chemicals such as fertilizers and pesticides and the energy applied as bio-chemical inputs such as seeds and hormones.

Uhlin (1998) stresses the relationship between several kinds of energy uses, product compositions and technical change in Swedish agriculture. Energy productivity has changed dramatically. Cash crops and non-ruminant animals have been more efficient in their use of support energy in all sectors. Manure has become marginal as a substitute for external energy inputs through fertilizer. Transforming a larger proportion of produced biomass to useful products outside
agriculture, changing from ruminants to non-ruminants production or finding fuel uses of manure will increase energy productivity and sustainability.

Ramachandra and Nagarathna (1999) measured the quantity of energy inputs in paddy cultivation in the Uttara Kannada district in Mid-western part of Karnataka State. Operation wise energy flow patterns were studied to find energy Consumption. The study showed that bullock power (BH) Human power (HP), seed (S) Farm Yard manure (FYM) and inorganic fertilizers (F) are the major components in energy input. In order to see the variation in yield due to the consumption levels of these factors, regression analyses were performed. To investigate the factors responsible and their contributions for variations in yield, stepwise regression analysis was performed zone wise and land hot ding wise by adding the variables one by one. Standardised regression co-efficient have also been computed, which help in identifying the importance of each variable in the least square formula. The main findings of the study were:

1. Variation in yield due to variable land was attributed to salinity and varying nutrient content of soil across the zones.

2. High dung availability due to higher livestock density and good Management practices have resulted in higher yield in the coast. While the interior zone has a scarcity of green manure and dung availability, Farm yard Manure contribution in the hilly zone was significant.

Hulsbergen (2000) made a study on a method of energy balancing in crop production and its application in a long-term fertilizer trial. They have found that
the input of energy was highly variable; it ranged from 8.9 to 36.9 GJ ha. per year. Crop rotation is depending on the N region and the crop. Because of the high soil fertility, the average biomass yield of all the crops grown within a rotation was as high as 13.5, dry matter (DM) ha-1 per year, the output of energy was as high as 215 GJ ha⁻¹ per year. On the fertilised plots, net energy output (energy content of the grains minus energy input) and energy utilization improved with time. Winter wheat, fertilized with moderate amounts of mineral and farmyard manure N showed an increase in net energy output of 86% from 1972 to 1995. During the same period, the energy intensity (input of fossil energy per grain equivalent) declined by 45%, and the output / input ratio increased by 67% In part, these trends can be attributed to the higher grain yield (+59%). Energy output and net energy output were the crucial parameters when the demand for plant products cannot be met because of the limited area for growing crops. Energy intensity and energy output / input ratio were integrative indicators of the environmental effects of crop production, which can be used to formulate recommendations for fertilization which was optimum as far as the environment was concerned.

Gupta et al., (2001) in their study indicated that, banana is a traditional plant cultivated widely for mankind. After harvesting of the fruit, the various other parts of the plant (by products) are not effectively utilised. It has been estimated that a residual biomass (Pseudo stem and leaves) of 13 to 20 tones dry matter/ hectare / year was available. Gupta et al., (2001) suggested that feeding of whole banana plants (stem and leaves) will meet the maintenance requirement of
cattle. Hembade and Patel (2004) concluded that banana leaves can be incorporated in the diet of kids. However, at present they are thrown out as waste on roadsides, or allowed to rot away in the fields or sometimes burnt in the field. In order to throw light on the efficacy of banana by products to serve as a potential source of roughage to ruminants, a study was undertaken to evaluate the various by-products of banana as a source of feed to ruminants through studying the effect of banana plant by products on rumen fermentation pattern.

Alam et al., (2005) have examined that, a qualitative energy flow analysis in Bangladesh agriculture has been made for a period from 1980-81 to 2000 -01 to evaluate the impact of energy input to produce output. Human and animal muscle power and machinery energy for tillage operation, electricity and diesel energy for irrigation, fertilizer and pesticides energy for growth and protection were taken into account. Energy values were calculated by multiplying respective quantity by their respective energy equivalents with the use of relevant conversion factors. Energy flow studied based on some energy dependent indicators: energy input per ha, energy output per ha, energy output of input ratio, mechanization index, energy input to generate per unit GDP output as well as per unit output in energy term. During the study period, energy input and output to Bangladesh agriculture were increased from 6.4 to 17.32 GJ ha$^{-1}$ and 72.22 to 130.05 GJ ha$^{-1}$, respectively. It was found that energetic efficiency (energy output to input ratio) declined from 11.28 per cent to 8.1 per cent, which indicates that the energy input increased
faster than energy output product and by-product depend on only level of energy input.

Kataria and Joshi, (2007) in their study revealed that rice-wheat cropping systems was absented to the most energy intensive wheat cultivation consumed a total of 14657 MJ/ha followed by Paddy, which consumed 13076 MJ/ha. The consumption of energy by pulses ranged from 3870 MJ/ha for black gram to 5464 MJ/ha. For Bengal gram and sugarcane cultivation consumed 59192 MJ/ha. The energy productivity measured as Kg/MJ has been recorded as the highest (1.17) for sugarcane crop, the same for paddy, wheat and maize being 0.239, 0.196 and 0.21 respectively. This analysis can be used for the judicious selection of crop rotation depending upon the energy usage so as to minimize energy inefficiencies.

Garg et al., (2007) have suggested that sugarcane, wheat, paddy and maize crops were important from the point of view of returns per hectare and also these crops were much significant from the production and availability of biomass. The most important energy sources were diesel, fertilizers, plant protection, chemicals and electricity which were used by the farmers of irrigated and un-irrigated farms for carrying out different agricultural operations. The use of tractors displaced the human and animal power and hence, the average use of animal and human power was only 30 per cent to 40 per cent of the total energy used. Further, the study areas had a big potential of crop production for energy purposes. However, the availability of crop residues and wastes which were being used for meeting the energy needs by village people, were considered to be a social cost.
Solomon Raj (2008) analysed and suggested that energy productivity was higher for small farm than large farm for Paddy crop. Further, large farm was more energy efficient than small farm in Paddy cultivation, but in banana cultivation small farm was more energy efficient than large farm. The cost of human labour was the highest for Paddy followed by fuel and fertilizers in both the farm groups. For banana crop the amount spent on fuel was the highest for the small farm and the amount spent on fertilizer was the highest for the large farm. Further the cost and returns of various farm groups, small farm maintains higher net returns.

Singh and Dinesh Kumar (2008) in their study revealed that the potential impacts of energy pricing on efficiency, equity and sustainability in ground water use. The analysis uses empirical data on water productivity in agriculture for crops. The analysis also compares data from diesel well owners and electric well owners in south Bihar. Introducing marginal cost for electricity motivates farmers to use water more efficiently at the farm level through careful use of irrigation water; use of better agronomic inputs; optimize costly inputs; optimize livestock composition and carefully select crops and cropping patterns, which give higher return from every unit of water and grow low water consuming crops.

Shahan et al., (2008) have suggested that better energy efficiency and productivity are found on the large farms. According to this criterion large farms were more successful in energy use. Energy management is an important issue in terms of efficient sustainable and economic use of energy. Reducing inputs would
provide more efficient input use of mainly machinery, fertilizer and pesticides. Application of integrated pest management techniques would improve pesticide use. In addition to these applications choosing the appropriate cropping systems would be useful not only for reducing negative effects to environment, human health, maintaining, sustainability and decreasing production costs, but also for providing higher energy use efficiency.

Dinesh Kumar et al., (2008), have suggested that cropping patterns of farmers in electric and diesel pump command area under different crops in different seasons for eastern Uttar Pradesh was dominated by the paddy and wheat. The cropping pattern of water buyers in electric well commands and farmers in diesel well commands in South Bihar plans was similar to that obtaining in the Eastern Uttar Pradesh viz., paddy and wheat cropping system. Due to high rainfall and poor drainage of land in the region, the agricultural land remains water logged during monsoon, and in this situation farmers are forced to take paddy. Farmers allocate a very small area for fodder crops to sustain dairy farming. During winter, they allocate larger area for wheat followed by potato, which gives high returns. During summer farmers allocate larger were for onion, which again provides cash income.

Further, this study concluded that the analysis of the farming enterprise of irrigators under differential cost (irrigation) regimes showed that farmers would be able to cope with very high rise in irrigation costs through irrigation efficiency improvements and allocating more area under crops that give higher returns from
unit of land and water, that enhance the farming returns from every unit of water and energy used.

Reshma et. al., (2009) have suggested that the energy requirement for the production of paddy and ginger was to an extent of 9519.61 MJ/acre/crop for paddy and 34311.78 MJ/acre/crop for ginger. When contributions of energy from different sources were considered, the energy through fertilizers was found to be highest in the production of both the crops. The employment of human energy was the second highest. The greater extent of escalation in the energy use pattern in crop production was thus due to the shift in cropping pattern from paddy to ginger in Kodagu.

In agricultural planning, crop production from limited arable land was to be maximized with minimum energy inputs. Therefore, the understanding of the interaction between crop yield and energy inputs was required for the formulation of the plan. (Gajendra Singh and Anuchit Chamsing, 2000)

2.4 Studies covering Determinant Factors of Energy Consumption in Agricultural Sectors

Dunkerley et al., (1981) while discussing the patterns of rural energy, mentioned that traditional fuels were not suited to one especially in the rural sector of many developing countries the pumping of ground water for irrigation and for human and animal consumption. For that purpose, primitive animal-powered pumps were normally replaced by diesel engines or by electric motors when
electricity was available. So also in transport, the typical succession from animals to gasoline or diesel fuel, kerosene lamps or electricity were also preferred for lighting at a quite early stage of development.

Jyothi Parikh (1986) estimated energy consumption in the poor-harvest food system of India, Pakistan, Burma and Sri Lanka in 1984. The components of the post-harvest food system were food processing, food transport and cooking. It was shown that they represent a significant share of national energy consumption and that the variation among countries depends on the variables such as urbanization, income, cropping patterns and whether a country was an importer or exporter of food. The study revealed that more than 50 per cent of commercial energy comes from Kerosene, except for Burma (Myanmar) where gas provides a major share.

Bhagavan and Giriappa (1987) made an attempt to develop a new method of analysis of rural energy crisis in Karnataka context. The researchers felt that in the context of rural India, a proper understanding of the production, consumption and reproduction of energy required a broader perspective including food, fodder and fertilizer taking into consideration labour, land, physical and monetary assets, indebtedness and caste as the basic parameters of analysis. The study has examined the energy crisis evolving among different classes of people in rural areas. The surplus energy generated by the labour power of the “wage-labour class” was grossly undervalued, under exchanged and underpaid. Hence the
researchers infer that the wage-labour class was the most affected by the energy crisis.

2.5 Studies covering Specific Problems of the Agricultural Sector in the Use of Energy

Gurunathan and Palanisami (2008) have revealed that in the ground water less exploited area, usage of energy inputs has been found very high for paddy and Cotton crops, as these two crops need high labour inputs in animal human and machine forms, which has led to high energy input consumption in the study area. Among the crops, cotton has been found to be the most energy – intensive crop due to usage of more plant protection chemicals, which have high – energy equivalent ratio of 120 MJ per kg of active ingredient. Energy efficiency has been observed higher for coconut, among crops. No more difference has been observed in gross value of output MJ of energy input in paddy and cotton crops.

2.6 Seed Related Studies

Singh and Singh (1973) conducted a study in Tarwa block of Azamgarh district in Uttar Pradesh. They found that the adoption of HYVs had been slow due to the non-availability of adequate credit.

There are studies which have analysed the relationship between the adoption of HYVs and land size of the farmers. The study by Parthasarathy et al., (1978) in Andhra Pradesh revealed that there existed a significant positive
relationship between size and HYV seed adoption. In contrast to the above study, Muthia (1971) found that the small and medium farmers of India adopted HYV on a larger proportion of acreage than did large farmers.

Seed is one among the important components in the modern agriculture technology package program. The adoption of high yielding seed variety is related to many factors such as mode of irrigation, availability of seeds, farm size, knowledge of the farmers, financial position of the farmers, quality of the lands etc.

A study conducted by Pandey (1979) in Kiul-Bandra- Chanda command area in some sample villages – three from irrigated and three from un-irrigated villages showed that the farmers were taking interest in adopting new seeds, although they were not available readily in the market. It also found that the farmers did not have the knowledge of sowing seeds in correct quantity.

Chinnappa (1980) conducted a study in south Arcot, Tamil Nadu. She found that HYVs areas were in largest Navarai. She also indicated that non-availability of suitable HYVs that can be grown in samba was one of the causes for low overall HYV adoption rates. Sometimes the low adoption of HYV rice was due to the low price. She also found that bigger cultivators extensively adopt the HYVs. Non-availability of credit appears to be a constraint on adoption of HYVs, especially among the small cultivators.

Dasgupta and Biplab (1980) also indicated that in many cases seeds were not treated with any insecticides before sale. He also mentioned that the low
germination was one of the main reasons for the lack of interest to adopt the Government depot seeds. Due to this reason the cultivators preferred the co-villagers seeds.

Chinnappa et al., (1980) found that big farmers allocated more area for HYV, whereas medium and small farmers allocated only very meagre area. This view has also been supported by Saini (1979) because HYVs technology is basically characterized by a capital-intensive and it has relatively easy access to the big farmers. Dasgupta and Biplab (1980) also found that there was a strong positive linear relationship between farm size and adoption of new varieties.

A study by Chattopadhyay (1986) relating to agronomic experiments and the farmers’ experience in West Bengal showed that local and improved indigenous varieties perform better than HYVs. This view has also been supported by Athreya et al., (1986). He also indicated that cash expense and availability of timely institutional credit were important considerations for adoption, profit and lower cost. They maybe more attractive to the farmers so as to favour low varieties and restrict adoption of modern varieties. He also found that bigger farm size had a definite and favourable impact on adoption.

Madhava Swamy (1986) conducted a study in Kurnool district of Andhra Pradesh and found that most of the farmers did not adopt the recommended seed rate. Further all the respondents were found using copper sulphate for seed treatment instead of sulphur or carbofuran. He also indicated that lack of suitable
variety under rain fed conditions was the major constraint for low adoption of HYVs in the area.

Supe et al., (1986) carried out a study in Maharashtra district to evaluate the role of the extension activities. They collected data from 240 paddy growers spread over ten villages in 1984-85 season. The study indicated that i) farmers are not aware of the HYV technology, ii) the attitude of farmers towards HYV technology is not favourable, this is due to the lack of conviction about the superiority of varieties. It implies that extension officials are not clearly demonstrating the superiority of the varieties so far to the farmers up to their knowledge.

Bhuiyan et al., (1987) conducted a study during the crop year of 1984-85 in Mymensig district in Bangladesh and found that adoption rate of HYVs of different paddy crops was relatively higher on owner farms than on part-tenants.

Dhawan (1988) in his study found out that, private wells especially private tube wells is a major force in the successful propagation of HYV seeds in Punjab. Raj et al., (1988) also confirmed that HYVs perform best during the dry and sunny rabi season. But IR-8 can be cultivated successful only on land having assured water supply and supplementary irrigation with a filter point or tube wells. He also explained that IR-8 consummates much better in rabi than Kharif.

Dasgupta and Satadal (1989) also indicated that it was impossible for a farmer to cultivate the HYVs of rice or wheat if the farmers have least accession to sources of water for irrigation.
Mann (1989) carried out a study on adoption of HYVs with the help of National Council for Agricultural Energy Research (NCAER) Additional Rural Income Sources (ARIS) data for the year 1970-71. The study covered 4118 households to find out the factors responsible for the adoption of HYVs seed (wheat) in India. The study indicated that increased proportion of irrigated land in the village is significantly related to adoption of HYVs wheat seeds.

Rajagopal (1989) conducted a study in a predominant paddy growing district in Madhya Pradesh and found that the level of adoption of HYV paddy seed did not relate to the factors like age, family size, formal education, but at the same time, it was related to extension contact, mass communication and income of the family.

2.7 Fertilizer Related Study

A Punjab based study by Bhajan Singh et al., (1976) found that there were large number of farmers who were using far less than the recommended amounts of fertilizers, they were generally the small and marginal farmers. It also indicated that there was some relation between fertilizer [N] use and use of Farm Yard Manure [FYM].

Harris (1980) has observed that most of the farmers decide themselves about the quantity of fertilizer use, only a very few of them followed the recommendation of the extension officers. This is partly because they believe that
the recommendation is not right for their fields and partly because of the shortage of money and inability to pay for adequate quantities.

It is obvious that among the various new agricultural technology components fertilizer plays a crucial role in the crop production next to seed. That is why the new technology of agriculture is otherwise called as HYV seed-fertilizer-water technology. The Economic and Social Commission for Asia and the Pacific (ESCAP) also estimated that the 31 per cent of gains in rice production in India for the period 1965-1980 has been due to fertilizer (Maricar B. Jara, 1985). Many studies confirmed that HYVs consume more fertilizer and the yields of those varieties are highly positively related with the use of chemical fertilizers.

However, the results of some of the available studies on fertilizer use are not similar. One set of studies revealed that there is a relation between the use of fertilizer and availability of irrigation, while some other studies showed that the relationship of fertilizer use and their land holdings. A few other studies have explained the relationship of fertilizer use and the crop season. Some studies showed that there is a relationship between availability and use of fertilizer.

Desai (1986) indicated that the diffusion of fertilizer use was much faster under irrigated conditions than under un-irrigated conditions.

Parthasarathy et al., (1986) found in Andhra Pradesh that the main factor for rapid use of fertilizer in agriculture was irrigation with growing consciousness about fertilizer among the farmers.
The application of fertilizer is also varied among the various categories of cultivators. In this connection, the study conducted by Bharadwaj and Krishna (1974) found with the help of Farmers Management Surveys Data (FMS) before the introduction of new technology (during 1954 to 1957) that the use of chemical fertilizers was limited and was used mostly by landholders. Parthasarthy et al., (1983) and Mandac et al., (1985) also found in their study that after the introduction of new agricultural technology, fertilizer use was found increase with land size as it was before 1965.

Ramasamy et al., (1986) have analysed the aspects relating to fertilizer use and farm size, difference in fertilizer use among varieties by using 90 farms in six villages in South Arcot district, Tamil Nadu, during 1985-86. They found that the fertilizer use increased in relation to increase in farm size. An analysis related to season and fertilizer use revealed that the farmers applied more fertilizer per hectare during the season January to July.

Application of fertilizer also varies among varieties. There is large number of studies which assessed that the use of fertilizer was high for HYVs compared with local varieties. Parikh et al., (1986) found in Haryana that the rate of application of fertilizer such as N.P.K. was much less in traditional varieties as compared to HYVs. It was stated that the use of fertilizer was much less than that of the recommended level in experimental field.

Dutta et al., (1986) in their study based on cross section data households collected under the cost of cultivation scheme (CCS) in West Bengal during 1981-
82 found that in both absolute and relative terms fertilizers are used more intensively in crops of HYVs rather than local varieties. Ramasamy et al., (1986) also found that the IRRI based varieties rank top in the list of consumption of fertilizers.

Another study by Madhava Swamy (1986) found that in Andhara Pradesh on an average, the farmers were applying 32+18+18 kg of NPK per hectare as against the recommended fertilizer dosages of 60+30+30 kg. The main reason for the low spread of fertilizer is the lack of capital and non-transfer of technology in rural areas.

Singh et al., (1986) found in Himachal Pradesh that the rate of fertilizer application was relatively high in the kharif than rabi.

Kalita et al., (1986) found in Assam that the use of fertilizer was very low, due to peculiar climatic conditions, lack of infrastructure development, inadequate distributional arrangements poor purchasing power of the farmers and inadequate purchasing power of the farmers. Desai (1986) also held the view that the actual use of fertilizers would still depend on whether adequate fertilizers were available at the right place and time.

Desai (1986) explained in the analytical work that the upward movement in the rate of application of chemical fertilizers is due to the replacement of local varieties by high yielding varieties. He also mentioned that the growth of fertilizer consumption was considered as a function of variables such as level of irrigation, area sown to HYVs, cropping pattern and prices of crops as well as fertilizers. The
The use of fertilizer also varies between the seasons. There are other studies which also explain recommended limit of fertilizer use and the season.

Some studies found negative relationship between the adoption of fertilizer and the size (Singh et al., 1986). Subramanian (1987) conducted a study in Madurai district of Tamil Nadu and showed that small farmers have used more fertilizer than that of large farmers. Subramanian and Nirmala (1990) in another study related to paddy crop in the same district indicated that there is a positive relationship between size and the use of fertilizers.

Bhuiyan et al., (1987) came to the conclusion from their study in 1984-85 that owner operated farmers used significantly higher doses of both organic and chemical fertilizers than part-teneants.

Rajagopal (1989) found in Madhya Pradesh that non-availability of chemical fertilizer at appropriate time was a major problem to adopt this input in time. Ratna Reddy (1989) suggested that the following measures would be helpful to use greater amount of fertilizer (i) ensuring timely availability and (ii) encouraging timely use of fertilizers.

It is clear from the review of the existing studies that they have concentrated only on the use of fertilizer in relation with land size, availability of water, season etc. But studies are rarely available regarding the use of fertilizer and its relation with farmers’ education, experience and age. Studies are seldom available regarding the recommended rate of use of fertilizer basal and top dressing. More importantly, relationship between the use of chemical fertilizers...
and the use of farmyard manures (FYM) and green manures have also not been focused seriously in the existing studies. Yield differences between the farmers who have followed recommended doses of fertilizers and who have not followed the same are also not systematically analysed in the existing literature.

2.8 Relative Efficiency of Modified Fertilizers and Cropping

According to Singh et al., (1994) high yielding varieties of cereals in general and wheat in particular, respond to fertilizers, especially nitrogen and phosphorus. In fact, a continuous growth in the use of fertilizers along with adoption or high yielding varieties under irrigated conditions has accelerated agricultural production resulting ultimately in self-sufficiency in food grains. Hence, in their opinion it is very important to study the response of wheat or any other crop to nitrogenous and phosphorus fertilizers and examine their profitability at different prices of wheat grain. They add that a number of studies have already been undertaken to study the response of wheat to either nitrogen or phosphorous their economic optimum levels have also been worked out separately. They conclude that the price incentive given to producers will result in higher fertilizer consumption and a consequent increase in the productivity of wheat.

A similar study has been conducted by Singh and Singh (1994) to find out the effect of a slow release urea for rice in rain fed low land to be very low ranging from 25 to 39 per cent. It seldom exceeds 50 per cent. It is mainly due to the loss of applied nitrogen and it may be improved either by incorporating it into the
puddled soil prior to transplanting split application, using coated nitrogen fertilizer like urea coated with rock phosphate, gypsum and or with neem cake. They show that the work done so far on coated materials has mostly been restricted to their direct effect. The beneficial effects of the application of nitrogen on various determinants lead to more production of rice at higher level of nitrogen.

An experiment has been conducted by Hedge (1992) to study input management for high productivity in different cropping systems under late sown conditions. In intensive cropping systems under irrigated conditions, the time selected for the planting of a crop will have profound effect on its productivity. Any delay in planting one crop generally leads to delay in planting succeeding crops which will have adverse effect on the total productivity of all the crops. Thus they argue that suitable adjustment in the plant population and fertilizer use, besides selection of appropriate variety for late sown conditions, may increase productivity. For late sown groundnut and wheat sequence, it is profitable to increase fertilizer application over the recommended level. However, there is no scope for curtailing fertilizer use without affecting profitability. In general, except in rice, rice sequence increased fertilizer use under late-sown condition becomes more beneficial in rainy season.

2.9 Pesticides Related Studies

Pesticide is one among the important bio-chemical inputs in the new technology package. After the introduction of new technology the consumption of
this input has increased all over India. The adoption rate also varies between the farmers, location, crops and between varieties.

A study of Programme Evaluation Organisation (PEO) (1970-75) found that pesticides application were frequently less than recommended level and only large farmers used it. They also indicated that this unsatisfactory performance was due to high cost of sprayers and chemicals. They also found that due to the low adoption of chemical, the yield was reduced considerably in some survey districts. It implies that low use or non-use of pesticides will drastically affect the yield of the crop.

Shrinath Singh (1976) found in Dohli block of Janupur district of Eastern U.P. that the large farmers generally spending more on plant protection than other farmers. The highest expenditure on plant protection is for HYVs paddy. Saika and Bora (1975) also confirmed from their Assam related study that small farmers use pesticides only occasionally and surprisingly reported that sometimes they do not get the pesticides in time.

Dasgupta and Biplab (1980) also found that the use of pesticides is still far from satisfactory among the various types of cultivators. There are two reasons for the low level of pesticide use (i) high price of pesticides and (ii) non-availability of dusting and spraying equipment.

Parthasarathy and Pothana (1983) carried out a study in West Godavari of Andhra Pradesh. They found that the use of pesticides was higher on large farms compared to small and medium sized farms.
Reddy (1985) carried out a study in Guntur district of Andhra Pradesh to find out the effect of Nagarjuna water project on cultivation. He found that there were marked differences among the cultivators with respect to amount spent per acre on plant protection measures. The socially backward classes are using relatively lower amount of pesticides than advanced castes cultivators. The big size cultivators work controlling the pests in time and getting better yields.

The author, further, indicated that the big farmers acquired the pesticides before the seeds are sown from the big traders in the nearby towns. But economically weaker cultivators tend to buy these inputs from local traders at the time of seed sowing at exorbitant prices. It shows that economic condition of the farmer is a devastating factor which determines the use of modern inputs in time.

The use of pesticides differs from variety to variety. Because, some varieties of crops are less resistant to pest attack, while some others have more resistance. Subramanian and Nirmala (1990) analysed the variety-wise use of pesticides in Tamil Nadu and came to the conclusion that the use of pesticides in milliliter (ml) was very high (1255ml) for Co-36 it is a locally improved varieties, as compared with IR-20 and IR-50. It shows that IR varieties have a greater pest-resistant nature.

Alagh (1988) analysed the pesticides use in Indian agriculture with the help of Cost Cultivation Studies (CCS) data collected by the Directorate of Economics and Statistics, Ministry of Agriculture. He explained that pesticide consumption has increased steadily from mid-fifties; application has increased both in quantity
and in area coverage. Plant protection coverage increased from 2.4 million hectares in 1956 to 80 million hectares in 1984. He also explained that nearly one-third of total pesticides used on the rice crop are consumed by Andhra Pradesh alone. The limited coverage of pesticides area in India is largely because of lack of scientific approach. This is because; the farmer is seldom exposed to proper application practices and training in handling of pesticides.

Rao and Prasad (1988) came out with an interesting conclusion in an Andhra Pradesh related study that the lower application of nitrogen fertilizer lead to better yield and reduced pest ravages considerably.

The studies which are available regarding the use of pesticides concentrate mostly on the user’s land holding position and the non-availability of pesticides. But the adoption or use of pesticides varies depending on the variety of the crop, extent of pest attack and importantly with season. There is a relationship between the use of pesticides and human resource factors: education, age and experience of the farmers. Mixing of recommended quantity of water with the recommended quantity of pesticides is also not focused so far in the existing literature. The relationship between greater use of chemical fertilizers (especially nitrogen fertilizer) and its impacts on the use of pesticides have not been seriously focused in any existing economics of agriculture related study.

Pandey (1989) carried out a study in two blocks of Varanasi district, Uttar Pradesh to study the adoption of agricultural innovations. The samples were collected from 150 farmers, 81 from small and 69 from medium farmers. The
study found that about 70 per cent of the farmers were using low amount of plant protection measures. Further, the author indicated that the reason for the low use of plant protection chemicals might be due to the lack of knowledge, feelings of farmers about its non-acceptance, its complex technology and high cost of plant protection measures.

2.10 Mechanisation Related Studies

The use of machineries like tractors, pump sets, power/manual sprayers, threshers and combined harvesters have increased to some extent after the inception of new technology in agriculture. This adoption also depends on land size, place, availability, area under irrigation, relative cost of substitutable inputs, awareness of the farmers, etc.

There are studies that have focused on the facts of use of the modern machineries to avoid time lag and for increasing efficiency. Kahlon and Gill (1967) conducted study in Patiala district to compare the cost of selected operations through mechanized and non-mechanized practices. It was found out that mechanized operations were economically efficient and timely than the traditional methods.

There are studies that have focused on the relationship between size of holdings and use of modern machineries. Bal et al., (1973) found in Punjab in 1971-72 that there was a significant difference in the pattern of investment in farm machinery in all size groups. The large size holdings made more investment on
tractors and tractor drawn implements whereas small and medium sized farmers had invested more in irrigation.

Shrinath Singh (1976) carried out a survey and showed that the main reason for the non-installation of irrigation sources was small and scattered holdings and lack of finance. It was found out that electricity also plays a predominant role in the adoption of modern machineries. Fredoun and Esfahani (1990) found in Iran that the use of machinery for major tasks such as ploughing and harvesting had become common on holdings over 10 hectares. Saika and Bora (1975) also came out with a conclusion in Assam agriculture that no small farmers have used tractors for ploughing.

National Commission on Agriculture (1976) study found that use of tractor facilitates intensive cultivation and diversification of cropping pattern.

One set of studies showed that there is relationship between the use of modern inputs and the use of machineries. Ray and Blase (1978) carried out study in Punjab with the help of cost cultivation studies on major crops grown in Punjab for the year 1971-72. The study shows that more intensive use of HYVs and chemical fertilizers on tractor farms vis-a-vis the non-tractors farms. They also found the average size of farm is higher in tractor used farms than the non-tractor used farms.

Saini (1979) found that the big farmers have relatively easy access to capital, so they can use more rationally the tractors, tube wells and pump sets.
Some studies have focused on the use of modern machineries and its impact on cropping pattern, cropping intensity, yield, etc. Pudasaini (1979) compared the mechanization strategy as combination of mechanization practices with traditional method of farming in Bara district of Nepal. A sample of 102 farmers was selected through stratified random sampling and regression analysis was conducted on the data. It was found that mechanized farm has more crop yield per unit area, higher cropping intensity than the traditional farms.

Dasgupta and Biplab (1980) confirmed that main advantage of the use of tractors is time saving and less expensive, despite being capital intensive in nature.

Harris (1980) found that the farmers were using tractors for ploughing wet land mainly to avoid delay of transplanting. Before this, the tractors had reportedly been used only for dry-land ploughing and for HYV threshing for the HYVs are difficult to thresh by hand because of their short stems and tough rachis.

Rao (1980) came out with an entirely new conclusion that the incentive for adoption of tractor use among the large farm arises due to the rise in wages and the cost of bullocks. He also stated that the investment on tractors is not profitable for small farmers because they are mostly using family labour.

Dhawan (1988) also found that the well and tube well irrigation is predominantly owned by private individuals it is undertaken by medium and large farmers than by the small and marginal farmers.

The relationships between the use of modern machineries and the development irrigation have also been focused in some of the studies. Jose (1988)
explained in his analytical work that the expansion of irrigation infrastructure has also been accompanied by extensive adoption of capital intensive machineries for farm operation. He also stated that experience of Asian countries shows a good deal of association between development of modern irrigation system and an extensive adoption of farm machinery within the agricultural sector.

Mander and Grewal (1988) found in Punjab for the agricultural year 1985-86 that mechanization increased productivity of some crucial resources like labour, irrigation, manures and fertilizers. He also stated that investment on tractors was economically justified only on farms of 20 acres and above.

Sreenivasamurthy et al., (1988) found in Karnataka state Bangalore district that tractor owner use more complementary inputs like fertilizer and other inputs. Bhatia (1990) also found in Punjab agriculture that fertilizer use was 16 per cent higher on tractor operated farms than the bullock operated farms.

Chakradhar Rao (1989) found that the use of tractor and other machinery is increasing in certain parts where assured irrigation is available.

Bhatia and Bhim Sen (1990) conducted a study in five districts in Punjab with the help of 375 farmers. The study came out with the following conclusions. Nearly 37 per cent were having sprayer-about 32 per cent manual operated and only five per cent power operated. There were 20 per cent of the farmers who did not use sprayer as it was not easily available for use at the time of need. About 77 per cent use of tractor was for field operations like ploughing, leveling, puddling,
sowing, etc. Dusters and seed treating drums were used quite sparingly, that is, by only one per cent farmers. The reason that farmers can do without owning them.

Bhimsen and Bhatia (1990) also found a strong positive relationship between the farm size and the adoption level of selected agricultural engineering.

A recent study of Narayananmoorthy (1992) related to bore-well irrigated area of Pudukkottai district of Tamil Nadu also confirmed that mechanized farm size is bigger than the non-mechanized farm. The author further stated that non-use of tractors is not only because of financial problem but because of scattered holdings and non-availability of inputs in time. Importantly, the author asserted that the use of tractor does not have the power to increase the crop yield.

2.11 Education Related Studies

There are some studies which show a positive relationship between the adoption and education of the farmers.

According to Rogers (1962) most of the early adopters are younger, more educated and venturesome and the late adopters are older, less educated and conservative. This view has also been supported by many authors like Sen (1974); Schultz (1975). They mentioned that in a static traditional type of agriculture, experience was a relatively more valuable commodity for the farm manager than education, while in modern agriculture the education is very important.

Rahudkar (1962) in his study of farmers characteristics associated with the adoption and diffusion of improved farm practices found that none of the socio-
economic factors of the farmers except the level of education was significantly related with the adoption of new farm practices. He also found that farmers with primary or middle school education tended to adopt half of the recommended doses and those with college education were likely to adopt more practices.

Singh et al., (1971) found in Bihar villages that the farmers with higher level of literacy and college level of education have consistently used more institutional sources of information with greater more frequently than the farmers with low level of literacy and education. Many studies came out with this conclusion Chole et al., (1978); Reddy and Reddy (1972); Reddy and Ramamurthy (1973); Sanoria, (1970); Shankar (1979).

Akhouri et al., (1974) found that there is no relation between literacy or education and the adoption of HYVs seeds. Recently much attention has been given to study the important human resource variable namely education of farmer on the use of modern technological components and productivity of the crop. There is great deal of controversy among the researchers about the farmers’ education and its role in modern agriculture in general and use of modern technological components in particular. However, the results of the existing studies are not similar. Majority of the studies showed that there is a positive relation between education and adoption of new components, while some other studies have shown that there is no direct relationship between these two aspects and they argued that experience of the farmers, advice of the neighbourhood farmers, urban contact etc., plays a more prominent role than education.
Sharma and Nair (1974) carried out a study to find out the variables related to the adoption of new technology component. They found that there was no significant difference in education level between the adopters and non-adopters.

Kalirajan et al., (1985) carried out a study in Tamil Nadu rice farming areas to know the impact of education on crop yield. They have mentioned that experience gained through personal observation was better than formal education.

Pandey (1989) found in U.P. that education of farmers was not a binding force for the adoption of HYVs and other components. Rao (1980) also supports the view that literacy does not seem to be significantly related to the fertilizer and other New Agrarian Technologies components, whereas urbanization and nearness of market do show such relationship.

Mann (1989) found that education plays a positive role in the adoption of HYV seeds, because the more educated farmers may have been able to collect more information about new seeds and may have been the leaders. Lockheed et al., (1980) also indicated that education has a positive effect on farming activities and on efficiency. Singh and Reddy (1965) also confirmed this conclusion.

Dasgupta and Satdal (1989) indicated in their analytical work that most of the studies show a positive relation between education and the adoption of new technology components and the use of various institutional sources.

A more recent study by Narayanamoorthy (1990) in Pudukkottai district, Tamil Nadu, shows that education is not a barrier to adopt the modern inputs and
to get more yields. He also found that experience and active involvement in agriculture were more important factors than education.

Azhar (1991) also found in Pakistan agriculture that education insures positive impact on productivity. However, elementary education (up to four years of schooling) is insufficient for increasing the productivity.

A most recent study of Duraisamy (1992) found in Tamil Nadu paddy cultivated area that education especially above middle school level of education has a positive role and has significant impact on agriculture, particularly on the productivity.

The studies which are discussed under this heading are taking into consideration the household heads’ education or the total household education for analysis. But neither household heads’ education nor family education show a reliable result. The farmers who are involved in agriculture irrespective of their gender and average education would be more reliable, since any decision related to practical agriculture is being taken on the basis of the collective decision of the family members who are involved in agriculture. The existing studies have also not taken for analysis some crucial points relating to farmer’s education. For instance, education of the farmers and its impact on various form of fertilizer use (NPK), especially the use of recommended doses of fertilizers, treatment of seed between more educated and less educated farmers, etc.
2.12 Extension Related Studies

Extension network plays a crucial role in modern agriculture, especially in disseminating the new information to the farmers. Though it was introduced in the late seventies, it has not reached all type of farmers and all villages. However, one can not completely ignore the usefulness of extension network in modern agriculture. Effective agricultural extension can bridge the gap between discoveries in the laboratory and changes in the individual farmer’s fields. However, all agricultural extension services do not convey information from research centres to farmers but also can ease reverse flow of information.

Perumal (1979) explained in his article “Effective use of farm leaders in extension”, that the new extension system increases use of inputs and consequently resultant rise in production has been quite significant. He also stated that the extension also induced the farmers to use the machineries like tractor and threshers, pumpsets, dusters and sprayers. It indicates that the extension agents are not only concentrating on the use of inputs but also giving idea to use the modern machineries and its advantages to the cultivators.

Desai (1986) explained that even in the developed countries agricultural research and extension system play a substantial role in the use of modern technological inputs like fertilizers. He indicates the importance of extension services in agriculture.

Programme evaluation organization (PEO) (1970-75) study shows that many village level workers and block staff have received only inadequate training.
It was found out that infrequent contact between farmers and extension worker, and poor supervision of trial and demonstration are major reasons for the low adoption and awareness of the modern technology.

As far as the concentration of extension network is concerned, it is higher where there is assured irrigation with large scale farming. Desai et al., (1989) carried out a study in Andhra Pradesh for the operational impact of training and visit. The analysis shows that still the greater concentration of the system seems to be continuing on big farmers and those with more than half of the irrigated area. The regularity of contact between the farmers and extension workers is not properly undertaken. This view also been supported by Chambers et al., (1980). It clearly indicates that extension officials do not give more importance to the dryland agriculture, but at the same time one cannot forget that Indian agriculture is predominantly occupied by the dry cultivated area, where we need more extension services to attain more production.

Some other studies show that television and mass communication (Mohammed Salim, 1986) play an important role in the adoption of modern technology components. It implies that mass communication plays a major role in the modern agriculture, especially in dissemination of new inputs to the farmers.

Rao (1986) stated that the limited spread of technology could be explained partly by the nature of available technology itself and partly by the uneven development of infrastructure, physical as well as institutional factors which would be the pre-requisites for the adoption of improved practices.
There are some other studies which show that the consumption of inputs is largely dependent upon their availability and availability of effective retail outlets (Suresh Kumar, 1986).

Some studies, confirming that risk factor of the farmer are also determining the adoption of modern inputs. Dillon et al., (1971) explained that recognition of risk and risk aversion are considered to be the major constraints to adoption of innovations particularly in developing countries. Binswanger et al., (1983) also stated that the risk is one of the major factors responsible for wide cross-sectional variations in the adoption of innovations. Rengasamy (1986) found in his study that the riskiness of investment of farmers is one of the main reasons for the low adoption of modern technology in crop production.

There are many other important factors determining the adoption of modern inputs in agriculture. They are more qualitative in nature and cannot been explained in any single form, since those factors are not constant (situational factors) and may vary from time to time (farmer’s perception). It can be found out through vibrant and vigorous survey and also with more direct farming experience.

Birkhaeuser (1991) stated in his review article covering 48 studies all over the world that the majority of the studies (36 of 48), show a significant and positive extension effect. However, in some areas the influence of extension network is much higher.
2.13 Others Related Studies

This sub-section is divided into three parts, viz., irrigation related, risk related, communication and extension related studies.

Without irrigation agriculture is not at all possible. Irrigation is very important, especially for the modern agriculture, since modern agriculture is costlier than traditional agriculture. If once they get disappointing remuneration, the very next time of cultivation they will feel as reluctant to apply all recommended inputs for the crop. It is obvious that the use of modern inputs is always higher in area with assured irrigation than the area of un-assured irrigation.

There are some studies which revealed that there is a positive relationship between the adoption of various new technology components and the irrigation. Niranjan Pant and Verma (1983) stated that availability of irrigation is the first and foremost pre requisite for using modern inputs in the cultivation. Panda (1985) found in Andhra Pradesh that in irrigated area, adoptions of technical improvements are faster than the un-irrigated area. Bal (1980), Chakradhar Rao (1989) also came out with the similar conclusion.

Alexander (1986) carried out a study in Sambalpur district, Orissa. He compared the irrigated area with the un-irrigated area and found that the introduction of canal irrigation increased the use of various new technology components seed, fertilizer and pesticides.
Shrikant Modak (1986) found in Gujarat that due to the gamble of rainfall, the yield is affected widely and thereby prices, affecting farmers’ incentives adversely to apply the modern inputs.

Bhalla and Tyagi (1989) stated that the assured irrigation (surface and Underground) induced widespread adoption of new technology components especially in North-West region of India.

Pathak (1983) has classified the energy source used in agriculture into commercial and non-commercial sources. Commercial energy includes electricity, mechanical equipment, chemical fertilizers which were obtained through commercial channels whereas non-commercial energy included farm and manure, seed and the power of the draught animals.

The total energy input in agriculture consists of all forms of energy, namely fertilizer energy, seed energy, mechanical energy, manure energy, leaves energy electrical energy, human energy and bullock energy (Dhanapal, 1997).

Indira Devi et al., (1990) examined the performance of banana cultivation in Kerala during the period 1967-68 to 1986-87. For the analysis of the supply response of banana crop in the state, data pertaining to its area, yield, price and rainfall for the past 17 years were collected Nerlovian Lagged Adjustment Model of Linear and double log forms were used to study the major determinants of acreage and yield of this crop.
The results obtained from the linear model revealed that weather condition have no significant influence on acreage allocation of the crop. The price variable was found to be positive to affect the farmers’ risk-bearing capacity on cultivation of banana. An adjustment factor that is area-lagged showed a positive significant influence. The yield of the previous year was found to be a positive significant influence.

Kataria and Joshi, (2007) have also made a study in which the energy use and productivity of different crops has been analysed. The results reveal the fact that a rice-wheat cropping system is the most energy intensive one. Wheat cultivation has consumed a total of 14657 MJ/ha followed by paddy with 13076 MJ/ha. The consumption of energy by pulses has ranged from 3870 MJ/ha for Black Gram to 5464 MJ/ha for Bengal Gram. Sugarcane cultivation has consumed 59192 MJ/ha. An effort has been made by them to ascertain the relationship between energy use and productivity by working out energy productivity. The energy productivity measured in Kg/MJ has been recorded as the higher (1.171) for sugarcane crop and the same for paddy, wheat and maize being 0.239, 0.196 and 0.215 respectively. This analysis can be used for the judicious selection of crop rotation depending upon the energy usage, so as to minimize energy inefficiencies.

Singh et al., (1998) and Subramnaian et al., (1998) have reported that energy efficiency is low on large farms which are using more irrigation energy,
especially ground water, because of the scale bias of this source of irrigation. Gurunathan and Palanisami, (2008) they have reported that the contribution of traditional inputs is higher than that of modern inputs due to the high energy intensity of ground water irrigation.

2.14. Concepts

Energy

Energy means the “Capacity of a body to do work.” It is measured in Joules. It exists in various forms and can be converted from one form to another but can neither be created nor be destroyed (Chand’s Dictionary of Physics, 1996).

Energy Elasticity

It is expressed in terms of the proportionate change in energy to the proportionate change in production. The lower the value of ‘c’, the lower is the change in product (Ramachandran and Subramanian, 1998).

Energy Conservation

Energy conservation means minimizing energy related goods and services. It is simplified as improving energy efficiency and reducing energy use, without affecting the standard of living. Energy conservation can also be defined as the substitution of energy with capital, labour or material and time. This definition also covers the substitution of scarce types of energy with abundant types of
energy or the substitution of energy with convenience (David 1983). In other words energy conservation would mean that a given amount of energy inputs will produce larger amounts of output than what it did previously. In a macro-setting it would imply that the nation’s energy consumption would be reduced without hampering the process of economic growth (Eric Hirst, McGraw Hill, Encyclopedia of Energy, Second Ed.).

**Joule**

Joule is defined as a unit of energy or work. The absolute joule is equal to $10^7$ ergs. The international joule is defined, in electrical term as the work required for maintaining a current of one international amp for one second in a resistance of one international ohm (Chand’s Dictionary of Physics, 1996).

**Tonne (t)**

It is a metric unit of mass. 1 t = 1000 kg. Generally called a metric tonne, it differs in size from an imperial ton (116 kg) by about 1.5 per cent (Chand’s Dictionary of Physics, 1996).

**Watt (w)**

It is the unit of power in the metre-kilogram – second system of units, equal to one joule per second (Chand’s Dictionary of Physics, 1996).
**Watt-Second**

It is an amount of energy corresponding to one watt acting per second; one watt second is equal to one joule (Chand’s Dictionary of Physics, 1996).

**Watt – hour (wh)**

Watt – hour is a unit of energy used in electrical measurements, equal to the energy converted or consumed at a rate of one watt during a period of one hour, or to 3600 joules (Chand’s Dictionary of Physics, 1996).

**Kilowatt – Hour (Kwh)**

It is a practical unit of work or energy. It is equal to the energy supplied by one Kilowatt of power in one hour. 1 KWH = 3.6 x 10⁶ joule (Chand’s Dictionary of Physics, 1996).